SOLID WASTE MANAGEMENT

ABSTRACTS AND EXCERPTS FROM THE LITERATURE

Volumes 1 and 2

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FOREWORD

To maintain the quality of our human environment, we must give high priority to increased basic research efforts in the area of solid waste management. The growing vitality of the field is attracting more workers, who have little acquaintance with the subject and who may help to overcome their lack of knowledge and experience by an examination of the literature.

Unitl now, however, both new and experienced researchers in the field of solid waste management have been severely handicapped by the absence of a well-organized body of literature. A limited number of outdated texts and widely scattered information in journals, magazines, and inaccessible reports have hampered the productivity of many. Workers who have had little experience in the field are forced to waste much time finding reliable authorities and collecting and searching through the ever-increasing accumulation of publications.

To meet this need, a collection of excerpts and abstracts of the literature has been made by the University of California under research supported by the U.S. Public Health Service. This report is a collection of abstracts and excerpts of the literature reviewed during the first two years of the project.

--RICHARD D. VAUGHAN, *Director*

Bureau of Solid Waste Management

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Volume 1

June 1968

PREFACE

The report herein presented is in the nature of an auxiliary report covering the literature search and data collecting activities carried on as a part of phases I and II of the major research effort "Comprehensive Studies of Solid Wastes Management" made possible by a grant (UI-00547-02) to The Regents of the University of California by the U. S. Public Health Service.

The report is a collection of abstracts and excerpts of the literature reviewed during the first and second years of the research project.

TABLE OF CONTENTS

Page

PART I
INTRODUCTION

PART II
ABSTRACTS AND EXCERPTS

TABLE OF CONTENTS (Continued)

PART III
INDEX

PART I
INTRODUCTION

NEED FOR STUDY

One of the distinguishing characteristics of the research activity concerned with solid wastes now being prosecuted so vigorously in the United States is the influx of a large number of workers having little or no past experience, or even acquaintance, with solid wastes management. The reason is fairly simple: interest in the subject, which had been relatively restricted or at least dormant prior to the past few years, has been aroused to a high pitch by the current concern over the threat to man's environment resulting from man's mismanagement of his wastes.

Following the dictum of all good research, newcomers to the field of wastes management in its various aspects endeavor to overcome their lack of knowledge and experience by a vigorous search and examination of the literature. It is here that they encounter the first of the many frustrations which they will meet in the pursuit of their newly found interest — the absence of a well-organized body of literature. Texts dealing with the subject of solid wastes management are few and generally out-of-date. Information is widely scattered in journals, magazines, proceedings of conferences, difficult-to-obtain reports, and a multitude of unpublished papers. Because he is a novice in the field, the newcomer must search for a so-called authority on the subject to obtain advice and information as to where to look for literature. Consequently, much time is lost in determining where to look, in collecting, and finally in "wading" through the constantly increasing accumulation of publications to glean the knowledge he is seeking.

Clearly the productivity of both the new entrant to the field of solid wastes and of the experienced researcher and practicioner would be enhanced if a collection of excerpts and abstracts of literature were readily available. One such collection is being made under contract with the National Center for Urban and Industrial Health of the USPHS and should become available in the summer of 1968. In a smaller way the collection herein presented should help fill the need for a summary of existing knowledge.

NATURE AND RATIONALE OF THE STUDY

The collection presented in this report represents a summary of literature gathered over a period of more than fifteen years by the Sanitary Engineering Research Laboratory of the University of California and abstracted as the first step in a program of definitive research in the planning, systems, economic, health, and technological aspects of solid wastes management.

During the course of the project "Comprehensive Studies of Solid Wastes Management," over five hundred papers, articles, and reports were collected and abstracted. In many cases, excerpts especially pertinent to the research were made. The collection is by no means exhaustive; nor is it claimed that the material reviewed in it is necessarily the best of the literature in solid wastes. For example, only a limited amount of foreign literature is represented. The literature on sewage sludge reviewed in this collection is mainly that concerned with the combined disposal of sewage sludge and refuse. On the other hand, it does inclued abstracts of many reports not readily available to the researcher newly embarked upon work concerned with solid wastes.

Because this report is intended to serve as a means of extending to as many researchers as is possible access to the information already amassed by others, articles are included for which information may be incomplete as to date of publishing, or to volume and page number of the journal in which they were published. Even though such articles may not be quoted as references in a formal paper because of the missing information, the material contained in them may serve as valuable background information to the researcher. It may enable the interested researcher to select for more intensive study those works which he judges to be suited to his needs.

OVERALL EVALUATION OF THE LITERATURE

A review of the literature surveyed in making the abstracts reported herein revealed many interesting facts. Generally, published papers concerned with refuse disposal are written in a "popular" style, i.e., nontechnical and slanted toward the "layman." Those concerned with agricultural wastes, especially the animal manures, are more technical in nature. Prior to the 1960's composting seemed to be the most popular subject of papers on refuse disposal. Occasionally an article on landfill appeared, in which case the subject usually predicted the advantages of abandoning an open dump disposal operation in favor of a sanitary landfill. Articles on the management of agricultural wastes have in the past been concerned more with handling than with disposal, probably because agricultural waste disposal did not constitute the problem which it does now. In those days individual operations were not as big as today's and satisfactory disposition of most of the agricultural wastes generated by many of the operations could be made by spreading on adjacent fields.

As time advanced in the 1960's, the number of published papers on refuse disposal increased. However, the papers continued to remain mostly "popular" in style. Papers of a general nature were less common than those of a particular nature. The articles usually dealt with a description of a particular installation or a specific community. Incineration received the greatest attention, while landfill constituted a close second. On the other hand, the use of composting declined as a subject of papers, and authors once blindly optimistic became more skeptical, and downright pessimistic in many instances. Authors of papers on the management of agricultural wastes became quite prolific and the style of their papers continued to be technical.

As was true with papers published prior to the 1960's, reports on the handling of agricultural wastes far outnumbered those on urban wastes. In fact, before the 1960's reports on refuse disposal and management were quite rare. The reason for the paucity undoubtedly was the scarcity of money to conduct the research on which reports are based. Noteworthy among the few reports are those published by the International Research Group on Refuse Disposal.

During the 1960's reports on wastes management became more numerous; the increase being directly proportional to the increase in influx of federal funds into research on the subject. Now in 1968 the number is legion. Especially worth mentioning is the series of reports issued by the Incineration Committee of the Division of Process Industries (ASME), the National Sanitation Foundation, and by various regional groups and public agencies. The subject matter of the reports ranges from surveys of existing practices in solid wastes management to comprehensive planning for environmental health, and from waste disposal methods to legal implications.

Prior to the 1960's American journals (in the broadest sense of the term) devoted solely to Solid Wastes Management were limited to Compost Science and to the Refuse Removal Journal. As the name implies, Compost Science was concerned chiefly with various aspects of composting, although it did occasionally treat other facets of solid wastes management insofar as they could be related to composting. The publishers of Compost Science now are planning to extend the scope of their periodical to include the land application of solid wastes. The Refuse Removal Journal is primarily a trade journal and is more concerned with the collection and haul aspects of wastes management than with disposal technology. It is a strong advocate of landfill and incineration, composting finding little favor with its editorial staff.

Public Cleansing, a journal published in England, has been in circulation for years. The journal covers all aspects of solid wastes management and invariably contains interesting and informative articles.

Although no new journals devoted exclusively to solid wastes appeared in the 1960's, the problem of solid wastes management began to receive increasingly more attention, and is beginning to achieve a position approaching that of water supply and waste water treatment in the more widely distributed periodicals. Thus The American City and Public Works generally have one or two articles devoted to solid wastes. Among other commonly-read periodicals whose orientation is toward the environmental sciences and in which solid wastes are receiving increasing attention are Environmental Science and Technology and Western City. Compost Science and the Refuse Removal Journal continue to be geared to solid wastes management.

From the trends observed in the survey of literature it seems evident that the pre-1960 situation of the scarcity of papers and reports on solid wastes management is changing to one of abundance; and as is the case with so many of the newly popular subjects, will eventually develop into one of superabundance.

ORGANIZATION OF REPORT

To promote ease of reference, the abstracts and excerpts (Section II of this report) are grouped into major divisions and subcategories according to the subject matter given the most emphasis in the material under review. Because in most of the articles a number of subjects may have been given attention, it was often difficult to fit an article into any one category. In such cases, the classification was based on the subject which was treated at greatest length. For example, an article on the design of incinerators will also contain information on economics of incineration. This should be kept in mind when seeking information on a given subject in this report.

The major categories into which the articles are grouped are Management, Collection and Transport, Disposal, Salvage, Environmental and Public Health, Pollution, and Agricultural and Food Processing Wastes. Subcategories are as given in the Table of Contents. The entries are arranged in chronological order under each subcategory.

MANAGEMENT

THE PROBLEM

Black, R. J.
"*The Solid Waste Problem* in Metropolitan Areas"
California Vector Views, 11:51, September 1964

The article deals with the health, economic, legal, and regional aspects of the solid wastes disposal problem. The present setup, one with many open dumps, faulty incinerators, and with a lack of regional planning, must be changed, and this requires a public interest.

Garbage men suffer worse occupational hazards than any other public workers. They have an extremely high injury frequency rate, which includes such injuries as arthritis, muscle and tendon diseases (especially in the back), skin diseases, and hernia. Health hazards to the public being served include water pollution at sanitary landfill sites, fly migration from garbage cans, air pollution from improper burning of refuse at open dumps and incinerators, and the feeding of raw garbage to swine.

Storage, collection, and disposal rank just behind schools and roads as the leading public expenditures. Collection involves 85 percent of the expense. Much of this expense is in salary for the garbage men. New methods of collection would alleviate the burden to some extent.

A metropolitan-wide approach is the most feasible today, for as cities expand, land available for disposal of refuse becomes more and more scarce. However, few states provide for this area-wide effort in their consitution, and this legal barrier must be hurdled as a first step to a regional program of disposal.

Rogers, P. A.
"San Francisco Bay Area Solid Waste Management and Planning Problems"
California Vector Views, 12:51, October 1965

The article points out the trends in wastes production up to the year 2000. It emphasizes the fact that the existing facilities will not be able to cope with the huge volume that will be produced. In the nine Bay Area counties, the area dealt with by the article, existing facilities will be able to handle refuse until the year 1979. A total of 33,125 acres of land would be required to accomodate the Bay Area refuse disposal needs to the year 2000.

In computing the future needs of an area, a standard of 3-4 lb/capita/day is used. This figure is not always accurate, for often it does not take into account agricultural and special wastes. For the Bay Area, 5.7 lb/capita/day were produced in 1963, including wastes from all classifications and origins. For normal refuse (refuse disposed of at a sanitary landfill site), the figure was 3.8 lb/capita/day.

The State Department of Public Health in its report to the Association of Bay Area Governments recommended the following:

1. Investigation of new or alternative methods of solid waste disposal, including the establishment of demonstration plants in the Bay Area.

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2. Acquisition of additional landfill sites in accordance with a master plan for the entire region.

3. Investigation of the feasibility of establishing a series of refuse transfer stations.

4. Improvement of operational practices at existing sites.

5. Investigation of the prospects of creating one or more large districts to consolidate planning and operation of disposal facilities.

President's Science Advisory Commission
"Restoring the Quality of Our Environment"
Report of the Environment Pollution Panel, President's Science Advisory Commission. The White House, November 1965

Sections abstracted and reviewed herein are "The Sources of Pollution," "Solid Wastes — Magnitude of the Problem," and "Salvaging and Reclaiming."

The excreta of farm animals are a major source of water pollution through surface runoff or underground seepage. Urban solid wastes, including paper, grass, brush cuttings, garbage, ashes, metal and glass, amount to 1600 lb/capita/yr — an equivalent of a total of 125 million tons/year. A large fraction of consumer goods ends up as urban solid wastes. Thus, scrap iron and steel are generated at 12-15 million tons/year. Of this, one-third comes from derelict automobiles. Of the 25-30 million tons of paper produced per year, about 10 million tons are salvaged. In 1962, plastics to the extend of 8 billion pounds were produced; 10 percent of the discarded material was salvaged. In the same year, 263,000 tons of rubber were reclaimed. This was 15 percent of the total production of rubber for that year. Forty-eight billion cartons/year (250/person), 26 billion bottles and jars (135/person), and 65 billion metal and plastic caps and crowns per person per year are produced. The salvage industries operate at a level of 5-7 billion dollars per year.

The nature of solid wastes is highly variable. Their composition and distribution are closely linked with national growth and technological advance. Comprehensive statistics on magnitude are not available. The probable composition of wastes generally may be as follows: paper, 45%; grass and brush cuttings, 15%; garbage, 12%; ashes, 10%; metallics, 8%; glass and ceramics, 6%; and miscellaneous, 4%. An example of the gradual change in composition is that occurring in Philadelphia. In 1959, the rubbish collected amounted to 380,000 tons, and in 1964, to 567,000 tons. In 1959 in Philadelphia, 120,000 tons of ashes were collected; in 1964, only 37,000 tons. Garbage production in 1957 amounted to 162,000 tons; whereas in 1964 it was 128,000 tons. In 1959, the amount of street sweepings was 100,000 tons, and in 1964 it was 137,000 tons.

Gilbertson, W. E.
"Scope of the Solid Waste Problem"
Journal, Sanitary Engineering Division, ASCE, 92(SA-3):1, 1966

Traditionally, solid wastes have been disposed of by individual communities and cities. With the rapid spread of urban and suburban areas, a need for regional planning has arisen. Along with the lack of planning and organization, there is a definite lack of public awareness and professional interest.

The Solid Waste Disposal Act of 1965 has two main objectives:

1. Initiate a National Research and Development Program, including studies of resource conservation and utilization of potential resources of solid wastes.

2. Provide technical and financial assistance to state and local governments and interstate agencies in planning, developing, and conducting solid waste disposal projects.

Allen, C. D.
"Fifty Years with Solid Waste Disposal and Air Pollution"
Paper - San Francisco Rotary Club Meeting, 8 September 1966

In San Francisco, the landfill and cover method of solid waste disposal has only a few months left. A new method of disposing of 1,500 tons per day of solid waste must be found.

A new method of disposal in San Francisco is needed. There are several methods of attacking the problem. To know what is best for the city, a three-month engineering study of all proven proposals must be undertaken.

The first part of the talk contains a brief history of the author's company and of incineration and air pollution levels in the U. S. The author cites the incinerator in North Hempstead, New York, which has a 600-ton capacity, and was recently built by his company at a cost of $5,500,000.

Gilbertson, W. E.
"Solid Wastes: A Worsening Urban Problem"
Paper - Public Works Congress and Equipment Show - American Public Works Association, Chicago, Illinois, September 1966

The waste problem is magnified and multiplied by the problems of urban environments to the extent that our capacity to meet and resolve it literally is taxed to the breaking point. We have reached a stage in evolution of urbanization at which the sickness of our cities threatens to bring an end to urban life.

The solid wastes problem affects quality and nature of urban environments as follows:

The problem existed from the time men banded together to create the first town. Disposal had to be accomplished in such a way as to make the living space livable. The modern problem differs from the ancient in that the nature of wastes is changing inexorably from easily disposed materials to one in which the materials the disposition of which is difficult, costly, and hazardous to health and welfare. Despite this change, present waste disposal facilities are geared to the needs of the last generation. A hazard to health and welfare is the contribution of incineration to air pollution. Junkyards depress the value of the surrounding land. Despite the huge expenditure (3 billion dollars per year), present management is inadequate. The complexity of the management problem aggravates the situation. For example, out of a total of 90 million automobiles, four out of every ten are junked per year. Therefore, the present number of derelict automobiles may be estimated as being 20 to 40 million. Of these 90 percent end up in the steel furnace. Recycling usally is a marginally profitable enterprise. Solutions which are proposed, are as follows:

1. Public agencies must be cognizant of fact that protecting the environment requires a hitherto unequalled commitment of public resources.

2. More money must be spent on research.

3. Cities and states must join the federal government in solving the problem.

4. It is necessary to develop broadly based plans, and to avoid fragmentation of responsibilities.

Vogel, H. E.
"The Refuse Problem of Swiss Resort Towns"
I.R.G.R. Information Bulletin 16, p. 1, December 1966

The refuse problem in tourist centers is very urgent. The problem is complicated since a small local population has to carry the costs of refuse treatment for many tourists. A few cities have incineration plants, in other communities the refuse is simply dumped. The latter cannot be tolerated any more.

First, M. W.
"Environmental Hazards--Urban Solid Waste Management"
New England Journal of Medicine, 275:1478, December 1966

The public health aspects of solid wastes are not as well defined as are those for liquid wastes. Hitherto, public health authorities have been content in recent years to delegate handling of solid wastes to departments of Public Works. Modern epidemiological evidence that disease is spread from accumulations of garbage and rubbish is largely lacking. With the exception of feeding uncooked garbage to hogs (trichinosis), refuse has not been demonstrated to be a reservoir for disease agents transmitted by vectors (rats, flies, etc.).

Anon.
"Solid Wastes"
Outlook, 1:199, March 1967

This is a survey of the solid wastes management problem and contains the usual statistics. In the article is described a test-demonstration project in Maryland to reclaim abandoned strip mines by sanitary landfill. Mention is made of a proposed Bureau of Mines demonstration plant in Minnesota to convert low-grade scrap (abandoned automobiles) into blast furnace feed; and of a contract awarded to Ralph Stone and Co., Inc. by the Bureau to conduct two studies on the copper contaminant problem in scrap iron, especially in automobile scrap.

Anon.
"Mountains of Solid-Wastes"
Bionomics Briefs, Protection and Toxicology Center, University of California, Davis, Volume 1, No. 5, September 1967

In the issue is examined the San Francisco garbage "crisis" and related factors. "In evaluating the extensive published material on the many facets of urban garbage disposal, and San Francisco's plight in particular, it is clearly evident that the total problem, as well as other problems of pollution control, must be approached on a regional basis."

The report is a rehash of the problems of solid wastes management. Among the points brought out in it are the following:

1. Costs of municipal solid wastes handling usually far exceed those of all public health functions combined.

2. Handling of solid wastes is carried out principally by unskilled and semi-skilled laborers. This class of personnel seldom is found in health agencies, which are predominantly professional in makeup.

Although solid wastes may rate low on a scale of sources of transmissible disease, improper disposal practices can cause serious air, water, and land pollution problems of a noninfectious nature. When buildings are erected on old landfills, care must be taken to prevent migration of toxic and explosive gases from the subterranean fill to the interior of the buildings.

The following are a few statistics of particular interest: Only one-third of 48 million tons reaching the U. S. market annually is salvaged. Forty-eight billion cans, 26 million bottles, and 8 billion lb of new plastics are discarded annually (10 percent of the plastics are recovered). In Los Angeles, 36 percent of the solid wastes either are noncombustible, or cannot be handled in an incinerator. Raw waste left after modern incineration is 50 percent by weight of the original.

With regard to new and old salvage and recovery operations from food wastes, rendering, tanning of hides, extraction of fish oil and meal, manure drying, and processing chicken feathers to proteinaceous animal feed are of concern. Unfortunately, installation and operation of effective devices for control of air and water pollution often make these salvage operations uneconomic. The problem of unfavorable economics also applies to the obtaining of scrap rubber from used tires, and lead and copper from rubber and resin-coated wire and cable. Economics of salvage (at least at present) means that it is cheaper to utilize new raw materials than to depend upon salvaged materials. It is the unspoken national policy to rely on the discovery of suitable substitute materials before the sources of traditional ones become impossibly degraded and completely exhausted.

> "It seems clear that for the foreseeable future all but a small fraction of the total quantity of solid wastes will be returned to the environment as a means of final disposal."

It is necessary to distinguish between contamination of the environment (addition of foreign substances) and pollution. Pollution is the accumulation of contaminants to the point at which undesirable effects begin to occur. "It is naive to maintain that nothing whatever can be added to the environment." Even standard conservationists may concede in good conscience that not every single acre of tideland is best utilized by being left alone.

The article includes a discussion of each of the main disposal methods now in use, mentions new methods, and discusses collection.

Alexander, Tom
"Where Will We Put All That Garbage?"
Fortune, p. 149, October 1967

The article contains pictures of an unsightly dump only four miles from downtown Washington, D. C., as well as of a beautiful canyon in Los Angeles reclaimed by landfill.

Among the items included in the article, are the following: New York annually uses 150 acres of the southern end of Staten Island for refuse disposal, i.e., disposal of residue from incinerators. It costs about $30/ton to collect, transport, and dispose of New York's refuse (3 times the cost of a ton of West Virginia coal, mined and delivered to New York). The cost of properly operating an incinerator is from 5 to 6 times that of operating a sanitary landfill.

Current economic trends render salvage unattractive. In New York there is no demand for waste paper. Offices now pay as much as $37/ton to have it hauled away. New steel melting process has reduced the demand for scrap.

The problem of compost: It has been suggested that the city pay farmers for the cost of plowing compost in the fields just to get rid of it. Chicago is investigating the possibility of pumping sludge to farmed-out lands in Kankakee County (90 miles away).

The author uses the following example to stress the need for a regional approach: Wegman Engineers developed a modern plan for a common disposal facility for three Connecticut towns — East Hartford, Glastonbury, and Manchester. The incinerator in East Hartford was to have been modernized for handling all of the refuse. When the citizens of East Hartford refused to have the refuse of the other two towns in their city, the plan fell through. For an example of lack of organization, he gives the following: Air pollution controllers discharge wastes to rivers; water pollution controllers put theirs on land; and solid wastes controllers pollute all three.

Los Angeles is a good example of the proper approach: In the Los Angeles area, a cooperative of 70 municipalities and a part of the city of Los Angeles was formed. As a result the collection and disposal costs are lowest in the nation.

Anon.
"Cities vs. Garbage — Who Will Win"
U. S. News and World Report, p. 116, 23 October 1967

"On top of other troubles, cities are caught in a garbage crisis. Many are out of places to bury refuse." In Washington, D. C., an incinerator had to be closed. In Philadelphia, a ten-year contract was let to haul 1,200 tons of refuse per day to strip mines in Central Pennsylvania. In Massachusetts, the majority of dumps in the eastern part of state will be filled in four years. New York burns most of its rubbish. Stopping 40 percent of the city's 20,000 apartment houses from burning their rubbish would increase the truck demand by 800 extra units. It is estimated that 3 billion dollars were spent in 1966 in the U. S. to collect and dispose of 165 million tons of solid wastes. This year (1967) the amount is expected to be 260 million tons. In Hempstead, New York, an incinerator produces power and desalinates 4,000,000 gallons sea water/day. In one community garbage is ground into sewers thereby reducing trash collection costs by two-thirds, and frequency to once every two weeks.

Anon.
"Treatment and Disposal of Wastes"
World Health Organization Technical Report Series No. 367 W.H.O., Geneva, 1967

The report is a survey of the status of waste water and solid wastes treatment in the world. Major problems are:

1. An increase not only in quantity of waste water but also in concentration and diversity of pollutants in the water.

2. A decrease in availability of dilution waters.

3. Inadequate collection and disposal of solid wastes (in industrialized countries as much as 20 percent of the total budget is spent on these items).

4. High cost of installing and operating complex systems for collection and disposal of wastes.

5. A great deal of private and public indifference.

Statements on the status of management and disposal methods reflect U. S. conditions rather than worldwide conditions, and are general in nature.

Anon.
"Automobile Disposal A National Problem"
U. S. Department of the Interior, Bureau of Mines, Washington, D. C., 569 p., 1967
U. S. Department of the Interior Library

The publication is a comprehensive treatment of the entire problem of the disposal of junked automobiles. It presents case studies of factors that influence the accumulation of automobile scrap.

"Future Solid Waste Accumulation"
Report by the U. S. Department of the Interior, Bureau of Mines, Washington, D. C., March 1968

Mineral consumption, excluding petroleum, is expected to rise 3.2 percent per year, and solid wastes generation 4.6 percent annually between the present and 1980. These estimates of mineral consumption are based on projected growth in mineral production, which in turn depends on increased population and GNP with a resulting rise in per capita mineral consumption. The effect of mineral imports has been included in projecting the growth of mineral consumption. Exclusive of petroleum, imports account for only a small part of the total. The major increase in wastes will result mostly from the production of lower-grade ores and minerals and from the increased processing of mineral products. Solid wastes from oil shale and ocean mining operations are not included in the estimates.

The volume of wastes will almost double in the 1965-1980 period. This is an increase from 1.1 billion to 1.9 billion tons. About 1/2 of the increase will be from copper production. Wastes from the remaining mineral processing steps plus those from imported ores treated and metals produced for immediate export will result in a total solid waste tonnage in 1980 of 2.6 billion tons.

Solid wastes from oil shale, which will be on a commercial basis before 1980, will add 570-850 million tons of solid wastes per year. The recovery of mineral products from ocean mining, however, should not produce significant wastes before 1980.

The type of wastes considered in this analysis are nine in number: among them, mill tailings, washing plant rejects, slag and processing plant wastes.

The report includes a table of the U. S. production of minerals and related solid wastes from 1965 through 1980. It includes a breakdown of the marketable production, annual rate of growth, total solid wastes, and ratio of wastes to marketable production.

Anon.
"Per Capita Figure of 5.1 pounds of Matter Daily Indicated by National Survey" Solid Wastes Management - Refuse Removal Journal, 11:14, March 1968

Approximately one billion, 380 million pounds of residential, commercial, and industrial wastes, or 5.1 lb per caita are generated each day in the U. S., according to a report made by Combustion Engineering Co. for the USPHS. Approximately 600 cities were surveyed, and officials in 50 of these were interviewed personally. Approximately 20 percent of the communities having populations over 25,000 use incineration to dispose of their solid wastes. On a national basis, this accounts for the incineration of only 9 percent of all urban refuse. About 50 percent of the cities with populations over 25,000 are currently using sanitary landfill whose capacity at existing sites will be exhausted within six years.

Table: Residential and Commercial Solid Waste Generation
(lbs/capita/day)

City	Municipal Data[1]	Private Contractor[2]	Total
Glendale, California	3.38	0.83	4.21
Los Angeles	3.36	0.06	3.42
San Francisco	2.54	3.00	5.54
Miami	3.11	0.64	3.75
Baltimore	4.18	0.09	4.27
Cleveland	1.73	0.34	2.07
Philadelphia	2.41	0.08	2.49
Woonsocket, Connecticut	2.58	0.56	3.14
Norfolk, Connecticut	4.36	0.65	5.41

[1]Data was supplied by municipality but includes refuse deposited by contractors.

[2]Only nine cities are shown because they were reported on by Solid Wastes Management magazine, and because the industrial segment could be broken out of the data.

APPROACHES

Rawn, A M
"Report Upon the Collection and Disposal of Refuse in the County Sanitation Districts of Los Angeles, County, California," 141 pp., October 1950

The report is concerned primarily with the County Sanitation Districts of Los Angeles County. The nature and classification of refuse and the quantities generated are dealt with in the first section. In the second, the collection of refuse receives consideration. Included in this section is a discussion of the collection of refuse, factors affecting refuse collection, and an analysis of refuse collection systems. The chapter contains a list of recommended practices, among which are:

1. The curbside type of collection should be used.

2. Refuse should be segregated at the household.

3. Household garbage should be collected twice each week.

4. The size of the refuse should be controlled.

The third section is concerned with the disposal of refuse. Factors characteristic of Los Angeles and which have a bearing on refuse disposal are air pollution, lack of landfill sites, and density of population. Methods of disposal include dumps and landfills for noncombustible refuse and ash residue; incineration (high temperature incineration in structures carefully and adequately designed to prevent air pollution), garbage grinding to sewers, garbage feeding to hogs, composting, and salvage. The fourth section is an analysis of District participation in the collection and disposal of refuse.

It is felt that the problem of waste disposal is too large for a private approach and that some sort of a cooperative enterprise is needed. Enabling legislation and methods of financing are discussed.

Among the interesting facts related in the report are the following: The average daily production per capita in all the districts averages 3.24 lb. Of this, 0.65 lb is garbage; 0.59 lb, noncombustible material; 1.16 lb, collected combustible material; and 0.84 lb, combustible material burned in the home incinerator. Added to the 3.24 lb are about 0.40 lb per capita per day of refuse not subject to routine collection. Of the 1,700,000 district population, refuse from the homes of but 145,000 is collected from the backyard. The operational costs of "fill and cover" varies from about $0.30 to $0.60 per ton. The overall cost varies from $0.40 to $1.00 per ton. Additional excavation in the "cut and cover" increases the overall cost of the process by 20 percent. A modern two-stage incinerator will cost approximately $2,000 per rated ton of capacity based on 24-hr operation. The total cost per ton for incineration will approximate $2.00 (24-hr operation). The area has 13 hog ranches for garbage feeding.

Anon.
"A Workable Solution to Refuse Disposal"
The American City, 74:32, August 1959

A study by the Refuse Disposal Study Committee, Institute of Local Government (University of Pittsburgh) recommends:

1. The county should assume responsibility for refuse disposal facilities and have exclusive jurisdiction over them.

2. Collection should remain the responsibility of each borough, city, and township.

3. All acceptable methods rather than a single system should be used.

4. Existing systems which are determined as being suitable for inclusion in the county system should be bought, those determined unsuitable should be closed, and those suitable but not included should be certified and allowed to operate for five years.

5. Capital investments financed from general county taxation and operating costs financed by uniform fees should be assessed against municipalities and private haulers.

"Master Plan of Refuse Disposal"
County of Orange, Highway Department, October 1959

Table of Contents:

1. Present situation.

2. Prospects for the immediate future (critical sites, life expectancy).

3. Ultimate needs.

4. Methods of disposal (incineration, composting, ocean disposal, grinding refuse to sewers, hog feeding, sanitary landfill).

5. Economics of transfer (justifying adoption of a transfer plan).

6. Review of unit costs.

7. Master plan (total capital investment).

The master plan includes the use of four transfer stations and five disposal stations. The total unit transfer cost is $1.09 per ton, and the capital investment for the five disposal sites is $3,143,000. The capital investment for the four transfer stations is $1,343,000.

Storm, M. I.
"Orange County Adopts Master Plan of Refuse Disposal"
California Vector Views, 7:32, May 1960

Orange County made a big step forward when in November, 1959, the Board of Supervisors adopted a master plan of refuse disposal. The result of this was a recommendation of a combined system of five landfill sites located in the foothill perimeter of the county.

While the county would maintain the disposal responsibilities, the matter of collection of refuse would be left to the individual communities. Four landfill sites have been filled to capacity in the last two years, and two new sites have been put into operation. A new 160-acre site has been purchased, and this site is designated to serve the northern part of the county until the year 2000.

The most important aspect of the Master Plan is the fact that there is now a policy of long range planning — looking ahead to the solid waste disposal problems of the future.

Watson, J. L.
"Engineering Aspects of Town Refuse Disposal"
The Surveyor, pp. 1163-1166, 23 September 1961

The service comprises four interdependent stages:

1. Storage,

2. Collection,

3. Haul,

4. Disposal.

Type and location of receptacles are important considerations in increasing efficiency and reducing costs of refuse disposal. Collection and haul planning should include: a) careful route planning with regard to traffic density, zoning, etc.; and b) choice of vehicle most suitable for local conditions with regard to type, design, size, and motor power, since labor accounts for 60-75 percent of collection costs. Close attention should be paid to this factor. Disposal considerations should include aerobic composting, sanitary landfill, and separation plant. As an organic fertilizer, compost is equal to average farmyard manure. The Domen pilot plant at Tel Aviv has composted the refuse from a population of 50,000 for the past 4 years. The Dano plant in Haifa has been in operation for 2 years, serving 85,000. In Israel, incineration and sanitary landfill are not as desirable as an efficient compost operation since, they do not allow for reuse of the refuse.

Winkler, T. E.
"Suburban Communities Join to Plan Refuse Disposal"
Public Works, p. 88, February 1965

Five communities in the Detroit area joined to form the Central Wayne County Sanitation Authority. The total population in 1963 was 235,000; the projected population for 1980 is 330,000. The Authority has constructed two 250-ton continuous feed incinerators and has provided for a third. After the first July following one full year of operation of the incinerator plant, each director (one director plus an alternate per community) is entitled to one vote/3000 tons refuse or major fraction thereof delivered to the plant during the preceding year. Surplus capacity will be available to nonmembers.

Gentieu, F. A.
"The Central Disposal Plant"
Brochure by the author, April 1965

This plan would eliminate the fly-carrying garbage truck as well as the fly-breeding domestic garbage can. This revolutionary plan would organize the country into Sanitation Areas of 8-20 million population each, allowing for a more complete segregation of refuse, and making the sale of the materials salvaged easier.

The wastes would be segregated at their source — in the home and at the industrial plant and businesses. Different colored containers would be used for different types of refuse. The segregated refuse would be brought to railroad stations and carried by rail to the Central Disposal Plant (CDP). At the CDP the refuse would be disposed of in different divisions, corresponding to the containers used to segregate the refuse. For example, garbage would go to the Composting

Division; paper, etc. would go to the Combustible Waste Division; and so on. The wastes would be converted into marketable items or disposed of by utilization to produce marketable items at the CDP, so that its operation should be a profitable one, and could be run by private enterprise.

The plan proposed by the author would replace many smaller wasteful and pollution creating means of disposal used at the present by municipalities. By organizing solid wastes disposal on a large scale, duplication of efforts and expenses incurred by smaller sanitation districts would be eliminated and more efficient service realized. The Central Disposal Plants would function at lower operating costs than do present operations. In coastal areas, the use of steam produced from the disposal of combustible wastes would be used for the conversion of sea water into potable drinking water.

While this plan is apparently feasible on paper, much study is still needed in all areas, particularly pertaining to rail transportation of wastes and sale of end products.

Hart, S. A.
"Solid Wastes Management -- Today and Tomorrow"
Paper - 1st Annual Conference California Refuse Removal Council, Los Angeles, California, May 1965

Wastes have been compartmentalized into smaller divisions to facilitate their disposal, i.e., into garbage, combustible refuse, sewage, etc. Disposal districts have been established mainly by municipalities on a small scale, often duplicating efforts of adjoining cities.

The author points out that management is necessary on a wider scale. Operations research and systems analysis should be employed. With these tools, it is possible to make evaluations to improve and optimize present wastes management systems and to develop new systems for tomorrow. New systems or plans may call for changes in jurisdictions which manage wastes, for the finding of alternate methods of disposal of wastes, and for the development of new kinds of equipment and procedures.

Along with better management, utilization of wastes is another aspect of solid wastes disposal to be looked into more carefully. Compost made from the refuse from cities and organic wastes from farms can be utilized by the agricultural areas which usually surround urban communities. Research is being done, but more is needed. A look to the future needs of the population is essential.

Anon.
"Regional Approach the Best Solution"
The American City, 80:44, May 1965

The Detroit Metropolitan Area Regional Planning Commission argues that a metropolitan region can best solve its refuse problems by combining the efforts of the municipalities on a region-wide scale.

In its new report, it also recommends public ownership and operation of disposal facilities — limiting dumps in the Detroit area and utilizing landfills, incinerators, and on-site disposal methods such as domestic incinerators and garbage grinders.

County of Orange
"The Orange County Refuse Disposal Program"
Orange County Road Department, 17 June 1965

This report is a completed study of the Master Plan of Refuse Disposal (1959) using data gained from its operation during five years.

Although some modification of the original Master Plan has been required, the basic principle of landfill disposal supplemented by refuse transfer, remains the most satisfactory method of handling the refuse disposal requirements of Orange County.

Parker, D. S.
"The Social Costs of Wastes Management"
CE 298-5 University of California, Berkeley, 1965-66

Air, land, and water resources which have traditionally been devoted to wastes management may now and in the future become so limited that all of the demands that might be placed on them for various beneficial uses will not be satisfied. Regional waste management can be seen as the guide maximizing the benefits accrued from waste management per unit of input of social capital.

Evaluation of social cost on a comprehensive basis is possible if the proper tools are used; namely, input-output regional economic tables, and modern systems analysis.

"California Solid Wastes Planning Study"
California State Department of Public Health, 1966

Objectives for the three-year study period are:

1. To determine the quantities and sources of each type of domestic, industrial and agricultural solid wastes produced in the state.

2. To document and evaluate current facilities and methods of handling solid wastes and the potential capacity for continued use.

3. To determine the extent of adverse or beneficial environmental effects created by present solid wastes handling and disposal methods.

4. To identify and evaluate current regulatory controls, policies, management practices and role of various agencies for all levels of jurisdiction including state, county, district, and city.

5. To determine the extent and nature of local planning for solid wastes management and to evaluate all existing local and regional solid wastes master plans.

6. To develop a standardized inventory system, utilizing electronic data processing for data storage and evaluation which can be continually updated as a routine program.

7. To project the future problems facing California in twenty-five to fifty years concerning quantities of wastes produced, changes and trends affecting solid wastes and the expected environmental effects if present methods are continued.

8. To develop the preliminary framework of a comprehensive state-wide plan for the effective management of solid wastes produced in California.

Proceedings National Conference on Solid Waste Management
University of California, Davis Campus, 4-5 April 1966

Table of Contents:

Brown, R. M., Editor
"Political Processes in Environmental Management"
Monograph No. 4, Monograph Series. National Sanitation Foundation, Ann Arbor, Michigan, June 1966

This monograph is a summary of a panel discussion held on June 24, 1966. The subject matter is indicated by the title. The following are interesting excerpts:

The bypassing of states in Federal Government — individual group relationships is referred to in this statement: "The above (medicare, research grants to educational institutions, etc. — editor's insert) are only examples of the shift from federal-states to federal-people relationships. They are reflected in the various programs to improve the quality of the environment. But here the purposes and the procedures are much less precise; the nature of the problems is much less clear and the means and ways of solutions involve a confusing array of agencies; some working as official political bodies and others fulfilling their concepts of voluntary functions and roles."

The panel saw no other approach than the multidisciplinary approach in solving problems. The question is how to initiate and expand multipurpose planning and multiagency action.

"The subject of environmental quality has an enormous spread. 'Pollution' is a word usually associated with water, air, wastes, etc., but the environment does not begin and end with these. Recreation, education, transportation urban-renewal — these too, are parts of the total environment. Faced with such a multiplicity of problems, etc., elective officials must make value judgments since costs are a common factor that bind all of the problems."

With respect to the multidisciplinary approach, the panel had this to state: "It is evident that little progress will be made in an area of environmental health — or in the enhancement of life in today's America, beyond mere survival — until and unless theorists, engineers, members of legislative bodies, representatives of regulatory agencies and an aroused public, spurred on by civic leaders versed in the techniques of pressure-group organizations, combine their efforts for a common purpose." The public unfortunately is often "for" something but is unwilling to pay for it.

Adequate and long-range planning is essential. In many instances, governmental decisions stem from crises.

"Environmental quality......connotes more than mere survival, prevention of disease, or even conditions permitting the individual to function at maximum efficiency. Rather it implies an environment which is conducive to thriving and a greater enjoyment of life."

Social movement is defined as "a long-continued series of events tending toward a more-or-less defined end." Steps in social movement are events which generate succeeding events, and the development of these characteristics (listed in the sequence of their appearance): dissatisfaction → inspirational leadership → technical leadership → new dissatisfaction → cycle is repeated. Ideally, the new cycle should lead to expansion. Unfortunately, however, it may end in the entrenchment of the original technical leaders. "Neither technical enaction nor outright opposition to expansion stops the social movement. The only thing that is assured by the decision of the technical leadership to remain in its protected trench, is the rise of a new inspirational leadership that attracts its own defined constituency. Thus — and it happens over and over again — instead of the movement progressing over a relatively even and cohesive front, it splits into independent and often competing segments."

"But many questions remain. Given a general and rather unfocused dissatisfaction, what should be the make-up of the inspirational leadership? What sparks its beginning and by what means does it expand to embrace voluntary and governmental resources? At what point are the multidisciplinary studies and refinements of programs introduced? What are the sources of funds to lay the foundations of programs and, ultimately, actions? What agencies might be utilized to provide objective analyses of problems and suggest solutions?"

Gilbertson, W. E.
"Cooperation: Key to Healthful Solid Waste Management"
Paper - First Governor's Conference on Orderly and Healthful Development of Metroplitan Areas, New Orleans, Louisiana, September 1966

The paper lists the following reasons for cooperating:

1. The nature of program is truly national, therefore participation at city, state, and federal levels is required.

2. Space available for living requirements is shrinking, one man's trash basket is becoming another man's living space. The problem no longer is urban. Because of industrialization of agriculture and of urban sprawl, it is becoming rural as well. Therefore, we need cooperation between urban and rural sectors.

3. The earth contains only three reservoirs for depositing wastes — air, water, and land. Disposal of refuse in one reservoir may cause pollution in another. To minimize pollution, cooperation is needed in the conduct of air, water, and solid waste pollution control programs.

4. There is need for an extensive program of research. Our technology in solid wastes disposal is primitive.

5. A need exists for a greater public investment in improved technology. Adequate management is beyond resources of the individual community. Therefore, a county, regional, and interstate management is needed. A solid waste collection and disposal service that transcends established political jurisdictions is essential.

6. Information and data exchange between communities, state, etc., are needed, so that the needs of one are known by the other, and mutual aid can be given accordingly.

7. Cooperation is also needed in training personnel. More people with engineering, administrative, etc., training in wastes must be recruited.

8. Cooperation in strengthening capabilities for meeting disposal problems is a necessity. This can be done by pooling efforts. Examples of pooling are:

    a. States can provide technical assistance in the development of regional programs by small communities now working individually.

    b. Specific authorization for such action from state legislatures can be obtained.

Remedies for the waste disposal problem and the development of processes for reuse or recycling; and the obtaining of public support.

Steven, D.
"Solid Waste Disposal and San Francisco Bay"
Report - San Francisco Bay Conservation and Development Committee, October 1966

The report is an updating of the ABAG report. Subjects covered are a list of refuse disposal agencies, present and future refuse volumes, effect of refuse sites upon the Bay, present refuse disposal situation detailed county-by-county, improvement of present technology with respect to transfer and long-haul, incineration, composting, salvage, grinding, and disposal at sea, and a possible future waste disposal system for the Bay Area.

At present 38 percent of the Bay Area disposal sites are located on Bay tide marsh and submerged lands. Berkeley is the only community employing a "transfer station." Estimates of the cost of incineration at San Francisco as given in the Wilsey, Ham, and Blair report are $6.50 per ton refuse delivered, and a land area of 7-10 acres.

The report gives extensive quotes from the Los Angeles County Sanitation District's studies on economics of hauling and of transfer stations.

Anon.
"Refuse Disposal"
Report - San Francisco Bay Conservation and Development Commission, San Francisco, California, October 1966

The report is a reworking of the ABAG report brought up-to-date, but with no original data. A major conclusion of the report is given this quotation from the "Summary:" "Rapid increases in population mean increasing waste disposal requirements. Overall, present waste disposal resources in the Bay Area are adequate for the near future. Meanwhile, research and experimentation is being undertaken to use improved methods of waste management within relatively few years." Other conclusions are: San Francisco Bay is the dominant feature of the Bay Area. There now appears to be no pressing need to permit any further filling of the Bay for additional refuse disposal sites. Future refuse disposal systems should be designed to provide the best possible service for the Bay Area with no further infringement upon the Bay.

Rogers, P. A.
"The Development of a Comprehensive Solid Waste Management Plan for California--A Preliminary Report"
Vector Views, 13:83, December 1966

Presents a comprehensive analysis of the magnitude of the solid wastes problem in California. Attention is focused on the inadequacy of present methods of solid wastes management as evidenced by air, land, and water pollution, aesthetic blight, and various public health hazards including the production of flies and rodents. A three-year study proposal designed to develop a comprehensive plan for the effective and economical management of solid wastes in California is presented. The study will include a comprehensive inventory and evaluation of data relating to waste production quantities, management practices, disposal facilities, planning programs, and environmental effects of solid wastes handling. The individual and collaborated roles of local, regional, and state governments as well as private industry are stressed.

Gilbertson, W. E.
"Cooperation: Key to Healthful Solid Waste Management"
Public Health News, 48(1):19, January 1967

The present situation of solid waste management is described. Six categories of nationwide needs in solid waste management are mentioned and ways of interagency cooperation are indicated.

The principal needs are: Basic and applied research, new and improved technology, the development of regional approaches to solid wastes management, statewide surveys and planning of disposal requirements, solid wastes personnel training, and strengthened technical capacities at all levels of government.

Golueke, C. G. and P. H. McGauhey, Editors
"Comprehensive Studies of Solid Wastes Management"
First Annual Report, SERL Report No. 67-7, Sanitary Engineering Research Laboratory and School of Public Health, University of California, Berkeley, May 1967

The report is of the nature of a progress report covering the first year of a comprehensive study of solid wastes management. The research plan on which the studies are based called for an initial organizational and general data-collecting phase, covering a major part of the first year, followed by a second phase of definitive research on such aspects as operations research, planning, economics, public health, and technology of wastes management systems. The first phase having been successfully completed, the report on this aspect is essentially a final report intended to acquaint the reader with the underlying concepts of the solid wastes problem and with the details of the multidisciplined research program set up to attack the problem. On the definitive research phase of the program, progress and preliminary findings of a number of coordinated research teams are presented in detail.

Wolfe, H. B. and Zinn, R. E.
"Systems Analysis of Solid Waste Disposal Problems"
Public Works, September 1967

Growing population density and concurrent changes in employment, land use, and levels of income, are creating new patterns of solid waste generation. As disposal problems become more complex, it is mandatory that all methods used be integrated with respect to each other and to the disposal of gaseous and liquid wastes. To predict the outcomes of alternative courses and make the choice that promises the most favorable return, a rational base for organized decision is required. Systems analysis provides this format. "Cost/benefit" refers to the process that has as its objective a presentation that depicts effectiveness as a function of cost for each alternative. The goal must be defined, ways to measure the relevant effectiveness must be established, cost units selected, qualitative effects expressed quantitatively, and measures of uncertainty in the parameters indicated. For multiple goals, tradeoff relationships must be examined, or substitution ratios and an optimum balance sought. This approach is an aid to judgment, not a substitute for it. By combining in a single model, the technical and social costs and benefits, the ideal integration of cost/benefit is obtained. The model ("linear programming") contains equations and inequalities representing the processes and the capacity constraints in the facilities.

The model can be used to evaluate existing facilities, and also to indicate the configuration of facilities that would meet future needs of the area. Therefore it can be used to determine the optimal balance between various waste management processes as a function of their costs and capacity, and of the imposed limitations. Analysis of waste-management procedures would require basic data on the current methods of handling, including: sources and quantities of solid waste generation, waste collection systems, and waste disposal methods. This should also include any benefits that are generated in the system. These should be estimated. A "sensitivity analysis" is required because projections of future population and economic activity and solid waste generation will not be precise. The estimates of future solid waste if varied, should determine the impact of alternative levels of solid waste. Technological possibilities for handling and disposing of waste materials should be reviewed and classified. The major objective in developing a list of all possible alternatives would be to identify and estimate the values of those parameters (such as capital costs, costs of operation, and impact on the environment) necessary for analysis in the mathematical model. With the information thus far developed, the effects of statutory and administrative problems that could inhibit the implementation of an optimum system can be identified and fed into the model as additional constraints. The paper has a management flow diagram and an example of a linear program model.

Maier, P. P. and P. A. Rogers
"The California Integrated Solid Waste Management Project"
California Vector Views, 14:60, October 1967

The California Integrated Solid Waste Management Project is an intensive study of solid waste management in an area of approximately 1200 square miles surrounding the city of Fresno, California. The objectives of the study are to investigate, plan, and design a regional solid wastes management system that will handle urban, industrial, and agricultural wastes.

"Fresno Region Solid Waste Management Study"
Vol. I - Study Report (1st of 6 volumes), Report to the California State Department of Public Health, Report No. 3413 (Final), Aerojet General Corporation, El Monte, California in cooperation with Engineering Science Corporation, Arcadia, California, March 1968

The report is an in-depth study of a regional area made with the objective of developing a specific approach to the management of the wastes within the area under study. The Fresno, California, region was selected as the subject of the study to serve as a case in point. The region has an area of 1200 square miles, has core city (Fresno) having a population of approximately 250,000, 12 satellite cities, interspersed and surrounded by a high density agricultural belt. The report covers four aspects, viz.; Aspect I - systems engineering; Aspect II - implementation; Aspect III - development of a set of criteria or management guidelines; and Aspect IV - special studies, e.g., special problem areas, collection efficiency (type of container, frequency, etc.).

An important feature of the report is the development of a scoring system for rating a given system, whether it be of collection or of disposal. The report deals with present, transitional, and future (to the year 2000) systems. It proposes a system of public education to provide the motive force needed to bring proposed systems to fruition.

Rogers, P. E., J. Cornelius, and L. A. Burch
"Solid Wastes and Water Quality"
Special Study - Solid Waste Disposal, Task VII-1c, San Francisco Bay-Delta Water Quality Control Program, Prepared by Solid Wastes Engineering Section, Bureau of Vector Control, California State Department of Public Health for California State Water Resource Control Board, Sacramento, California, April 1968

The report is the result of a review and evaluation of the solid wastes disposal problems within the San Francisco Bay region as they might affect ground and surface water conditions. Among the subtasks, which taken together constituted the task, were:

1. Determine, by geographical area, existing quantities and types of solid waste generated in the study area and methods of disposal.

2. Locate and characterize solid wastes disposal sites as to type, input, and life expectancy.

3. Assemble and collate readily available hydrologic-geological data in the vicinity of solid wastes disposal sites. A listing of the remaining subtasks would be too lengthy for this compilation of abstracts.

Especially interesting items in the report are the following: On a population basis, the 13.8 million tons of solid wastes generated during 1967 represented 13.4 lb/capita/day. Broken down into categories this represented 5.7 lb/capita/day of municipal wastes, 1.6 lb/capita/day of industrial solid wastes, and 6.1 lb/capita/day of agricultural wastes. Of the total wastes generated, about 49 percent are disposed of at diposal sites, the remaining 51 percent is spread on the soil (e.g., manures), burned (e.g., prunings), or carted to sea (some cannery wastes). Approximately 37 percent of the wastes are disposed of at landfills. This represents 4.9 lb/capita/day. Since 1963, there have been 11 solid wastes disposal management studies conducted by federal, state, regional, county, and city agencies within the study area. At present landfill is the most widespread method of disposal. Within the next decade, several incinerators undoubtedly will be constructed.

Anon.
"Solid Waste Disposal Systems Analysis"
(Preliminary Draft) Prepared by FMC Machinery/Systems Group, Engineering Systems Division, FMC Corporation (Santa Clara, California) for the City of San Jose and County of Santa Clara (California), Project 75291, Document R-2697, 16 April 1968

This is an excellent report on a survey made of solid wastes sources and quantities in Santa Clara County. Important qualities of the report from the standpoint of planners and individuals concerned with operations research are:

1. The data given in the report are useable.

2. Seasonal waste factors are given.

3. Alternative site location patterns in Santa Clara County are listed. (The patterns are based on the assumption that landfills would be used. The use of a different type of disposal might result in different linages.)

4. The industrial waste factors are according to the Standard Industrial code by two digits.

The report includes projections of the annual solid wastes quantities expected in the years 1970, 1980, and 1990 by source and geographic location. The work described is best summed by quoting from the report:

> "Potential incineration facility sites were selected for system cost and environmental evaluation. Service areas were defined for these selected facility sites when combined in various numbers and ways to handle the solid wastes of the county. Estimated refuse hauling costs were computed for these various multi-site configurations.
>
> "On the basis of estimated hauling costs, a final ten disposal system configurations were selected for estimated facility operating cost

evaluation, and combined (or system) cost evaluation. An environmental evaluation was made of the disposal facility sites involved in these ten disposal configurations.

"During the solid waste system survey, a survey was also made of resource recovery processes as possible supplements to the incineration disposal system."

Among the items of interest are the following two: Survey results indicate that solid wastes quantities are much larger than suspected. By 1970, the annual solid wastes production in Santa Clara county is expected to be 3.4 million tons, and over 13.8 million cu yds (in the loose or noncompacted condition). The survey of resource recovery processes indicates that caution should be exercised in any attempt to recover materials from solid wastes finally reaching disposal sites.

MANAGEMENT FOR ENVIRONMENTAL HEALTH

Stead, F. M.
"Managing Man's Environment in the San Francisco Bay Area"
Institute of Governmental Studies, University of California, Berkeley, 1963

Table of Contents:

Historical Concepts of Environmental Sanitation

Air Sanitation - Water Sanitation - Food Sanitation - Shelter Sanitation

The Emerging Concept of Environmental Health

The Air Resource - Water Resource - Food Resource - Shelter Resource

Need for a New Value Scale of Environmental Quality

Need for a New System of Decision Making

Appendix: Man in California - 1980's: A Digest

Stead, F. M.
"Managing Man's Environment in California and the Bay Area"
Institute of Governmental Studies, University of California, Berkeley, 1963

The historical concept of environment sanitation is described with respect to air sanitation, water sanitation, food sanitation, and shelter sanitation. The present resources of air, water, food, and land and evaluated, and the needs for determination of environment values and systems of decision-making are discussed.

Anderson, R. T.
"Comprehensive Planning for Environmental Health"
Center for Housing and Environmental Studies, Division of Urban Studies, Cornell University, Ithaca, New York, June 1964

Thesis for the degree of Master of Regional Planning. Its table of contents is as follows:

Environmental Health and Urban Planning

Maintaining Air Quality Through Urban Planning

Planning for Refuse Disposal

Water Supply and Sewage Disposal: Determinants of the Urban Pattern

Healthful Housing in a Planned Environment

Planning for Nuclear Industry

Metropolitan Planning for Environmental Health

The President of the United States
"Natural Beauty of Our Country"
89th Congress, 1st Session, Document No. 78, 8 February 1965

A proposal is made concerning the cities, the country side, highways, rivers, trails, pollution, federal government activities, solid wastes, pesticides, and research sources.

Bagdikian, B. H.
"The Rape of the Land"
(Second in a Series on the American Environment) The Saturday Evening Post, 1966

"As our cities spread out cancerously in all directions, we are destroying - for profit - too many of the green and open places we need to make life livable."

The President of the United States
"Preserving our Natural Heritage"
89th Congress, 2nd Session, Document No. 387, 23 February 1966

Programs for controlling pollution and preserving the natural and historical heritage are outlined.

White, Lynn, Jr.
"The Historical Roots of Our Ecologic Crisis"
Science, 155(3767):1203, 1967

"With the population explosion, the carcinoma of planless urbanism, the new geological deposits of sewage and garbage, surely no creature other than man has ever managed to foul its nest in so short a time." "The simplest solution to any suspect change is, of course, to stop it, or better yet, to revert it to a romanticized past.... But neither atavism nor prettification will cope with the ecologic crisis of our time.

"What shall we do? No one yet knows. Unless we think about fundamentals, our specific measures may produce new backlashes more serious than those they are designed to remedy.

"Christianity, in absolute contrast to ancient paganism and Asia's religions, ... not only established a dualism of man and nature but also insisted that it is God's will that man exploit nature for his proper ends."

Patterson, R. W.
"The Art of the Impossible"
(In the issue "America's Changing Environment"), Daedalus, Fall Issue, pp. 1020-1033, 1967

"Despite its innumerable technical and economic complications, conservation is basically a social problem. Any accomplishment in conservation requires change in habit and thinking, a willingness to pay both in dollars and freedom of action. Given that willingness, technical obstacles could be overcome, without the one, the other will always hold us back,...."

The author equates a large part of our present pollutional problem with an unwillingness to pay the price of alleviating it.

"We know for example, that the many forms of pollution must be controlled. Nevertheless, although we like to add "at all costs," we do not yet mean it. In almost every case, the real stumbling block is cost - cost in dollars - the only measurement that we have learned to use.

"Only by imposing equal requirements on everyone can we eliminate the deadly competition that tempts states, cities, business, and industry to gain an advantage by not spending money on the protection of the environment.

"America was founded on the principle that the rights of minorities be protected, but today the public opinion survey has taken the place of thought."

Darling, F. F.
"A Wider Environment of Ecology and Conservation"
(In the issue "America's Changing Environment") (Issued as Vol. 96, No. 4 of the Proceedings of the American Academy of Arts and Science), Daedalus, Fall Issue, pp. 1003-1019, 1967

Important new researches are called for. The discipline must be capable of adjustment and compromise in a complex world where politics is a major ecological factor in the total environment.

Among the many interesting statements made in the article are the following:

"Our conservation must not be just the classic conservation of protection and development, but a creative conservation of restoration and innovation. Its concern is not with nature alone but with the total relation between man and the world around him .... and the ecologist should not avoid considering subjective values ecological factors.

"Psychosomatic diseases are manifestation of varied patterns of environmental conditions bearing on persons of different habitus types .... Pure water and pure air are accepted as being desirable, but the nature of the environment is too little considered.

"The so-called rise in the standard of living is being attended by a definite lowering of the standard of living in environmental terms.

"Ecologists might conduct surveys methodologically similar to the "scenarios" of the Hudson Institute. There imaginary debacles are set forth, including the hypothetical dropping of atomic bombs .... The consequences are followed through in considerable ecological detail by the time the scenario is presented. Ecologists could learn much from this technique.

"In the same line of thought, ecological reconnaissance can be developed further to give fairly accurate, reasonably quick answers to specific problems.

"Pollution of the environment is a product of our age, resulting from increase of human population, from technological activity, and from the linked phenomenon of urbanization."

Landsberg, H. H.
"The U. S. Resource Outlook: Quantity and Quality"
(Journal of the American Academy of Arts and Science, Vol. 96, No. 4),
Daedalus, Fall Issue, p. 1034, 1967

We have learned of the advantages of "disaggregation," i.e., separate utilization of different inherent features of natural resources, as opposed to their joint use in which they occur in nature.

Titles of the sections of the article indicate its contents:

1. The Role of Technology
2. Farm Land
3. Forests
4. Outdoor Recreation
5. Other Uses of Land
6. Demand for Energy
7. Metals
8. Water
9. Quality of Resources: How Good?
10. Technology - Two Sides of the Coin

11. Quality as Grade Differential

12. Economic Characteristics of Side Effects

13. The Case for Quantification

Quotations of note from the section on economics are:

"There is no answer to 'what price beauty' that would furnish a zoning authority a ready method of weighing the claims of, say, a stone quarry, ..." "For the sake of efficient management, it is frequently desirable that measures dealing with questions of environmental quality be considered for large areas at a time. This is almost a necessity where air and water are concerned. Action then tends to become collective and regional, rather than individual and local. The rationale is that the smaller the community considered the more the costs will be of the 'external.' Decisions made on the basis of large areas.... are likely to produce a result closer to optimum than the sum total of many individual situation."

Excerpts from the section on The Case for Quantification are:

Costs serves as a rough common denominator and as an integrating element. They help us determine the magnitude of what we must do or forego to achieve a given degree of environmental control. "We must, therefore, ask how we determine the point of equilibrium, beyond which additional purity costs more than is gained in terms of health or aesthetics?"

REFUSE PRODUCTION

Eliot, G. F.
"Garbage is a Nasty Word...But"
Reprint - Suburbia Today, May 1961

The per capita production of household refuse is 2-1/4 lb/day. A brief description of landfill and incineration is given. Also listed are their advantages and disadvantages, viz., cost, limited land, and air pollution.

Gordon, M.
"Cities Rubbish Woes Grow as Volume Rises, Dumping Sites Fill Up"
Reprint - Wall Street Journal, 18 October 1961

Over 40 percent of municipalities of 5,000 or more population still use open dumps. Three hundred and fifty cities now impose refuse collection fees. Ralph J. Black of the U. S. Public Health Service estimates local governments will spend over $1 billion for collection and disposal of refuse, as compared to $300 million in 1940. Descriptions are given of various cities' unique problems, and solutions are suggested.

Gilliam, H.
"The Bay's Odoriferous Garbage Explosion"
San Francisco Chronicle, This World, 4 April 1965

San Francisco Bay is being converted into a series of monumental garbage dumps. Candlestick Cover is the most infamous of these dumps, and San Francisco wants to flank the other side of the Bayshore Freeway with a similar dump. San Francisco produces 1,600 tons of garbage/day. The entire Bay Area produces 10,000 tons/day. There are two feasible means of disposing of the refuse: viz., destructive distillation – converting the refuse into carbon products, and composting.

Mix, S. A.
"Solid Wastes: Every Day, Another 800 Million Pounds"
Today's Health, p. 46, March 1966

Approximately 1,420 lb/capita/year (urban U. S.), or 800 million pounds/day of solid wastes, are produced in the U. S. The amount is expected to be three times as great by 1980. The annual outlay for collection and disposal is 1.5 billion dollars. Special problems of various communities are described. Salvage and use of waste as an energy source are areas to be exploited. A severe problem is that of the ignorance on the part of public and local officials.

Zane, Maitland
"Growing Mountain of Garbage"
San Francisco Chronicle, p. 5, 4 July 1966

San Francisco produces 1,500 tons of garbage/day which are collected by two family firms, Golden Gate Disposal Company and the Sunset Scavenger Company. The job is hazardous and unpleasant and pays $3.30 per house. Fill areas are Candlestick Lagoon and Brisbane. However, the latter's permit has been revoked. Nonsmog incinerators would cost $5,500 per ton, or $8,250,000 for 1,500 tons capacity.

Atkinson, B.
"Discarded Bit of Trash"
Oakland Tribune, p. 26, 24 July 1966

America's rivers are an important part of her tradition, yet the population pollutes these rivers at an ever increasing rate. Of the 11,420 U. S. communities with sewers, 2,139 continue to dump their raw sewage into local streams and watersheds. Not only that, but picnickers and boaters pollute with their wastes the waters they use. Conservationists hoping to help clean up the Potomac River found old automobile tires, mattresses, boxes, discarded automobile batteries, and a sewing machine. Industry pollutes rivers with its effluents. In 1963, the treatment projects then needed would cost the country $2,200,000,000, and that figure has grown since then.

Pollution is not only a matter of aesthetics, but one of public health. Waters will have to be reused in the near future as the demands of the cities increase. Polluted waters carry disease producing organisms and kill fish and shellfish, thereby endangering the public that eats the fish. Although human beings love their rivers, they often use them contemptuously.

COMPOSITION

Haefeli, R. J.
"Refuse Analyses"
I.R.G.R. Information Bulletin 15, p. 16, August 1962

The methods of refuse analyses as described, frequently serve as a prerequisite to the construction of large incinerators. Analyses of refuse for incineration plants are most difficult to make because the refuse may contain any and all substances having any connection at all to mankind. A method for analyses is described which is simple, reproducible, etc.

(Editor's note: One analysis made according to this method would cost more than $2,000. The results would be available after one month. Efficiency tests (direct and indirect method) of large power generation plants (incineration) showed that the analyses were not accurate. The method of sampling was insufficient.)

Rogus, C. A.
"Refuse Quantities and Characteristics"
In Proceedings of National Conference on Solid Wastes Research, A.P.W. Association Research Foundation, p. 17, December 1963

Most of the available information was gathered sporadically and usually for short time cycles by individual municipalities to serve their special needs. In the absence of authoritative guidelines, this information lacks uniformity and consistency. Nevertheless, the following tables are given because the data in them do represent trends.

MONTHLY DISTRIBUTION BY WEIGHT OF ORGANIC AND INORGANIC REFUSE

(New York, 1939)

Month	Organic (%)					Inorganic (%)			
	Garbage	Misc.	Paper	Wood	Total	Metal	Glass	Ashes	Total
Jan	5.7	1.0	12.4	0.3	19.4	4.3	4.0	72.3	80.6
Feb	9.0	1.7	12.6	0.7	24.0	6.6	4.9	64.5	76.0
Mar	9.7	2.1	20.6	0.3	32.7	7.4	7.3	52.6	67.3
Apr	18.1	2.8	21.6	2.0	44.5	7.4	6.9	41.2	55.5
May	26.7	3.3	23.0	3.1	56.1	7.1	6.8	30.0	43.9
Jun	35.1	3.8	24.3	4.6	67.8	6.4	6.8	19.0	32.2
Jul	43.8	4.1	25.5	5.9	79.3	6.6	6.3	7.8	20.7
Aug	23.1	7.4	37.6	3.8	71.9	11.6	5.1	11.4	28.1
Sep	12.6	5.6	26.7	4.9	49.8	8.2	9.1	32.9	50.2
Oct	10.1	3.8	31.0	2.6	47.5	8.9	4.0	39.6	52.5
Nov	6.6	1.9	18.0	2.1	28.6	3.8	2.9	64.7	71.4
Dec	3.5	0.8	9.0	0.8	14.1	3.1	1.9	80.9	85.9
Avg.	17.0	3.2	21.9	2.6	44.7	6.8	5.5	43.0	55.3

PHYSICAL ANALYSIS OF REFUSE BY WEIGHT
(Chicago, 1956-58)

Date	% by Weight						
	No. of Samples	Paper	Grass	Garbage	Metal	Glass	Ashes
3/56	10	50.1	-	6.4	18.5	-	25.0
4/56	8	64.0	-	7.4	13.9	-	14.7
5/56	9	57.3	11.9	5.6	14.0	-	11.2
6/56	6	60.7	6.5	2.5	13.6	-	16.7
10/56	6	56.0	4.5	3.5	11.9	-	24.1
2-3/57	4	49.2	-	6.1	17.5	-	27.2
4/57	1	53.3	19.7	3.2	9.3	5.9	8.6
9/57	2	42.0	23.0	3.6	7.4	5.4	18.6
11/57	1	59.3	-	2.3	5.2	6.5	23.0
2/58	3	61.4	-	3.3	9.0	7.4	19.0
4/48	3	63.7	-	1.5	8.1	5.8	20.9
6/58	1	54.7	34.4	0.8	6.2	3.5	0.4
Avg.		56.5	9.6	4.8	14.8	-	18.7

Kaiser, E.
In the general discussion of "Characteristics of Municipal Refuse" (By John M. Bell) in Proceedings of National Conference on Solid Wastes Research, A.P.W. Association Research Foundation, p. 37, December 1963

COMPOSITION AND ANALYSIS OF AN AVERAGE MUNICIPAL REFUSE

	% of Total Refuse
Rubbish, 64%	
Paper, mixed	42.0
Wood and Bark	2.4
Grass	4.0
Brush	1.5
Greens	1.5
Leaves, ripe	5.0
Leather	0.5
Rubber	0.6
Plastics	0.7
Oils, paint	0.8
Linoleum	0.1
Rags	0.6
Sweepings, street	3.0
Dirt, household	1.0
Unclassified	0.5

	% of Total Refuse
Food Wastes, 12%	
Garbage	10.0
Fats	2.0
Noncombustibles, 24%	
Metallics	8.0
Glass and Ceramics	6.0
Ashes	10.0

The following data are given under "Analyses of Composite Refuse:" moisture content, 20.7%; C, 28.0%; total H, 3.5; available H, 0.71; oxygen, 22.35; N, 0.33; S, 0.16; noncombustible, 24.93; ratio C:H, 39.4; btu/lb, 4917.

Anon.
"Refuse Quantities and Characteristics"
In Municipal Refuse Collection and Disposal, pp. 6-10, Issued by Office for Local Government, New York State Executive Department, 1964

Typical characteristics of refuse are as follows:

1. Weight

   a. Loose combustible refuse, 200 lb/cu yd.

   b. Compacted ashes, 1200 lb/cu yd.

   c. Uncompacted ordinary refuse, 200-300 lb/cu yd.

   d. In collection, 400-500 lb/cu yd.

   e. In fill, 700-1000 lb/cu yd.

2. BTU Value

   a. 9,000 to 10,000 btu/lb dry combustibles.

   b. Ordinary refuse:

Item	% by Weight
Combustible	45
Ash	25
Water	30
btu/lb	4,500

3. Stability

   The trend is from the former ratio of 50:50 mixed garbage and rubbish to a present one of 85-90% rubbish and 10-15% garbage. The production of refuse is indicated by the data in the following table:

	Lbs/Capita	
	Per Year	Per Calendar Day
"Ordinary Refuse"		
Garbage	200	0.5
Rubbish	1,300	3.6
Trash	400	1.1
Total	1,900	5.2

   According to a field survey, production is from 700 to 1500/capita/yr.

   The report also contains sections on collection and disposal technology.

Anon.
"Composition of Municipal Refuse and Properties of Typical Combined Refuse"
In California Waste Management Study, Report to the State of California, Department of Public Health, Report No. 3056 (Final), Aerojet General Corporation, Azusa, California, p. II-27, August 1965

MUNICIPAL REFUSE COMPOSITION

Material	% by Weight
Garbage	15
Noncombustible Rubbish	
Tin cans	5
Other metals	2
Glass	2
Stone, ceramics	1
Ashes, dirt	5
	15
Combustible Rubbish	
Paper	54
Rags	2
Grass, leaves	10
Wood	2
Leather, rubber	1
Synthetics	1
	70

TYPICAL COMBINED WASTES PROPERTIES

	Range	Median
Density (lb/cu yd)	200-300	300
Garbage (% by weight)	10-30	15
Noncombustibles (% by weight)	-	15
Combustibles (% by weight)	-	70
Total moisture (% by weight)	-	30
Calorific value (btu/lb)	2700-5300	4000

Kaiser, E. F.
"Chemical Analyses of Refuse Components"
Proceedings 1966 National Incinerator Conference, New York, 1966

The paper gives the proximate and ultimate analyses of 20 usual constituents of municipal and commercial refuse. The constituents include nine different types of paper and carboard, four food wastes, four foilage wastes, and three other assorted wastes. The amounts of each of these constituents will vary with different municipalities and even with different collections in the same city.

The proximate analysis of each constituent gives the general picture of the type of refuse moisture content, amount of volatile matter, etc. The ultimate analysis gives the chemical constituents of each refuse component as percent of carbon, hydrogen, oxygen, etc.

The analyses are useful to incinerator engineers, since they serve as the basis for calculations of air requirements, flue-gas volumes, and heat and material balances. The main problem in incineration is the fact that the content of municipal refuse varies so much. Knowing how much heat will be given off by each of the major constituents of refuse possibly will enable the engineers to predict, within a reasonable area of error, how much heat will be given off by the total refuse. When this is known, the heat can be used as a constant energy source by neighboring industries and institutions.

Anon.
"Office of Solid Wastes to Zero in on Polyethylene: Calls P-E 'Biggest Problem'"
Waste Management Report, Patton-Clellan Publishing Company, Washington, D. C.,
3 October 1966

The growing use of polyethylene containers has aroused concern among members of the Health, Eduction, and Welfare's Office of Solid Wastes. The officials view it as probably the "biggest problem" in solid waste management in the next few years. Polyethylene (P-E), which is not naturally degradable and which burns at temperatures high enough to melt conventional grates, now accounts for only one percent of non-returnable containers. But, Solid Wastes officials informed the Waste Management Report, the use curve is soaring. The Office of Solid Wastes plans to give P-E major attention. As an example of problems, the Office of Solid Wastes cites a truckload of one company's P-E waste that was misdirected to a conventional incinerator. The result of the encounter was $3 million in damages and a one-year shutdown.

Under a $154,032 Solid Wastes grant, Combustion Engineering, Inc., Windsor, Connecticut, is studying the rate of growth of P-E along with growth rates of other materials that cause solid wastes problems. At the same time, Battelle Memorial Institute, Columbus, Ohio, is examining the other side of the coin: the state of the art with respect to the problem of reclaiming materials. The Battelle study does not include iron and steel scrap for which data already are available.

Though still a new agency, the Office of Solid Wastes already has awarded grants totaling about $2 million for 19 demonstration projects. So far, the grants have been made to institutions and state and local governments, but officials say next year's batch will include many to industry.

Anon.
"World Survey Finds Less Organic Matter"
Refuse Removal Journal, 10:26, September 1967

In general, the organic content of refuse is declining. A rule of thumb is, generally speaking, the more electricity, gas, and oil a country uses for heating, the less the ash content of its refuse. Consumer packaging winds up being increased paper and plastic refuse.

A SUMMARY OF INTERNATIONAL REFUSE COMPOSITION (%)

	Ash	Paper	Organic Matter	Metals	Glass	Misc.
United States	10	42	22.5	8	6	11.5
Canada	5	70	10	5	5	5
United Kingdom	30-40	25-30	10-15	5-8	5-8	5-10
France[a]	24.3	29.6	24	4.2	3.9	14
West Germany[b]	30	18.7	21.2	5.1	9.8	15.2
Sweden	0	55	12	6	15	12
Spain[c]	22	21	45	3	4	5
Switzerland	20	40-50	15-25	5	5	-
Netherlands[d]	9.1	45.2	14	4.8	4.9	22
Norway (Summer)	0	56.6	34.7	3.2	2.1	8.4
Norway (Winter)	12.4	24.2	55.7	2.6	5.1	0
Israel	1.9	23.9	71.3	1.1	0.9	1.9
Belgium[e]	48	20.5	23	2.5	3	3
Czechoslovakia (Summer)[f]	6	14	39	2	11	28
Czechoslovakia (Winter)	65	7	22	1	3	2
Finland	-	65	10	5	5	15
Poland	10-21	2.7-6.2	35.3-43.8	0.8-0.9	0.8-2.4	-

[a]Paris (considered representative of national average).

[b]West Berlin.

[c]Madrid.

[d] The Hague.

[e]Brussels.

[f]Prague.

Anon.
"Glass Group Studies Disposal of its Packaging Materials"
Refuse Removal Journal— Solid Wastes Management, 10:28, November 1967

The estimate is made that glass accounts for 6 percent of the total 4.5 million lb waste/year. A study of the problem will be by the Glass Container Manufacturing Institute.

ECONOMICS

Cleary, E. J.
"Economic Implications of Industrial Waste Control"
Public Works, p. 64, February 1963

The author asks some questions (which are not answered) such as: What has industry to lose and to gain? The conduct of water pollution control? What is the price of quality degradation of water sources? What are the costs of preventing degradation?

National Sanitation Foundation
"Resources Economics and a Quality Environment"
Research Project on Fundamentals of Environmental Health, Summary of a Discussional, 2-3 May 1966

Three practical issues were selected for the principal focus of the discussional. They are:

1. What can the economist contribute towards the solution of problems relating to the quality of the environment?

2. What questions does he ask in this connection, which ones can he answer, and which ones are most difficult to answer?

3. To what extent is the institutional framework of laws, administrative agencies and policies an inhibition to the determination of economically optimal solutions?

Time Essay
"In Defense of Waste"
Time, 18 November 1966

The present economical situation and how the waste-problem fits into this economy are described. Factors which are considered are materials relatively cheaper than labor, principle of use rather than possession, luxury vs. necessity, and material vs. human.

Rao, S. Ananda
"Economics of Solid Waste Disposal - A Regional Approach"
Paper presented in the Seminar entitled Man and His Total Environment, Oakland, California, 5-8 November 1967

This paper was presented as part of the continuing Education Seminar sponsored jointly by the University of California (Berkeley and Los Angeles), the University of Hawaii, and the Western Regional Office of the American Public Health Association and Northern California Health Association. The paper is concerned with all aspects of environment. The case relating to the solid wastes management problems was treated in detail. The need for a regional approach to solving problems was established. The paper summarizes preliminary studies on economics and planning in relation to the overall comprehensive studies, conducted at the University of California.

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Rao, S. Ananda
"Regional Solid Wastes Management - An Empirical Approach"
Presented at the 7th Annual meeting of the Western Regional Science Association, San Diego, California (Accepted for publication in the Annals of Regional Science) 2-4 February 1968

The paper begins with a discussion of the general background, and description of the factors which complicate solid wastes management problems, and establishes the need for the study of the many aspects of wastes management. The main factors complicating the solid wastes management problem are the presently retarded state of the technology of disposal and fragmented jurisdictional approach to wastes management. The Regional Model is formulated with reference to the nine-county San Francisco Bay Area as an illustration. The framework, scope, and objectives of the model are clearly specified with their due implications for empirical work.

The long term objectives of the study were to formulate mathematical models, to develop consistent and comparable information on solid wastes generation and other economic variables, to determine the implications of wastes generation on land use planning, to review the technology of transfer and disposal, and finally to expand the concept of the regional approach and its ramifications on private and public expenditure, jurisdicational conflicts, and public interest.

The actual planning and design of the model and its data needs have been finalized and are reported. The innovation of the concept of the "Disposal Service Area" or "Functional Boundary" is made. The empirical portion of the model currently is being investigated. The portion of the study program relating to model formulation is nearing completion.

MISCELLANEOUS

Balmer, B.
"Garbage Collection and Disposal Methods and Practices in Washington Cities"
Washington Municipal Bulletin, Information Bulletin No. 5, Association of Washington Cities, 5 February 1954

The report is a survey of the refuse collection and disposal practices in the State of Washington. The report is divided into five main sections:

1. garbage collection systems,
2. garbage collection rates,
3. collection and disposal cost data,
4. different methods of refuse disposal,
5. legal regulations concerning the collection and disposal of refuse.

There are four systems of refuse collection in the state-municipal, contract, the regulated operation, and the unregulated operator. In the municipal operation, the garbage department is a utility, subscription to the service is usually mandatory, fees are charged, and city equipment is used. Under the contract system, the city regulates the contractor both by regulations and by the agreed upon contract. Fees are collected by the city and the contractor is paid a fixed amount. Under the regulated operator system, private operators collect the garbage and also collect the revenue, and the city's only income is from the contract or license fee. The unregulated operator has not city organization of refuse collection and disposal operations, and is prominent in cities of small population. Residents who do not pay the fee for the service dump or burn their garbage wherever they can.

Rates for collection are dealt with in various ways in the report, e.g., by the type of collection system used and by the population served. But regardless of approach, the charge averages about $1.00 per month for a single can. In four pages of data are listed various cities in the State and the economics of collection and disposal.

Twenty-nine percent of the cities disposed of the refuse by sanitary landfills, 14 percent by the burn-and-cover method, 23 percent at dump-and-burn operations, 30 percent used open dumps, and only 4 percent used incinerators. At the time of the report, the use of garbage grinders was not extensive enough to provide an adequate source of data concerning their effect on collection and disposal practices. The final section of the report dealt with laws and regulations that have been passed by the State concerning the collection and disposal of refuse and the regulation of costs.

Farkasdi, G.
"The Preparation and Utilization of Municipal Wastes in Hungary"
I.R.G.R. Information Bulletin 5, p. 3, August 1958

The report mentions the general taking over of private enterprises by the government in 1949. A national organization deals with all wastes. In 1952 the management problems caused by the complicated bureaucracy were too great. Four branch organizations were founded.

The newly founded Institute for Peat and Fertilizer Research is responsible for solving scientific problems, planning new plants, etc. All proposals must be submitted to the Ministry.

The interconnected system for collection, processing and utilization of all urban wastes of the entire nation has proved exceptionally good for the general and agricultural economy. Following the good results achieved in Hungary, the disposal of refuse soon should be similarly organized in Czechoslovakia.

Anon.
"APWA Session on Solid Wastes Research Needs"
Paper - APWA Session on Solid Waste Research Needs, February 1962

This paper is a rough draft of a panel discussion among the leading researchers and administrators in the field of Solid Waste Disposal. The purpose of the discussion was to find a possible best solution to the disposal problem, and to point out the areas where the most productive research might be done.

Many proposals were discussed — leading to possible areas of research and futher study. The idea of restriction of solid pollutants, as was done with the air pollution problem, was considered. If the general public and/or industry will not cooperate with proposals aimed at preserving health standards, then either federal or local jurisdications should have the power to force offenders to obey regulations. The idea of grinding refuse and depositing it in truck sewers was discussed often. The reduction in hauling and disposal costs make this method one worth looking into. Further research into preventing air pollution from incineration was recommended, as was the investigation of the value of compost as a fertilizer.

The possible development of wastes for use as by-products was mentioned. In the case of air pollution, when industry was forced to control pollutant emissions, it found that escaping gases could be reused. Perhaps some of our solid wastes can be converted into a beneficial by-product also. Penumatic pipelines were discussed as a possible means of transporting wastes to a transfer station. Research was recommended in the area of the use of incinerators in small rural communities.

It was recommended that studies be made of the present refuse production by municipalities. With the use of such data, and the predictions of future changes in the packaging industry, plans for tomorrow can be formulated.

Proceedings National Conference on Solid Wastes Research: University of Chicago, Illinois
American Public Works Association, December 1963

Table of contents:

23. Resources for the future and industrial conservation.

24. Metroplitan problems of refuse disposal.

Hart, S. A.
"Solid Waste Management - Today and Tomorrow"
Paper presented at the First Annual Conference, California Refuse Removal Council, Los Angeles, 7-9 May 1965

Described in the paper is the overall situation in wastes management with respect to the three sources of wastes, viz., municipalities, industry, and agriculture; the three kinds of wastes, viz., solid, liquid, and gaseous; and the three resources for waste disposal; viz., land, water, and air.

A sanitary and desirable environment for the future can only be obtained if removal, disposal, and utilization are accomplished properly, and their effect on the environment is known.

"The Solid Waste Disposal Act"
U. S. Department of Health, Education, and Welfare, Public Health Service, Office of Solid Wastes, Title II of Public Law 89-272, 89th Congress, S-306, 20 October 1965

The intent of the Act is to initiate and accelerate a national research and development program for new and improved methods of proper and economic solid wastes disposal, including studies directed toward the conservation of natural resources by reducing the amount of waste and unsalvable materials.

Carberry, J.
"Some Day--Paper Shirts You Wash Down the Sink"
Newspaper - Berkeley Daily Gazette, p. 14, 27 October 1965

Product designers need to consider the ultimate disposal of their merchandise. Along these lines, disposable clothing such as shirts may be the style of tomorrow. Businessmen of tomorrow may be able to come home from work, take off their paper shirts, and wash them down the kitchen sink.

Railroads and sewage systems may be used in the future to handle the bulk of refuse — transporting the wastes to a more suitable area of disposal than their source. Regional planning — disregarding political boundaries — must be set up so that wastes can be disposed of in the most efficient manner possible. Professor P. H. McGauhey of the University of California has doubts, however, concerning the baling of refuse and the ultimate dumping of these bales in the ocean, as do marine biologists and others familiar with sea life.

A program must be started to educate the general public on the scope of the solid wastes problem. Once the public becomes concerned, private industry will be stimulated to investigate efficient, and profitable, methods of wastes disposal.

National Academy of Sciences, National Research Council
"Waste Management and Control"
Publication 1400, National Academy of Sciences, National Research Council, Washington, D. C., 1966

Table of contents:

National Sanitation Foundation
"Political Processes in Environmental Management"
Research Project on Fundamentals of Environmental Health, Summary of a Discussional - 24 June 1966

The objective of the discussional on Political and Governmental Science was to explore the roles and responsibilities of those persons constituting the political and executive structure of government in defining and solving problems of man in relation to his environment; and to examine the adequacy, functional effectiveness, and limitations of the various levels of representative government in dealing with environmental problems of society.

Special consideration was given to the following activities: planning; legislating, enforcing and educating; budgetary, taxing and economic evaluation; later jurisdictional cooperation.

Loehr, R. C.
"Research and Engineering are Keys to Progress in Solid Waste Management"
Western City, p. 46, September 1966

The accumulation of people who produce the waste, the increased quantities and types of solid wastes, the lack of enough qualified people to solve the problem, the general disinterest and apathy of people, and the relatively few people who can think creatively and imaginatively to provide new ideas and possibilities — all are factors in the fundamental cause of the solid waste problem.

Contributions to solve the problem will come from experts in law, management, planning, education, and engineering, but the greatest contribution will come from engineers.

Anon.
"The W. H. O. Programme in Solid Wastes"
World Health Organization Bulletin, WHO/WD/67.2, 1967

The W. H. O. will expand its program of assistance to member countries along the following lines:

a. Advice and assistance on the planning, organization and implementation of national and local waste management and control programmes.

b. Organization of conferences, seminars, and training courses for the discussion and exchange of technical information and experience in solid waste management and control.

c. Provision of fellowships for the training of local personnel in this field.

d. Convening of expert committees and scientific groups of experts, to study specific problems arising in waste management and control.

e. Technical services, to assist Member States, upon request, in providing remedial measures for urgent solid wastes disposal problems and in planning preventive programmes for the future.

f. Pre-investment studies, by the provision of consultant services or through the financial assistance of the UNDP/SF, for the preparation of engineering/economic feasibility reports for sewage and solid wastes collection and disposal.

g. Collection and dissemination of information, through the preparation of monographs, technical documents, guides, etc. This activity will be expanded considerably with the establishment of the WHO International Reference Centre on Wastes Disposal.

h. Continued cooperation with other international professional associations and nongovernmental organizations concerned with waste management and control.

U. S. Dept. of Health, Education and Welfare
"Summaries of Research and Training Grants in Solid Wastes Management"
Public Health Service, 1967

This publication describes briefly 53 research and training activities in solid wastes management supported by Public Health Service grants through January 1, 1967.

Anon.
"Solid Waste Research Projects"
The American City, 82(6):63, June 1967

The following is a list of projects named in the paper:

Barrington, R. I.: Feasibility of refuse collection and disposal by the bag system in a sanitary landfill.

Madison, Wis.: Study of the Gondard-Process. Physcial changes in the conditions of "milled" versus "as collected refuse" in the fill site.

University of Illinois: Study of the geological factors influencing the movement of ground water into landfills and the leachate of ground water away from landfills.

King County, Wash.: Demonstration of the feasibility of a refuse burying compactor.

West Virginia University: Disposal of solid wastes and sewage sludge using fluidized-bed techniques.

Stamford, Conn.: Design, construction and demonstration of a 175-ton incinerator.

Santa Clara, Calif.: High-rate composting (Ralph Stone and Co., Eng.).

Bergen County, N. J.: 600-ton incinerator with heat recovery and power generation.

Calif. Dept. of Public Health: (Aerojet General) Development of a regional solid waste management system.

Bridgeport, Conn.: Construction of an incinerator for difficult wastes. Determination of the relative hazards of disposing volatile and explosive substances.

Gainesville and Alachna County, Fla.: High-rate composting including sewage sludge.

Washington, D. C.: Demonstration of feasiblity and cost of an 800-ton incinerator.

Los Angeles, Calif.: Control of gas movement from existing and new landfills.

Maryland State Dept. of Health: Use of abandoned strip mines for landfills.

Raleigh, N. C.: Mathematical simulation model to refuse collection and landfill site selection.

Broome County, N. Y.: Method of county wide disposal program.

Gentieu, F. A.
"Unified System of Waste Disposal and Management"
Private Communication, 30 October 1967

An updating of Mr. Gentieu's original plan which called for the division of the U. S. into Sanitation Areas – areas serving from 8 to 10 million inhabitants. Examples and details of such areas are given. The plan covers everything from economics to technology, and goes into detail for each subject. Although sound in most of its premises and proposals, it is ahead of its time with respect to present public attitudes.

Black, R. J. and L. Weaver
"Action on the Solid Waste Problem"
Proceedings of American Society of Civil Engineers, Journal of Sanitary Engineering Division, 93(SA6):91, December 1967

> "It is clear that the solid waste problem is of such increasing magnitude as to demand the utmost in imagination and innovation. Engineers associated with solid wastes disposal activities would do well to keep in mind the availability of the grant mechanism under the solid wastes program. It offers a unique opportunity to make important technical contributions that will help many U. S. communities solve waste management problems of serious, and often critical proportions, by recovery and utilization of potential resources in solid wastes; and to provide technical and financial assistance to state and local governments and interstate agencies in the planning, development, and conduct of solid waste disposal programs."

Feibusch, H. A.
"Planning the Future of San Francisco Bay"
Civil Engineering, ASCE, p. 68, January 1968

The article describes the work of the San Francisco Bay Conservation and Development Commission.

CONTAINERS AND STORAGE

Jacobson, A. R.
"Refuse Collection Will Save $600,000 Annually"
Public Works, 93:186, June 1962

In Orlando, Florida, a 100 percent containerized system is used. It consists of 78,000 carry-out refuse pickups and 38,000 curbside trash and trimmings pickups. The new system saves the city $600,000 annually.

Magy, H. I, and R. J. Black
"An Evaluation of the Migration of Fly Larvae From Garbage Cans in Pasadena, Calif."
California Vector Views, 9:55, November 1962

This report is an account of a five-week study in Pasadena, where garbage containers at thirty households were studied.

When flies infest garbage cans, the larvae produced are usually concealed in the garbage. Because the inside of the can generally is too moist, the mature larvae crawl out of the can, either through a hole or up the sides of the can and out from under the cover. Once on the ground, they crawl to a dry place or burrow into dry ground to pupate.

Each garbage can was placed inside a larger fiber drum containing several inches of a mixture of sawdust and sand. The can was used in the usual manner, and garbage was collected every week. After each collection, the sawdust and sand and any larvae that had migrated from the can were removed from the fiber drum. The larvae were then separated from the sand and counted. Averages of the number of larvae collected from each can each week ranged from 84 to 767. The containers were classified as either satisfactory or unsatisfactory. Satisfactory cans were those with tight lids and no holes. The unsatisfactory containers produced an average of 877 larvae/can/week; whereas the satisfactory containers produced an average of 92 larvae/can/week. Other factors, besides the condition of the can, which affected the fly production included:

1. how well the garbage was drained and wrapped,
2. what kind of food was prepared and how much was left as garbage,
3. how long the garbage was left exposed to ovipositing flies before it was wrapped,
4. whether the can was washed out after each collection, and
5. whether or not the garbage was placed in the can carefully.

Other factors considered were the size of the family, size of the container, and exposure of the container to the sun.

Only 26 percent of the satisfactory containers produced flies. When a can is new, entry of adult flies is less frequent. On the other hand, 46 percent of the unsatisfactory cans produced flies, and produced an average of four times as many flies per week as did the satisfactory containers.

The data suggested that there were two primary variables which affect the number of fly larvae migrating from the garbage cans under study: temperature and the condition of the cans.

JOINT ABSTRACT OF SIX ARTICLES ON PAPER REFUSE DISPOSAL BAGS
(References to each article are denoted by the number of the article in parenthesis.)

(1) Fox, Gerald G., "Paper Bag Disposal System Finds Ready Acceptance," Public Works, November 1964

(2) MacDonald, James P., "One Man Refuse Collection," The American City, September 1965

(3) Sanborn, Kenneth M., "Garbage Cans. Who Needs Them," Public Works, March 1965

(4) Anon., "Refuse Sacks Are In," The American City, December 1965

(5) Anon., "Half of Sweden Uses Paper Sacks," The American City, June 1965

(6) Rogus, C. A., "Refuse Collection and Disposal in Western Europe: Part I: Refuse Collection and Street Cleaning," Public Works, pp. 98-103, April 1962

The following American cities have adopted paper refuse bags. (A mixed paper bag and other container system in which some subscribers use bags, while others use their more traditional containers is denoted by an asterisk.)

	City	Date of Adoption	Type of Bag
(1)	Camden, Arkansas*	1964	Garbax
(2)	College Park, Md.	1962	Papercan
(3)	Junction City, Kansas*	1964	Westvaco
(4)	Mt. Wolf, Pa.	1965	St. Regis Refuse Sacks

The use of disposable paper bags for refuse reduces the following problems associated with trash cans: Odor (1) (3) (4) (5); flies, maggots, and other insects (1) (3) (4); dogs knocking over the cans to reach their contents (4). These bags are treated with a resin for strength and water resistance. They are weatherproof and hold wet and greasy materials well (1) (3) (6). Spillage and noise are reduced, as well as the unsightliness associated with trash cans and boxes (1) (4) (5) (6).

The use of bags is preferred by an overwhelming majority of those using them, as shown by surveys (1) (3) (5), and by general impression (4). Those cities in which both bags and other containers are used, expect more bags to come into use despite the higher collection fee.

The light weight of the bags lead to several advantages. College Park, Md., was able to convert to a pickup system with seven small trucks, each making 300 stops per day and operated by a single man. Previously 3 large trucks manned by crews of four were used. Although the initial capital cost of the new system was $21,000 in comparison to the previous system's capital cost of $15,000, the new payroll is $19,000 per year less due to the reduction in the necessary work force from 12 to 7 men. Subtracting $2,000 per year from capital costs leaves a net savings of $17,000 per year (2). Elsewhere, the work load for the crews has been lightened (3) (4) (6), and a reduction has taken place in injuries to workers (3).

The refuse sacks were supplied by the collection agency to the homeowners in all communities cited.

More than half of Sweden's 1,005 municipalities either use or are testing them, and one city in five has converted completely to paper bags (5). The practice is followed on a modest scale in other European communities (6).

There is an initial cost for the bag holder. Bags cost about 8 cents each.

Fehn, C. F., J. O. Hall, M. Rosenthal, J. R. Cain, J. H. Rigby, and H. Farmer
"Bulk Storage and Mechanized Collection of Combined Refuse"
Public Works, p. 130, September 1964

Bulk storage containers provide for in-place mechanized transfer of refuse from bulk-storage containers to large-capacity collection trucks equipped with compactor mechanisms. These systems eliminate the need to transport bulk-storage containers to the disposal site.

Containers range in capacity from 1/2 cu yd to more than 8 cu yd. The heavy gauge metal containers are watertight and exclude small animals and most insects. They are suitable for use at short term community events such as fairs, where a large volume of refuse is generated for a short period of time.

Operational problems include the difficulty in opening the heavy doors, and the occasional use of the containers for shelter by indigents. Cleaning and servicing are still problems.

The system is used in installations of the Armed Forces, in Orlando, Fla., Valdosta, Ga., and in Savannah, Ga.

Containers are also suitable for the collection of refuse at parks, roadside rest stops, and other recreational sites, commercial areas, public housing, and industrial areas.

Ecke, D. H. and D. D. Linsdale
"Fly and Economic Evaluation of Urban Refuse Systems. Part I: Control of Green Blow Flies (Phaenicia) by Improved Methods of Residential Refuse Storage and Collection"
California Vector Views, Vol. 14, No. 4, April 1967

This study was concerned with the green blow-fly production from household garbage containers, and the density of adult green flow flies in four comparable areas of 500 homes each in Santa Clara, California. Traps collected all fly larvae migrating from 40 representative garbage containers in each area. Adult fly density was determined at 20 standardized attraction stations.

The systems studied were: once-a-week cans, once-a-week suspended paper containers, twice-a-week cans, and twice-a-week paper.

Frequency of refuse collection was an important control factor in that neither of the once-a-week systems achieved satisfactory control, but both the twice-a-week systems resulted in good to excellent control.

Control must be evaluated in terms of total fly production as well as in terms of frequency or distribution of fly sources. Using these criteria, the systems ranked as follows:

a. Once-a-week metal cans - extremely high production from about 67 percent of containers.

b. Once-a-week paper bags - high production from 20-25 percent of containers.

c. Twice-a-week metal cans - high production from about 10 percent of containers.

d. Twice-a-week paper bags - no containers with consistently high production.

e. Mixed refuse containers are independent fly sources with little or no dependence upon nearby sources as to their productivity.

Rogers, P. A. and G. J. Bellenger
"Fly and Economic Evaluation of Urban Refuse Systems. Part II: An Efficiency Analysis of Paper Bag Containers"
California Vector Views, Vol. 14, No. 5, May 1967

This study is an economic evaluation of once-a-week garbage can service, twice-a-week garbage can service, once-a-week service from suspended paper bag containers, and twice-a-week service from suspended paper bag containers.

Four comparable areas of approximately 500 homes each were selected in the City of Santa Clara, one for each of the four systems studied. Evaluation was based on a time and motion study which compared the various aspects of pickup service between each of the four areas. Up to 30 percent savings in manpower was achieved by substituting paper bags for metal cans; but unless the collection system was actually designed around the paper bag concept, the savings in time would probably not be sufficient to pay for the additional cost of the paper bags.

EQUIPMENT

Wilcox, F. F.
"Only Modern Waste Collection Programs Can Use Labor Efficiently"
Public Works, 86:99, May 1955

The use of modern packer trucks in Lynbrook, N. Y., increased worker efficiency by reducing strain, increasing speed of loading, and decreasing injuries. The work is organized so that each crew has the same share of residential and business collections.

The men are allowed to salvage rags, waste paper, and scrap iron. This increased worker satisfaction and reduces the amount of waste that must be disposed of by the city. Cost in 1953 was 120,000 dollars — a per capita cost of $4.80 for two household collections each of garbage and rubbish, and for daily business collections.

Henning, E. G.
"Refuse Collection Equipment will Pay for Itself in Two Years"
Public Works, 93:112, May 1962

The article concerns Orlando, Fla. The city has switched to 100 percent containerization. Involved are 72,000 pick-up and 38,000 curb-side trash and trimmings pick-ups/week. The containerization system saves $600,000/yr. In 1960 "Dumpmaster" principle was adopted in which containers are emptied on the spot in a self-loading packer. The city also switched to front-end loaders for hand-collection routes.

The master plan includes the following features:

1. A properly sized container is placed at each location.

2. Twenty 24-cu yd self-load Dempster Dumpmaster trucks, and 1100 containers of 3 to 8 cu yd capacity make up the physical equipment.

3. All commercial services are containerized.

4. Wages and fringe benefits for "hand pick-up" crews were increased. Drivers were made crew bosses.

5. Light fiberglass 40-gal tote containers were purchased for the pick-up men.

6. The crews work on a combination hourly task-force basis (example, a hard working crew can finish the day's assignment in 5 hours and yet get 8-hr pay).

7. Eighteen hand-collection routes with twice-a-week pickup for 36,000 dwelling units were established. Weekly trash and trimming pick-ups amounted to 38,000. Each Dumpmaster was allotted 6,000 pick-ups per week.

8. Commercial pick-ups are made at night by 5 Dumpmasters.

Warner, W. P.
"Better Refuse Collection for Less Money"
Public Works, 93:70, December 1962

By changing to compaction type trucks, Lakeland, Fla., is now able to collect trash with garbage twice a week, as opposed to the separate but less frequent collection of the two. Dumpmaster containers now are used for schools and commercial establishments. Three 20-yard Dempster Dumpmaster packers needed. The 256 containers serve 580 establishments, have a total storage capacity of 1,707 cu yd, and are emptied on an average of three times per week. The annual operating budget has been reduced from $281,000 in fiscal year 1960-1, to $215,000 in fiscal year 1961-2, to $200,106 in fiscal year 1962-3. The total net savings expected during the life of the equipment are three million dollars.

JOINT ABSTRACT OF SIX ARTICLES ON REFUSE TRAINS

The following articles are abstracted jointly here. References may be identified by numers in parenthesis.

(1) Gill, Jack, "A Vote for Good Service," The American City, p. 96, May 1965

(2) Green, L. B., "Keep Refuse Collectors on the Route," The American City, pp. 110-111, July 1965

(3) Tyson, Charles B., "Refuse Collection Train Improves Service," Public Works, pp. 99-100, July 1964

(4) Anon., "How to Solve the Holiday Collection Problem," The American City, p. 20, March 1965

(5) Anon., "Refuse Trains Keep Trash Collection on Schedule," The American City, p. 18, September 1965

(6) Anon., "Trailers Help to Solve Park Refuse Problem," The American City, p. 158, August 1965

The following cities make use of trailers and trains for refuse pickup: Alberquerque, N. M. (1); Montgomery, Ala. (2); Valdosta, Ga. (3); Tucson, Arizona (4); St. Petersburg, Fla. (5); East Meadow, Long Island (6).

Refuse trains can operate with smaller crews and cover the same amount of territory in the same amount of time as do more conventional vehicles (3) (4). They require less maintenance and are cheaper to run (3) (4). In Valdosta, Ga., refuse trains consisting of three-cu yd LoDal containers mounted on wheels and run by three-man crews do the same job as a packer truck with a crew of four. This saves $5,000 in manpower costs. In addition, a train costs $33,032 which is $6,000 less than a packer truck, and maintenance costs are 20 percent those of conventional trucks (3).

Tucson, Arizona (4) and St. Petersburg, Fla. (5) use them for brush collection. Their versatility eases route changes (2) (3) (5). Trailers can be left at special functions such as public gatherings, and can pick up later (2) (3) (6). Salisbury Park, in East Meadow, Long Island, uses trailers for trash pickup, since they do not damage surfaces and grass due to their light weight. Manpower requirements are reduced by 2/3, thus releasing men for other duties. The bouncing of the trailers compacts the refuse by about 25 percent (2). These trailers are serviced by mother trucks (2) (3) (4) (5).

Anon.

"More Refuse Collected with Less Work"

The American City, 80:26, July 1965

In Wyandotte County, Kansas, a small 3-wheeled Cushman Dump Truckster is used to service long driveways and widely spaced houses in the suburbs. The hopper holds 1-1/2 cubic yards of refuse, or 1,000 lb, and can be dumped directly into the large truck with which it is used. The vehicle's small size permits it to be turned around in narrow driveways.

Anon.
"One Truck Serves 4,400 People"
The American City, 80:21, April 1966

The Waynesborough, Ga., Sanitation Department uses a compaction type truck which loads at the side near the front. It needs no tail gate. It serves 4,400 residents.

"Refuse Storage and Removal in City Centres"
Public Cleansing, 57(2):85, February 1967

A description is given of the application of the Carchy system of waste handling (sometimes inaccurately referred to as waste disposal). Apparently the system is suitable principally for highly concentrated waste output, i.e., apartment complexes, etc. Judging from the sketchy description, it consists of an interconnected system of piping through which refuse from individual buildings is hydraulically transported to a central receiving chamber. The contents of the chamber are pumped into a tanker truck. Here, the water content is reduced by pressing the refuse within the vehicle and draining off the excess water. When the tanker is filled with compressed refuse, the load is taken to the tip and is disposed of. The writer believes a static press would be preferable. The tanker, equipped with pump, etc., weighs 17,900 lb – which does not leave much for the refuse! Bulky articles (any article above 10 in. in length and 4 in. in diameter) must be handled separately.

Apparently this waste handling system is intended to constitute the "answer" to on-site incineration at apartment houses.

Anon.
"Convey Refuse by Vacuum"
Refuse Removal Journal, 10:34, February 1967

> "A London high housing development will adopt a Swedish system of piped refuse disposal to serve a 1700-apartment complex, according to Muncipal Engineering, a British public works magazine. The system, called "Centrolzug" is vacuum sealed and refuse is conveyed by suction. In place of the usual storage chamber or incinerator on the ground floor of the apartment, the refuse which has accumulated in the vertical chute is drawn by air pressure through a horizontal pipe to a central collecting point. Turbo-extractors are used to create the vacuum in the horizontal pipes. A program is arranged so that the valve of each chute is opened in turn and the contents drawn quickly through the transporter pipes to the central collecting points for disposal. To offset high capital installation costs, savings are possible by eliminating the need for refuse storage containers and chambers and multiple pick-ups."

Zandi, I. and J. A. Hayden
"Collection of Municipal Solid Wastes in Pipelines"
Paper presented before the Transportation Conference, American Society of Civil Engineers, San Diego, California, February 1967

In the paper an examination is made of the feability of the application of solid transport in pipelines to the collection and removal of solid wastes. "Whether the pipeline transport of solid waste may be considered as a serious alternative to truck collection, depends upon the answers to two fundamental questions:

1. Is pipeline transport of solid waste technologically feasible?

2. How does solid waste pipeline compare economically with the truck collection?"

According to the paper, that under the conditions prevailing in Philadelphia, Pennsylvania, the collection and removal of solid waste in a combined pneumatic and slurry system would be technologically and economically feasible. The longer the haulage to the disposal site, the more attractive the pipeline system becomes. The more waste to be handled, the less expensive the pipeline would be for a unit of waste; on the other hand, the costs of truck collection would increase proportionately. The problems involved are overwhelming and the initial capital required is huge, but the gains are attractive.

Bjorkman, A. A.
"Vacuum Network Serves 3,000 Apartments"
Refuse Removal Journal, 10:12, March 1967

In the article is described a system of refuse transport by underground pipeline between apartment dwellings and a central collecting station. The installation is located in Stockholm, Sweden. The scheme will embody 3,000 apartment units and have a maximum distance of 1-1/2 miles. The main pipe will be 24 in. in diameter. At the bottom of each refuse chute is a valve room. Rooms are connected by pipes to a central refuse bunker equipped with a turbine exhauster, dust filter, etc. Valves under the different refuse chutes are opened for a few moments consecutively and periodically by an automatic remote control device. The power consumption is 90 KW.

Anon.
"Japanese City Adds Mechanized System"
Refuse Removal Journal—Solid Wastes Management, 10:4, November 1967

To meet the increasing production of wastes in areas of heavy population density, a mechanized system for collection was developed. It combines the action of a collection truck with a crane and a new type of container. The crane is located in appropriate places, such as under apartment houses. In use, the crane lifts the bin, empties its contents into the vehicle, and returns it to its original position. The truck is equipped with a sprayer to disinfect the container. Three-hundred and sixty households can be served during a 9 hour day.

FREQUENCY AND PROGRAMMING

Pearson, E. A. and H. B. Gotaas
"Refuse Collection and Disposal Practice in California"
Public Works Newsletter, 19:1, September 1953

An investigation was undertaken in 13 California cities to study collection practices. Field investigations were conducted during the summer months of 1950 and 1951 in the cities of Bakersfield, Berkeley, Burbank, Fresno, Lodi, Long Beach, Oroville, Palo Alto, Riverside, Sacramento, Santa Rosa, Stockton, and Watsonville.

To study collection practices and to determine what method of collection is the most efficient and economical in a given situation, the type of refuse generated and the quantity must be known. In the 13 cities studies, the more often the collection service, the greater were the amounts of refuse generated per person. The collection operation, including the round trip to the disposal site, constitutes the major cost of the refuse activity. The investigators found that the container location had much bearing on the amount of time needed for collection and costs in man-minutes. The pick-up time varies from approximately 103 man-minutes per ton for zero percent rear-of-house collections (100 percent of curb), to 165 man-minutes per ton for 100 percent rear-of-house collection (zero percent alley or curb). Assuming an average wage rate of 2.5 cents per man-minute, the cost of labor for pick-up of refuse at the alley or curb is approximately $2.56 per ton and $4.15 per ton for 100 percent rear-of-house pickup. The difference in costs between rear-of-house and alley and/or curb refuse collection is approximately $1.59/ton.

Noe, T.
"Revised Schedule Streamlines Garbage Collection"
Public Works, 90:100, January 1959

The Winston-Salem sanitation divides its territory into three areas, labeled A, B, and C. Before July 1958, collections were on identical days each week, with Area A being collected on Monday, Area B on Tuesday, Area C on Wednesday, and a second collection in each area crowded into Thursday and Friday. This short interval resulted in less garbage in the second collection than in the first. A survey showed the following

Day	Average Amount/House (lb)
Monday	20.18
Tuesday	19.30
Wednesday	18.63
Thursday	11.24
Friday	9.71

It cost the city $10 to $11 per ton to collect garbage from Monday to Wednesday, but $16.41/ton on Friday due to the small amount of garbage.

Collection was reorganized into a 3-week schedule. In the first week, Area A is collected on Monday, B on Tuesday, C on Wednesday, and then A again. After weekends and holdays the sequence is picked up where it was left off, with the order remaining A, B, C. Every dwelling unit receives at least two collections every eight days.

The new collection system has made possible the reduction in number of trucks from 31 to 25 and scows, from 13 to 5. To compensate, the number of load packers was increased from 18 to 20. The working force has been reduced by 16 laborers.

Campbell, E. and R. J. Black
"The Problem of Migration of Mature Fly Larvae from Refuse Containers and Its Implication on the Frequency of Refuse Collection"
California Vector Views, 7:9, February 1960

The problem of the migration of fly larvae from garbage cans is a serious one. The article deals mainly with the solution of the problem in Concord, California. The Contra Costa Mosquito Abatement District did the research — becoming the first public agency to engage in a sustained and intensive fly control program.

Regular garbage cans were enclosed in open fiber drums, which had a three inch layer of sand and sawdust in the bottom. After each collection, the sand and sawdust, along with any larvae which had migrated from the garbage cans, were collected, and the number of larvae counted. In 1957, 3.2 percent of the larvae migrated from the can in the first 4 days of the week, while 96.8 percent migrated on the last three days of the week. This indicated that the best way of lessening the number of flies in an area would be to collect the refuse twice per week and thus greatly reducing the number of larvae which escape from the cans.

The 1958 studies showed similar results, with 10.6 percent of the larvae leaving during the first four days of the week, 89.4 percent migrating at the end of the week. Chemical studies were also made in 1958. The results of the chemical tests showed that when attached to the underside of the garbage can lid, neither PDB nor naphthalene are of any value in reducing substantially the number of fly larvae that migrate from garbage cans.

In a warm climate, there are three ways to control the fly-migration problem:

1. Establish twice-a-week community-wide collection of mixed refuse.

2. Require each householder to drain the securely wrapped garbage.

3. Require each householder to install and use a garbage grinder.

The twice-a-week collection idea is the most feasible.

Hume, N. B.
"Refuse Collection in Los Angeles"
Public Works, p. 136, January 1962

The first public service rendered in Los Angeles was garbage collection (food wastes only). This was followed by noncombustible refuse service, later by the separate collection of combustible refuse service in 1957.

Within each of the city's major operating districts, a dispatcher controls the activities of a number of collection crews, averaging about 55 per dispatcher. Each crew has on each day a regular assigned route for which it is responsible. Generally, two sections are allotted per route. The first section is the more remote of the two from disposal area. Most collection crews make at least two trips per day, the average being 2.25 trips per day. In establishing route boundaries, it is important that the size of the first section of each route be kept such that it is unlikely that a truck would become loaded to capacity prior to completing service in that section. The second section generally is on the way to the collection point. Thus, if the truck is not yet loaded to capacity it can collect in the second section; thereby reducing the probability of encountering a greater than capacity load within the second section.

Whenever a driver finishes his regular route before loading the truck to capacity, or if his vehicle is loaded to capacity before completing the route, he must telephone the dispatcher and report. The dispatcher can then make appropriate assignments or reassignments to equalize the loads and the services rendered. At least one mobile-radio equipped vehicle is used in each major operating district. This allows for the immediate assignment of crews to areas requiring additional collection help, for the prompt servicing of complaints, etc.

Pedo, D. J.
"Reorganization Cuts Refuse Collection Costs"
Public Works, p. 110, July 1964

In south Milwaukee, Wisconsin, the refuse collection schedules and routes proved to be insufficiently flexible to meet needs of population growth and disruptions due to holidays, heavy snow, etc. Its refuse ordinances were too vague either to be enforced or to be interpreted by citizens.

Public pressure for a change was implemented through the local newspapers, pamphlets delivered by the service crews, and through the city council.

Basic changes implemented in new ordinances were:

1. Burnables were to be separated from nonburnables in different containers.

2. Size and location of containers were specified.

3. Better housekeeping of storage areas through the use of racks and other devices to keep containers out of standing water, snow, and mud was specified.

Since the physical layout of the city permits its being divided into halves or quarters, collection routes were redesigned so that four garbage trucks could be assigned to the four quarters of the city and two trash trucks to the two halves of the city. Small adjustments have been made continuously to even out fluctuations.

Result of changes are as follows: Five trucks and crews do the work which previously required six. This results in a saving of $35,000 per year, i.e., a saving of 30 percent. Although collection frequency is now the same as before, service is improved due to the new flexibility which allows rapid recovery after delays, as well as provides the capacity for handling unusually heavy loads, and the equipment for special pickups.

Quon, J. E., A. Charnes, and S. J. Wersan
"Simulation and Analyses of a Refuse Collection System"
Journal, Sanitary Engineering Division, American Society of Civil Engineers, 91:17, 1965

The article contains a detailed, computerized analysis of a municipal refuse collection system. The main objective of the computations with the simulation program developed by the researchers was to point out the relationships of the several significant variables involved in the functioning of a refuse collection system.

The simulation method of analysis allows an economical means of investigating changes in the operations of a refuse collection system without resorting to actual field trials. The parameters to be considered in the simulation of the daily route of refuse collection are:

1. number of hours needed to complete assigned task;
2. frequency of trips to the disposal site;
3. overall collection, pickup, and haul efficiences;
4. truck capacity;
5. service density;
6. average and variability in the quantities of refuse produced daily;
7. haul distance;
8. frequency of service;
9. number of unloading docks at the disposal site.

The report used charts, graphs, equations, diagrams and a flow sheet to explain the process which was used. The report is of a technical nature.

Ecke, D. E., D. D. Linsdale, and K. E. White
"Migration of Green Blow Fly Larvae From Six Refuse Container Systems"
California Vector Views, 12:35, August 1965

In previous studies of the migration of fly larvae from garbage cans, it was theorized that twice-a-week garbage collection would solve the migration problem. However, no one had ever conducted tests to learn if this were true. Ecke et al. tried six different methods of garbage collection, and made a comparision among the six in terms of their relative efficiency.

The six systems were:

1. Once-a-week collection from a 30-gallon metal can (control system).
2. Twice-a-week collection from a 30-gallon metal can.
3. Once-a-week collection from a 30-gallon can with a Vapona (2, 2-dichlorovinyl dimethyl phosphate) strip attached to the inside of the lid.
4. Once-a-week collection from an exposed, freely suspended paper bag.
5. Once-a-week collection from a suspended paper bag enclosed in a rectangular metal container.
6. Once-a-week collection from a supported paper bag liner in a rectangular metal container.

In all three paper bag systems heavy-duty wet strength bags were utilized. The bags were disposed of with the garbage.

The study was conducted in three different areas, and the six types of systems used for storage were evenly distributed throughout the test areas. The use of a garbage grinder was noted. (In general, the frequency of migration was greater at households without garbage grinders than at households with garbage grinders.)

The six garbage systems fall into two well defined groups separated on the basis of comparisons with respect to larval migration. Larval migration was substantially less in the systems which involved twice-a-week collections, the use of a Vapona strip, and exposed or enclosed bags, than in those involving once-a-week collection and the use of liner bags.

The existence of any appreciable difference between the more efficient systems could not be determined in the tests. Only from 33-39 units were studied in each system. In such a small study no real differences could be noted. Which of the systems would be the most feasible for a community cannot be determined until carefully observed, community-wide demonstrations are conducted.

Rogus, C. A.
"Refuse Collection and Refuse Characteristics"
Public Works, 97:96, March 1966

The continuing trend in both Europe and the U. S. is to collect and treat mixed, unsegregated refuse in a single system. The exception is in the handling of oversized wastes such as lumber, timber, and furniture. Detailed information on the composition and properties of refuse is necessary even with a single treatment system for mixed refuse because:

1. The layout of collection routes and the design of collection equipment are governed by the total refuse output for any given period, its daily and seasonal variations, its density, compaction, and composition.

2. Incinerator design and operation computations require a knowledge of the amounts of combustibles, their abrasiveness, their moisture and calorific contents, and the availability of C, H, O, etc.

3. Density and compactibility must be known to estimate the area, space needs, and useful life of landfill sites. Chemical composition must be known so as to enable the prediction of odor and methane gas production.

European refuse collected per capita for seven continental cities has risen from 475 lb/capita/yr in 1953 to 725 lb/capita/yr in 1964 – a 53 percent increase in 11 years. The density of the refuse decreased in these same years from 485 to 390 lb/cu yd, due to an increase in the percentage of paper, paper products, and synthetic wrappings. Nevertheless, it is heavier than American refuse – mainly because of high output of domestic ashes.

In European cities, the use of dustless refuse collection trucks is becoming widespread despite the small capacity of the trucks, viz., an average of about 16 cu yd. The trend in the U. S. is towards larger (20-30 cu yd) trucks.

Several collection aids are found in buildings. (On-site apartment house burning of refuse is frowned upon in Europe.) These include apartment house dual type shafts, central pneumatic tube systems, and the Garchey hydraulic system. All of these are fully described. In the Garchey hydraulic system domestic refuse is transported hydraulically from a special receiver in each apartment through a vertical 6-8 inch stack to underground collection chambers. It is used in France. Graphs of refuse characteristics are also presented in the article.

Rogus, C. A.
"Collection and Disposal of Oversized Burnable Wastes"
Public Works, 97:106, April 1966

Oversized burnable wastes are comprised of items not readily collected in normal mechanized compaction trucks or disposed of in a conventional incinerator. The annual upward in amount of oversized burnable wastes produced per person is from 2 to 3 percent. In Europe, the out is from 1/3 to 1/2 that in the U. S.

ANNUAL OUTPUT OF CERTAIN OVERSIZED BURNABLE WASTES (O.B.W.)

	New York City		U. S. A.	
Material	Annual Tons	Pounds/Capita/Yr	Annual Tons	Pounds/Capita/Yr
Christmas Trees	2,000	0.51	60,000	0.6
Tree Trunks, Stumps, and Branches	24,000	6.15	585,000	6.0
Driftwood	6,000	1.56	49,000	0.5
Waste Lumber	292,000	75.00	5,850,000	60.0
Furniture and Fixtures	58,500	15.00	975,000	10.0

Separate collection of O.B.W. in manually loaded open-type dump trucks is costly, unsightly, and unsanitary. Most of the oversized wastes can be handled in the large hoppered mechanical crushing truck of 25-30 cu yd capacity. Only extremely large-sized lumber, timber, and furniture require separate collection.

Disposal Methods:

1. On-site burning is simple and inexpensive, but creates a fire hazard and a considerable amount of air pollution.

2. Burning at sea is direct and economical; however, a change in wind brings smoke to on-shore communities.

3. Salvaging is not generally practical because of the high cost of cleaning building materials. Reuse is limited to lumber.

4. Landfill is limited by the necessity of crushing the material for the fill and by the high cost of land.

5. Incineration: most incinerators have been built to handle normal sized refuse. Special centralized incinerators could be built to handle oversized wastes for a large area. "Hogging" reduces the size of large refuse. It is not common in the U. S., but it has been successfully tried in Europe. Such a device is described. Composting is not practical for these wastes.

Rogers, Peter A. and Geoffrey J. Bellenger
"Fly and Economic Evaluation of Urban Refuse Systems"
An Efficiency Analysis of Paper Bag Containers, Vol. 14, No. 5, May 1967

This study is an economic evaluation of once-a-week garbage can service, twice-a-week garbage can service, once-a-week service from suspended paper bag containers, and twice-a-week service from suspended paper bag containers.

Four comparable areas of approximately 500 homes each were selected in the City of Santa Clara, one for each of the four systems studied. Evaluation was based on a time and motion study which compared the various aspects of pickup service between each of the four areas. Up to 30 percent savings in manpower was achieved by substituting paper bags for metal cans; but unless the collection system were actually designed around the paper bag concept, the savings in time would probably not be sufficient to pay for the additional cost of the paper bags.

Hume, N.
"Management Information System Studied for Los Angeles"
Refuse Removal Journal - Solid Wastes Management, 10:39, November 1967

The Los Angeles Refuse Collection and Disposal Division serves the third largest city in the country. The collection fleet logs 7 million miles per year. The division covers 454 sq miles. Over 1,130,000 tons of rubbish are hauled annually. It is mostly residential in origin. The labor force consists of more than 350 employees. The services include more than 950 indirect activities. Approximately 4,000 tons of garbage per day are collected by 500 trucks.

Information system research provides:

1. information at each supervisory level to increase visibility and control of operations, facilitate decision making, and assist in identification and solution of problems;

2. historical data from which information for special studies could be retrieved and analyzed;

3. development of procedures for eliminating need of intermediate manual processing between acquisition of source data and preparation of payroll, personnel, and cost accounting;

4. reduction of the time lag between the close of the reporting period and the distribution of cost and analytical reports to management.

A description is given of the organization of collection activities, decisions making, and specifications of the management information system.

TRANSPORT

Anon.
"Refuse Giants"
The American City, 80:44, May 1965

In King County, Washington, giant trailers are used for hauling refuse from transfer stations to a central disposal site. Each trailer consists of two 20-ft long boxes of 45 yd capacity each, giving a total of 90 yd capacity. The gross weight of tractor and semi-trailer is 72,000 lb. The county has 10 of these units.

Dykes, E. B. and S. G. Serdahely
"The D-S Proposal for Solid Waste Disposal"
Private Communication, 25 June 1966

This new type of disposal "will eliminate all of the disadvantages" of the methods of disposal presently in use. In the D-S system, "Transit-Digesters" are used. These are huge cylindrical tanks mounted on railroad rolling stock. Ground solid wastes and sludge is dumped into these rotating digesters. Final disposal takes place somewhere in an uninhabited area.

Hamlin, G. H.
"Propose Train Haul to Desert Landfill"
Refuse Removal Journal, 10:10, March 1967

A system of transporting San Francisco Bay Area refuse by train is described. Transfer stations would be operated by a district at 10-mile intervals along existing railroads on either side of the Bay. Two "unit trains" will be used, each composed of 70 to 90 high-volume cars of 70 tons or more capacity and four 3000 hp diesel locomotives. A district-managed landfill would be operated in desert lands along the eastern border of California and adjacent to existing railroads for easy access by a railway branch. The landfill operation would include the use of modern car dumpers and conveyor belt systems. It is estimated that with the use of a fill depth of 18 ft, an area of 9,125 acres would serve for 50 years. Existing agencies would do the local collecting and transporting to the transfer station. Transport and disposal would be carried on by the specially created district.

	Costs Per Ton Refuse[1]
Operation	$ 0.785
Amortization	$ 0.420
Sinking Fund (15 yr)	$ 5,250,000.00
Interest (5%)	$ 0.04634-0.112
Railroad Cost	$ 3.00
Total	$4.317

[1]Based on the following tonnage: 1967 - 5,000; 1981 - 7,000; 15-yr avg. - 6,000.

The reduced operating cost realized by the use of the railroad system because of shorter hauls and more favorable operating conditions are: reduced haul, 6,000 tons at $0.50 x 360 = $1,080,000; savings on tires and repairs, $100/day = $36,000; avg. dump cost/ton, $1.50 x 6,000 x 360 = $3,240,000; administration and overhead, $250,000.

Summation of Costs:

1. Estimated total cost per ton = $4.12.
2. Anticipated savings in collection costs per ton = $2.14.
3. Therefore, the increased cost per ton = $2.18 (i.e., 18 percent increase).
4. The present collection charge of $1.25 per month would be increased to $1.47 per month.

The cost estimates do not take into consideration income obtained from return haul of suitable loads — salvage of scrap metal, etc.

Piazzi, F.
"Report Favors Desert Dump for Garbage"
San Francisco Examiner and Chronicle, 10 December 1967

The article describes Hamlin's proposal for transporting Bay Area refuse to the desert. It points out that there are enough desert sites to handle Bay Area refuse for the next 600 years. Each container car would hold 70 tons. A daily 100-car train could handle the entire Bay Area output of refuse.

Anon.
"Denver Eyes Rail Transfer Stations"
Solid Wastes Management - Refuse Removal Journal, 11:8, January 1968

A proposal recently submitted to the city of Denver by the Denver and Rio Grande Railroad offers to dispose of household wastes via rail lines and equipment. Contract terms call for Denver to continue collecting from homes. Municipal trucks would haul the refuse to a pair of in-city truck-rail transfer stations to be built by the railroad. The railroad would then assume complete responsibility for disposal. Landfill, Inc., a Denver firm will operate the disposal site as a subcontractor. The company has enough property for 40 years of operation. The Rio Grande would charge Denver $4.50/ton for a guaranteed minimum of 875 tons/day with the operation in service 5 days/week.

Refuse burial, exclusive of transportation, now costs the city $1/ton. Vehicle cost is $4.18/hr; labor cost (3 men/truck) per vehicle is $13.13/hr. The total cost per vehicle is $17.17/hr. Use of the railroad system would result in a savings of $81/hr/vehicle/week or a total of $1,394/week. (Details of the calculations are given in the article.)

Advantages:

1. Accessibility of the transfer stations (centrally located and adjacent to through streets).

2. Located in commercial zones.

3. Flexibility.

4. Reduction in capital expenses.

Operation: The truck drives up an elevated ramp and dumps its contents into a surge bin. A rotary plow moves the trash onto a conveyor belt which carries it to the shredders. The shredders reduce all types of refuse, including metals, to one-tenth its original bulk. The shredders accept trash at 370 lb/cu yd and grind it at 175 cu yd/hr. The shredded refuse is dumped into railcars, each having a capacity of 50 to 70 tons. Three top-locking compartments are secured during transit. At the disposal site, the train pulls off onto a siding. The cars are designed to tilt. Opening the side doors causes the shredded refuse to fall into the concrete receiving bin. A covered conveyor belt carries the refuse to landfill trenches for burial.

Ed. Note: Twice before Denver rejected railroad disposal plans — 1964 and 1966.

Anon.
"Railhaul Project for Philadelphia is Dead"
Solid Wastes Management - Refuse Removed Journal, 11:34, February 1968

The city council of Philadelphia has rejected the plan for the Reading Railroad to haul the municipality's refuse to abandoned mines in Schuylkill County. The cost of the project was estimated at $7,000,000.

Anon.
"Giant Railhaul Landfill Plan"
Solid Wastes Management - Refuse Removal Journal, 11:12, March 1968

> "Construction of a golf course atop of a landfill, a $1,000,000 outright payment, and 10 cents a ton royalties to the communities involved were some of the proposals offered by Associated Development Corporation to several Upstate New York municipalities in an effort to obtain a landfill site. The location would be used as the end-point for depositing baled refuse railhauled by the New York Central Railroad."

The system as proposed by Associated Development and the New Central envisages the construction of a transfer compaction station, removal of the compacted refuse on railcars to landfill, and procedures for ultimate disposal and reclamation of the site.

Transfer Station: The process consists of loading refuse into continuous-acting, extrusion units. Refuse would be compacted by the machines into bales having a weight of approximately 3,000 lb, and 18 in. x 36 in. x 96 in. in size. After the railroad cars are loaded, they are closed to facilitate shipping, eliminate odors, and promote sanitation.

At first, the cars would be a part of regularly scheduled freight runs. Once tonnage grows to 1,500 to 2,000 tons, the cars would run as a unit train. Present plans call for railcars 50 ft long and having a carrying capacity of 240,000 pounds or 120 tons. The car will be closed on three sides with only one side equipped with overhead-type doors. Material not subject to compaction will be carried in open gondolas.

The article lists safeguards to be provided against strikes and the requirements for the landfill operations.

ECONOMICS AND OWNERSHIP

Anon.
"Three Alabama Cities Adopt Garbage Collection Fees"
The American City, 74:40, March 1959

Three Alabama cities (Arab, Elba, and Haleyville) adopted garbage collection ordinances which include collection fees to cover the cost of the service.

Johnson, T. F.
"Contractor Refuse Collection"
The American City, 74:104, June 1959

In 1956 the city of Rockford, Illinois decided to give up the city-owned sanitation unit in favor of a private hauler. The entire problem was turned over to the Rockford Disposal Service, which was already serving many cities in the area. In 1959 the city paid an estimated $333,000 for garbage and rubbish collection. In 1955, when the city owned the disposal service, $345,000 was spent, and that was when the population was smaller and labor costs, etc., were lower.

Lynch, F. J.
"Jersey City Solves Its Refuse Disposal Problem"
The American City, 74:89, September 1959

Jersey City, New Jersey decided after an engineering study to collect refuse itself rather than leave it to private contractors. In 1957 a 600-ton/day refuse incinerator was completed. It has four 150-ton furnaces. The ignition chamber has 1,650 cu ft per unit; the combustion chamber, 2,250 cu ft per unit; and the expansion chamber, 4,280 cu ft for two units. A hydraulic dumping grate system was installed in 1958. Fly ash is controlled by 125 psi water sprays and two 127-ft stacks.

Two waste-heat boilers supply steam at 15 psi to 18 blower-type heaters in the main building.

Anon.
"Abilene Cuts Collection Costs"
The American City, 76:27, November 1961

Abilene, Kansas cut collection costs by rearranging schedules to allow only two coffee breaks per day and requiring that workers work until quitting time; and by eliminating long hauls by constructing a transfer station.

Knowles, V. C.
"We Save 37% on Refuse Collection"
The American City, 77:90, January 1962

Oak Park City, Michigan switched from a municipally owned refuse disposal system to a contract system. When the city owned the operation, costs per year were approximately $140,000 for refuse collection and disposal. Under private contract, the costs per year dropped to $87,000.

The contractor provides a curb-side service, and requires separation of combustibles and noncombustibles. Collections are made in separate vehicles. Disposal is no problem. Oak Park is one of 14 cities belonging to the Southeastern Oakland County Rubbish and Garbage Authority, which incinerates refuse and disposes of residues and noncombustibles at an 80-acre sanitary landfill site.

The contractor supervised the transformation of the old city dump into a sanitary landfill operation, and the disposal site is now free from pests and odors. The company provides weekly garbage collection to the residents.

Kunsch, W. M.
"Planned Refuse Vehicle Replacement: Better Service, Lower Maintenance"
Public Works, 95:105, March 1964

The cost of incineration is $2.85 per ton of garbage and sludge burned. A disposal area for large combustibles and noncombustibles was operated at a cost of $1.11 per ton, or 23 cents per capita for the year.

Unit costs of collection, not including equipment replacement, were $3.97 per capita or $16.92 per ton for garbage and combustibles and $25.30 per ton or $0.99 per capita for noncombustibles.

Average per capita wastes (total of both kinds) was over 1,000 lb per year or a bit less than 3 lb per person per day.

The policy of timely replacement of worm refuse collection units resulted in charges of $13,750 in 1962 for vehicle maintenance – a reduction of $10,000 from the two previous years. A radical decrease was noted in the problems of keeping a properly operating fleet on the routes.

Garrison, W. T., F. Otis, M. B. Gay, and M. DeVon Bogue
"A New Approach to Refuse Collection"
Public Works, 95:121, June 1964

Many areas of Madison County, Alabama are considered rural only because they are not within municipal boundaries. In other respects they are identical to municipal areas. To meet their peculiar problem, detachable bulk-storage refuse containers are placed at intersections and other locations along county roads and highways in each rural area. The containers were purchased by contributions from the residents in each area, and a specially equipped compaction type truck which mechanically empties the containers was purchased by the county. Large contributions for containers were discouraged, while everybody in the community was provided with an opportunity to contribute, no matter how little; this generated a sense of pride, possession, and ownership in the local container on the part of every individual in the community.

The containers were overloaded at first, but later the tendency to overload subsided. At the end of the first year, 46 containers were in use. Eight more were put into service in 1963. The cost of the 53 containers was approximately $28,850. One was purchased by a local firm for public use. Six-cu yd containers cost $435 and 8-cu yd containers cost $525.

Cost of Equipment and Operations

	1962	1963
Containers	$23,000	$ 4,000
Collection truck	18,983	-
Salaries, wages	6,000	6,760
Depreciation	-	5,000
Gas, oil, tires, maintenance	2,500	1,240
	$50,560	$17,000

Eppig, T. C.
"Refuse Collection Truck Purchase Includes Guaranteed Maintenance Program"
Public Works, 96:98, August 1965

In Chicago, Illinois a new concept for acquiring collection vehicles was introduced, viz., "Total Cost." In the "Total Cost" systems, bids include the cost of trucks, refuse collection bodies, and a guaranteed maintenance program for the anticipated useful life of the trucks. The reason for the adoption of the policy was the need for expanding the fleet to increase the number of daily truck assignments, and thus reduce collection crew overtime and compensate for the ever increasing volume of refuse production. Problems involving rates of pay, employment practices, and fringe benefits also were considerations. A comparison was arranged by buying 75 trucks on the new basis and 25 on the old basis (i.e., no maintenance). The 25 were maintained at the city shops.

A list of contract specifications is given in the article.

At the time of writing it was too soon after the initiation of the policy to evaluate it.

Mealey, M.
"Garbage Cleanup a Staggering Task"
Oakland Tribune (California), pp. 13, 19, 31 October 1965

The costs of garbage cleanup are more than merely municipal refuse collection once-a-week. Many persons do not subscribe to this service, and dispose of their garbage themselves. Often they simply throw their garbage away in parks and along road sides, or they dispose of it in litter cans placed on sidewalks for purposes other than residential garbage collection. These people will not pay the collection costs, which vary from $1.35 to $2.00 per month. As a result, the cost to the city is $1.80 per person annually for the disposal of the refuse on the streets.

Anon.
"Denver Transfer Station Handles 30 City Packer Trucks Daily"
Refuse Removal Journal, 9:8, November 1966

Four 60-yd transfer trailers capable of holding 3-4 collection loads constitute the trucking equipment. They make from 8 to 10 trips per day to the disposal site. The distance to the disposal site is 10 miles.

The collection costs for the Denver municipality are $8.43 per ton or $2.11 per cu yd of compacted refuse. The basis of the costs is three men per truck at two trips per day and 5 tons per trip. Collection costs for commercial haulers are $7.98 per ton or $2.00 per cu yd compacted refuse. The basis is 2 men per truck at 3 trips per day and 5 tons per trip.

At the transfer station liberal use is made of hydraulically operated doors. Transfer is made from the collection truck to the transfer truck with a minimum of dust and debris. All controls are tied to one system, which is controlled by a single operator. The station is designed to handle 145,000 cu yd of compacted refuse per year. The operation costs are $0.11 per cu yd. This covers amortization, salaries for two men, and equipment maintenance.

Dair, F. R.
"Time/Crew Size/Costs"
Refuse Removal Journal, 10:6, August 1967

The article is subtitled "How to make up collection teams for any type of equipment." In it is discussed the matter of the proper size of crews and vehicles for refuse collection. Tables on labor and vehicle costs and graphs showing relation of costs/ton to crew size, load size, and travel time are presented. The article is a good one for use in studies on economics, planning, and transportation.

FOREIGN PRACTICE

Davies, A. G.
"Sanitation Operations in Frankfurt, Germany"
The American City, 73:94, February 1958

Frankfurt's collection system rivals that of any U. S. city of comparable size. The city has laid out $180,000/yr for equipment, and the capital value of depot buildings and equipment is over $750,000. The containers in which residential refuse is stored are municipally owned. When they are in need of repair the city fixes them at no charge to the resident. Fire equipment at the open dump is valued at over $9,000.

Despite the excellent collection facilities, Frankfurt's disposal methods are very poor. An open dump is operated and dumping facilities are extremely limited. However, the city is comtemplating the installation of an incinerator for refuse disposal.

Anon.
"Barges Serve as Trucks for Refuse Collection"
The American City, 74:25, February 1959

In Venice (Italy) refuse is collected in containers mounted on cycles. The refuse is loaded on barges equipped with compressor bodies and having a capacity of 10 m^3. The barges are towed to areas at which the refuse is used as a fertilizer. Some of the refuse is hauled by truck to dumps. Here the refuse is allowed to decay. The decomposed material is used as a fertilizer.

Rogus, C. A.
"Refuse Collection and Disposal in Western Europe--Part I: Refuse Collection and Street Cleaning"
Public Works, 93:98, April 1962

Solid waste problems in Europe are generally handled on a metropolitan, sometimes on a regional, and in some instances on national levels. Refuse is treated as conglomerate material from which valuable components can be extracted for industry and agriculture.

TABLE I

REFUSE OUTPUT--DOMESTIC AND COMMERCIAL
(Avg. values in lb/capita-yr 1959-61)

Country	Population Served (range for communities reported)	Range	Median
U. S. A.	50,000 - 8,500,000	1,100 - 1,700	1,400
England	70,000 - 8,600,000	450 - 1,080	650
France	50,000 - 4,500,000	400 - 900	575
Germany	700,000 - 2,200,000	470 - 535	480
Scotland	500,000 - 1,125,000	450 - 600	635
Sweden	400,000 - 800,000	400 - 750	635

The article contained several tables. In Table II, a breakdown is given of the physical composition of refuse in Berlin, six towns in England and Scotland, in Chandler, Arizona, Philadelphia, and Chicago, between 1953 and 1958. American refuse has a higher percentage of paper refuse and lower percentage of dust, cinders, and ashes than that in Europe.

In Table III, further data are given on the composition and properties of combined refuse in the U. S. and in six European countries. Generally, European refuse is about 20-40 percent more dense, has 30-60 percent less salvables, about 30 percent less combustibles, 65 percent less putrescibles, and about 15-25 percent lower calorific value than that of the U. S.

Reasons for differences between European and American refuse are:

1. The European market for salvables is consistently better and more constant; and therefore, more materials are separated out at source.

2. A large proportion is burned for domestic heating.

3. On-site destruction of refuse is common.

4. In most English communities salvables, usually paper, by ordinance are segregated. These are collected by the municipal refuse crews and placed either into separate compartments of the truck or into special trailers.

In Europe the work is almost exclusively the responsibility of municipal forces — often with technical and financial assistance from the central government. Financing is generally out of general tax revenues. Collection is made mostly on a 2 or 3 times/week basis. Generally refuse is combined and unsegregated, except in England and Scotland. There salvables are segregated. Collection characteristics are described in Table IV. Refuse containers are more uniformly standardized, sturdier, and more sanitary than ours. In Table V is described refuse container characteristics. Two-ply bags are coming into use. Vertical collection chutes are popular in apartment buildings.

The quality of collection crews is high. Working conditions are comparable to ours. Purchasing power of the average sanitation employee's salary is equivalent to about $2,300 per year.

Rogus, C. A.
"Refuse Collection and Disposal in Western Europe--Part II: Refuse Collection and Street Cleaning--Operating Techniques and Equipment"
Public Works, 93:11, May 1962

In the British Isles and on the Continent, refuse is brought to a central station for progressive separation before final disposal. First of all, fine dust, dirt, and ash are removed for subsequent use in farming; then cinders and unburned coal are salvaged for reuse as a fuel; metals are magnetically separated; and finally, other resalvable materials are removed. The remainder, i.e., tailings, either go directly to landfills, or are incinerated and later removed to landfills. Thus, the tailings are considerably less both in volume and in weight than was the original refuse as collected.

Generally, a single agency is charged with the collection, treatment, and disposal of refuse. Responsibility for removing dirt, litter, and snow and ice from streets is as confused in its organization and jurisdictional authority in Europe as in the U. S. – although the trend is to assign this to the refuse collection agency.

Major differences between European and American collection systems are:

1. Increasing use of incentive systems in Europe.

2. Use of larger truck crews--4 or 5 to as many as 7.

3. Increasing use of the "dustless" collection system.

4. The often-times limiting of the collection to a single morning truckload with a subsequent reassignment of personnel to street cleaning.

Data are presented on collection performances and costs in six European countries and in the U. S., and on characteristics of the trucks used. Generally European municipalities use fewer trucks, larger in capacity, and more highly mechanized. Although the capital costs of these trucks are higher, per capita costs are less due to greater longevity and lower inventory. Trucks are superior because of the use of aluminum alloys and reinforced fiberglass materials, and of the streamlined design for the body housing, which provides smooth, readily cleanable surfaces, corrosion resistance, and reduction of body maintenance. Generally, dead weight also is reduced. Four types of compaction trucks are described.

The hermetic dustless system is widely used. The essential components of the system are uniformly sized rugged containers with hinged lids, and a combination lifting, tilting, and shutter mechanism on the tailgate. A major advantage is that it is inherently hygienic and permits an aesthetic collection operation. Major disadvantages are the high capital cost, noisy operation, inability to handle bulky materials, tendency to clog with rags, wires, and stringy materials, relatively poor compactability, and the mandatory need for standardized costly containers.

Battery power and diesel engine powered equipment is common in Europe.

European cities spend a higher proportion of their street cleaning and refuse disposal budgets on street cleaning than do American cities, although their amounts of street litter and dirt are smaller. In addition, snow is less of a problem.

388-400 O - 70 - 6

Rogus, C. A.
"Refuse Collection and Disposal in Western Europe--Part III: Salvaging, Landfilling, and Composting"
Public Works, 93:139, June 1962

Salvaging: Although European refuse usually is unsegregated at the pickup point, salvageable materials generally are separated before the refuse is treated. England and Scotland are the only European countries in which salvaging is practiced extensively as a means of refuse disposal. Reasons for the decline in salvage are:

1. Manual sorting is prohibitively expensive and working conditions are unsanitary. Manual work is necessary even with a highly mechanized process.

2. The reuse of paper has declined with the wider use of synthetics.

3. Buildup of printing inks makes reuse of paper for newsprint difficult without an ink removal process.

4. Recovery of dirty, oily textiles is now unprofitable.

5. Admixing of scrap metals has a cumulative adverse effect on the physical properties of steels, and is practiced less.

Data on the quantities and revenues derived from garbage, scrap metal, paper, and other materials salvaged in England are presented.

Composting: Direct spreading of domestic refuse on farm land without any intermediate preparation now is seldomly used, largely because of attendant unsanitary conditions, nonuniformity as to size and composition, and of the presence of metals, glass and other harmful items. Composting is most common in the low countries.

Sanitary Landfilling: Is the dominant method of refuse disposal used both for direct disposal and for the final disposal of residues from other processes. Long haul distances are compensated for by compressing the material to two or three times the original density. Whenever possible, Europeans reclaim nonusable marshes, quarries, and ponds before resorting to trenches and cut-and-cover operations. Utilization of completed landfills is limited almost exclusively to parks and playgrounds, with some farming and forestry. Use of landfill sites for construction is practically unknown.

Data are presented on the relative use of each method in various European countries and in the U. S., and on the operation and use of sanitary landfills.

Grindrod, J.
"Modern Weighing Methods Speed Refuse Disposal"
Public Works, 94:74, January 1963

The Wandsworth Borough Council in London has installed a weighing information system which records and analyzes details of vehicles emptying their loads at a refuse transfer station. Analysis of the tonnage record is used as an ultimate disposal point, and for the charges made by the Council to private persons or companies who use the transfer station facilities.

The weighbridge indicator has been adapted by incorporating a specially designed coding switch to transpose the angular position of the printer into digital form.

An internal master record and a punched tape are provided. Both are removed daily.

Anon.
"Install Vacuum Collection for $750,000"
Refuse Removal Journal, 10:12, 8 August 1967

A vacuum collection system will be installed in a Westminster housing development covering 195 acres and housing some 4,575 people in blocks of 3 to 22 story apartment buildings. In the system, pneumatic or vacuum ducts lead to a central disposal unit. (Such a system has been operating in Stockholm, Sweden, since 1958.)

Scheme: The householder discards refuse in a chute. The refuse lands in a container about 1 cu yd in size. At the circular bottom of the container is a disc valve which is opened and closed by a separate mechanism. The time lapse between the closed and the fully open position is 1-1/2 seconds. The chamber is emptied in 6 seconds. Refuse is pulled by vacuum through transporter pipe to a central point. Refuse travels at speeds up to 9 ft/sec. The diameter of pipes is up to 24 inches. Pipes are buried at a depth of 2 ft. They should be laid in straight lines, angles greater than 30° are to be avoided. The storage silo is 35 ft high. The vacuum is maintained by high speed turbo air exhausters powered by 110-kw electric motors. The air is exhausted to 1/4 atmosphere. In Sweden, the refuse is incinerated and the heat is fed to the central heating system of the apartment houses.

MISCELLANEOUS

Pearson E. A.
"An Analysis of Refuse Collection and Sanitary Landfill Disposal"
Technical Bulletin 8, I.E.R. Series 37, Issue 8, Sanitary Engineering Research Laboratory, University of California, Berkeley, December 1952

Field studies of refuse collection and disposal operations in 13 California cities were made during the summer of 1950 and 1951.

Among the subjects covered in the bulletin are: Collection Operation — Hauling — Analysis and Design of Refuse Collection Systems — Disposal Operation — Public Health Aspects — Administration.

The bulletin defines various terms in use in refuse management. It discusses all aspects of collection, including frequency, point of pickup, and presents methods for making systems analyses. Various methods of landfill are defined and discussed. Design criteria are presented. The status of landfill is treated.

"Refuse Collection and Disposal: A Bibliography"
U. S. Department of Health, Education and Welfare, Public Health Service — Prepared by Interstate Carrier and General Engineering Program, Division of Sanitary Engineering Services, 1953

This bibliography is a supplement to PHS Publication No. 91, which included references published during 1941-1950. It was prepared by Mr. Leo Weaver under the general supervision of Mr. Eugene L. Lehr, Chief of the Municipal and Rural Branch of the Program.

It covers regulations, finances, storage, collection equipment, composting, garbage grinding, hog feeding, incineration, open dumps, salvage, and sanitary landfill.

Updegraff, W. R. and F. R. Bowerman
"Refuse Collection and Disposal in 194 Western Cities"
Western City, May, June, July 1958

In three issues of the magazine, solid waste collection and disposal were thoroughly covered. Each issue is concerned with a different aspect of the problem. The first issue deals with the 79 cities which provide municipal service, with city crews, and with equipment. In the second issue, the concern is with the 68 cities whose service is provided by private collectors under varying degrees of municipal regulation and control. The third issue deals with forty-seven cities under a contract service — the city paying a contractor or contractors for a specified service.

Each article contains a chart of data, and lists various aspects of the operations. Information in the charts include population served, type and size of equipment, method of disposal, and length of haul to disposal site, monthly charge for service, contracts, and other economic aspects and costs for service.

Rates for the services described in the three articles varied from 50 cents to $2.80 per month for single family residences. In 165 of these cities, individual householders paid the charge; in 29 municipalities the service is tax-paid to the city.

Mortenson, E. W. and F. W. Scott
"Community Services District Used to Solve Urban Refuse Sanitation Problems"
California Vector Views, 7:49, August 1960

The unincorporated community of Avenal in Southern California has undergone an interesting transformation in its refuse storage, collection, and disposal methods. Before the changeover, only 40 percent of the residences were served by a private contractor with once per week service. The remainder of the community and the contractors dumped garbage in a large ravine in the hills outside the town. Many of the residents with no pickup of refuse burned it themselves, littering their backyards and alleyways.

The residents decided to do something about the problem, and voted for a proposal that made refuse collection and disposal a responsibility of the city. The city hired the same contractors, but with the help of Kings County, changed the open dump into a sanitary landfill operation in which cover material was added at the end of each 48-hour period. All refuse is stored in 30-gallon containers, and is picked up twice weekly. At the beginning of the new service, the contractors sent a dump truck around to pickup all the old refuse which had accumulated in the backyards of those who had not had service previously. This was in addition to the regular garbage collection.

The new refuse disposal program has resulted in a markedly improved refuse sanitation situation and in greatly cutting down on the amounts of flies.

Bergmann, John W.
"Prowlers: Sanitation Uniforms Attract Better Men"
The American City, 76:104, August 1961

In Hyatsville, Maryland, a town near Washington, D. C. and having a population of 15,167, trash collectors were accused of theft and were mistaken for prowlers until uniforms were provided them. Since the city has begun to supply uniforms to the refuse collectors, accusations have stopped, calls to the police have declined from 200 to two or three weekly, worker morale has risen, and better men have been willing to take on the job.

Anon.
"Council Gets Report On Garbage"
Oakland Tribune, 24 May 1966

Of 35,000 householders in Richmond, California, 5,000 dispose of their own garbage rather than pay the garbageman. The city health officer considers this situation to be a health hazard, and certainly contributory to poor aesthetics.

A proposed ordinance would make collection mandatory. Persons who do not produce any garbage would be exempted. Only trash collection would be mandatory. The city would pay the franchised collector for hauling any garbage for which a householder refuses to pay. That amount plus 10 percent would then become a lien on the property served.

Govan, F. A.
"High Rise Disposal Problems"
Refuse Removal Journal, 10:6, March 1967

The article is concerned with the removal of wet and dry household wastes from apartments, its transfer to a collection system, type of on-site disposal, and delivery to the collection agency. In it is noted that low-income tenants produce refuse at 3 lb/person/day with a unit weight of 6 lb/cu ft, and a composition of 50 percent rubbish and 50 percent garbage. Middle-luxury class dwellers generate 2 lb/person/day at 5 lb/cu ft, and composition of 80 percent rubbish and 20 percent garbage. The reason for the differences is that menus of the poor tend towards lower grades of meat and poultry and to the inclusion of fresh vegetables and fruit, whereas those of the more affluent includes more of the prepackaged and preprepared foods.

Five methods of disposal from dweller's apartment unit can be practiced:

1. All refuse can be placed in containers for periodic removal.

2. Wet garbage can be ground in garbage disposal units and dry refuse discarded into a chute for central collection.

3. The same as in No. 2, except that the refuse is compacted on site.

4. Wet garbage, cans, bottles, etc., are placed in a specially designed sink unit, and the dry refuse in a container for periodic removal.

5. Refuse is discarded into chute-fed incinerators (directly or indirectly), and periodic removal of residue is provided.

Method No. 1 is the quickest and most convenient where economically feasible, but it can lead to sanitation and odor problems.

The economics of system No. 1 are based on a collection time of 3 minutes per unit to collect and transport refuse to a central storage area plus 45 minutes to police the area. For a 5-story (60-units) building, this would amount to 3.75 hours at $1.35/hr or $5.00/day; and for a 21-story (180-units) building at 4 minutes per unit (including elevator time), this would amount to 12.75 hours, or $17.20/day. However, collections involving times longer than 1.5 hours are not feasible.

The central chute is recommended because of convenience, flexibility, short-term of storage in apartment units, elimination of trash accumulation, central collection, single source of storage, low fire hazard, easy adaptation to end-use destruction or collection devices, and potentially satisfactory environmental conditions. The author gives design specifications for the chute system.

Central Storage:

1. For smaller units, cans of 20-30 gal capacity can be used. For 125 people, 12 cans per day would be needed. This number is based on a refuse production of 2.5 lb/person/day (0.4 cu ft/person/day), or a total need of 60 cu ft of container capacity per day.

2. Wheeled-refuse containers (capacity 500 lb) should be used in large multi-family structures.

This refuse would be disposed of by a destructor-type incinerator, hammermill, or compactor. The system is simple and flexible. However, it has the disadvantages of being noisy, of involving on-site labor costs, spillage, use of ramps, and other construction costs.

Although much remains to be learned about the design of incinerators, they are necessary because with their use, refuse is reduced to 30 percent of its original weight and to 20 percent of its original volume. Crushers, disintegrators, and balers are not feasible for single multi-family units. A description is given of a British method for servicing a number of multi-family units. The method essentially is one of grinding and resorting to the liquid transport of ground refuse through sealed pipes to a central storage area. From this storage facility, the suspended solids are transported to the municipal disposal plant.

SANITARY LANDFILL

Design and Operation

Allis-Chalmers, Construction Machinery Division, Milwaukee, Wisconsin
"Sanitary Landfill"
Brochure

Theory and practice of sanitary landfill — how it can be done with the use of Allis-Chalmers equipment.

ASCE Committee on Refuse Collection and Disposal
"Dumping and Landfill"
Report of Task Committee 2, 31 July 1953

This report is a compilation of information furnished by the individual members of the 1953 Task Committee 2, and by others. Material already covered in the "Technical Bulletin No. 8 of the Sanitary Engineering Research Project of the University of California" is included in this report.

The main topics are: Materials dumped, burning in open dumps and landfills, general operation of dumps, public health aspects of dumping, costs, sanitary landfills, compaction of landfills, and salvaging on fills.

Anon.
"Miscellaneous Articles Dealing With Sanitary Landfill"
The American City, Special Print, 1954

This publication is a collection of special series of articles dealing with particular phases of the sanitary-fill operation. The articles are based on a survey of all sanitary fills in use at that particular time. A summary of operating details (people served, annual volume, type, settlement, equipment, etc.) in 138 sanitary fills throughout the country is included.

Anon.
"The Ramp-Type Sanitary Fill"
The American City, 69:88, January 1954

In a step-by-step demonstration, the St. Louis County Health Department and the U. S. Public Health Service illustrated the method of building a ramp-type fill to about 100 health and sanitation officials from 65 nearby cities. The demonstration took place on rolling ground to show that the method could be operated on such terrain. Between 1952 and 1954, two cities — Iowa City, Iowa, and Columbia, South Carolina —

took the initiative in adopting the sanitary fill for refuse disposal and the ramp method for building it.

Iowa City converted an old 13-acre "burning-dump" to fill-and-cover. The operation serves 30,000 people. A tractor transverses a shallow, valley-like trench compacting the refuse and covering it. This allows a substantial reduction in the amount of maneuvering that would be required of the tractor in other methods of disposal. When the report was made, Iowa City had used the ramp-fill for only a year, but the results had been satisfactory. The insect-ridden, rat-riddled open "burning-dump" had been replaced by an efficient sanitary fill that was not a nuisance problem at all. Along with this effort to improve sanitation, the city acquired two new refuse collection trucks.

A ramp-type operation is used at Columbia to reclaim a pitlike area that adjoins railroad property. Because of the dense population concentration, the process must be kept running in a manner to prevent nuisances or objectionable odors. The fill receives refuse from a population of about 87,000, and extends over an area of approximately 3 acres. The entire site was excavated to a depth of 18 ft. The refuse is compacted into 3-ft layers and is covered each night with 3 or 4 inches of earth. The completed sections of the fill are covered with 3 ft of soil.

Basgall, V. A.
"Civic Pride"
The American City, 69:102, February 1954

Junction City, Kansas, abandoned the open dump system of refuse disposal in favor of the sanitary landfill method because firstly, the city wished to rid itself of the nuisance of smoke and odor, and of rats and insect breeding places near the city; and secondly, the state passed a law prohibiting the use of raw garbage for hog feeding. Because the garbage now had to be disposed of, and since it is highly putrescible, it was necessary to bury it.

The city uses the trench type of landfill. All trenches are dug to a depth of 6 ft and to a width of 10-12 ft. The refuse is compacted often during the day and is covered with 4-6 ft of earth each night. The final cover is 2 ft thick.

There have been no complaints of the site being a nuisance. The city intends to convert the site into a city park when filling has been completed.

Lemon, T. J. and R. J. Poss
"The Area Method of Landfill"
The American City, 69:116, April 1954

In the area method of solid waste disposal, the refuse is simply packed in place with a tractor or bulldozer and then covered with earth each day. If the layers of refuse are kept to a maximum of 6 ft in depth, less difficulty will be encountered in compacting the refuse and therefore less settlement will take place.

It is only feasible for Sanford, Florida, to use the ramp method of sanitary fill due to marshy wasteland and a generally high water table. The refuse fill is built in 6 ft layers and each day the fill is covered with earth to a depth of 12 inches. It is claimed that this cover is thick enough to prevent rats from burrowing through to the refuse and to positively kill any fly larvae that might develop.

The refuse crews collect garbage twice each week from all homes, and rubbish once each week. Twelve thousand people contribute 11,600 tons of mixed refuse per year.

In South Boston, Virginia, a community of 7,000, the area method of fill is used to convert 23 acres of wasteland to productive purposes. Since the fill is in 5 ft lifts, little settlement takes place. The site receives about 7,800 cu yd of refuse annually.

In Marinette, Wisconsin, wasteland is reclaimed by the area method of landfill. The refuse is compacted in 6 ft lifts. Nearly 100,000 cu yd of refuse are buried annually. The refuse is generated by a population of 15,000. One-fourth of the waste comes from municipal collection. The remaining 3/4 comes from private contractors. The reclaimed land is used for parks, playgrounds, and other recreational puposes.

Booth, E. J. and N. Bartholomew
"Cold Weather Is No Obstacle To Fill-And-Cover"
The American City, 69:*, June 1954

Cities which are subjected to severe cold have hesitated to adopt the sanitary landfill method of waste disposal because frosts often make winter excavation virtually impossible. However, both Bismark, North Dakota and Eau Claire, Wisconsin have adopted sanitary landfill without any encountering significant problems.

In Bismark, North Dakota (population 22,000) the landfill operation was started in 1951. About 50,000 cu yd of refuse are disposed of annually. Operating costs do not exceed $25 per day. The ramp method is used. Each active ramp area measures 50 ft in width and 100 ft in length. When the desired elevation of refuse on the ramp is reached, a 12-18 inch blanket of earth is spread for cover. Settlement has been negligible, and the sandy soil of the vicinity has presented no serious problem to winter operations.

Despite a cold climate, a trench-type of landfill is used without difficulty in Eau Claire, Wisconsin (population 36,000). The city purchased a 160-acre site to replace an old open dump, but winter excavation proved to be a problem. Consequently, in 1951, the city awarded a contract to an excavator for the sanitary landfill trench. The trench was to be kept open at least 100 ft in front of the present level of fill at any one time. Garbage and rubbish are hauled by private contractors, and many individuals haul their own refuse. The operation requires the excavation of about 30,000 cu yd of trench per year — dug about 15 ft deep. The trench is 30 ft wide at the base and 60 ft wide at the top.

*Page number not on our copy.

Knudsen, E. J.
"Village of 16,000 Saves $24,000/Yr With Sanitary Landfill"
Public Works, 86:81, February 1955

By switching to a sanitary landfill operation, Melrose Park, Illinois apparently saves up to $24,000 per year over other means of refuse disposal. The city purchased a 10-acre site back in 1941, and since it has a population of only 16,000, it hopes to maintain the same site until approximately 1975.

Collections are made once each week in the residential section of town, and once daily in the commercial section. Compacted slag cover is used at the fill. This use helps alleviate the problems of odor, rodents, and vermin which plagued the old open dump operation. Odors are now almost nonexistent. Rats are no problem because they do not like to burrow through the gritty slag, and flies are a very rare occurrence.

Chanin, G.
"Evaluation of Sanitary Fill Procedure"
Report - East Bay Municipal Ultility District, September 1955

The District has disposed of bar screenings, grit, grass clippings, rubbish, etc., in a cut and cover sanitary landfill operation ever since the sewage treatment plant went into operation. This study was made to determine the efficiency of this disposal practice.

Four post holes were dug in the fill, each tapping a portion of the fill representing a different time or condition, and each resulting in different samples. Laboratory tests were performed on the samples to determine the degree of stabilization that had occurred. Some generalizations were made from the results:

1. An equation was set up to estimate the percentage reduction in volatile matter. Ordinary materials, grit, screenings, etc., decomposed almost entirely after one year, according to the equation.

2. Material containing canning wastes, especially tomato wastes, decompose much more slowly. The amount was only 53 percent after one year.

3. Field observations substantiated these results. Cannery wastes had a strong ordor of decomposition after a year. Other samples had very little or no odor.

4. Although cannery wastes decompose slowly, grit, bar screenings, grass clippings, rubbish, and other material collected at the sewage treatment plant can be successfully disposed of at a sanitary fill site.

The article includes tables of results of samplings made at the fill. Total sulfides, a 5-day BOD sample, percent total solids and percent total volatile solids of the samples were measured and reported.

Dunn, W. L.
"Seattle's Refuse Disposal Reformation"
The American City, 72:110, March 1957

Since June 1956 the city of Seattle has compacted its domestic refuse and completely covered it at the end of each day's operation at the Union Bay site. This is a 70-acre swamp at the north end of Lake Washington, adjacent to the campus of the University of Washington. The city disposes about 1/3 of its wastes at this site. About 25 collection trucks deliver 125 loads of domestic refuse Monday through Friday. Loads are dumped at the toe of the slope and cover dirt is deposited at the top. Refuse disposal at the Union Bay site is most desirable because it provides a convenient and economic place for the disposal of much of Seattle's wastes, and by it is reclaimed much-needed land for use by the University of Washington.

Rector, R. C.
"Moses Lake Gets Rid of Its Open Dump"
The American City, 72:94, December 1957

Moses Lake had an open dump for twenty years. The dump was a constant source of air pollution, rat infestation, and general nuisance. The City Council decided to study the matter. As a result it purchased 40-acres of land four miles from the center of the city. This land was used for sanitary landfill purposes only. The population of 11,495 had 3,028 residences which required weekly garbage collection, and 303 commercial accounts which needed six collections per week.

The contractor who runs the dump must dispose of the refuse by sanitary landfill methods. Fill cells are not to exceed 52 sq ft in area and 6 ft in depth. The final cover must be at least 2 ft deep, and all garbage and refuse must be covered at the end of the day.

The city bills all customers at the end of the month along with the water bills. The contractor collects all dumping fees from refuse hauled privately by citizens to the dump. All citizens in the city must subscribe to the service, and those outside the city may do so, providing they pay the prescribed dumping fees.

Anon.
"How To Get Good Compaction In A Sanitary Fill"
The American City, 73:36, December 1958

The more times that refuse in a landfill is pushed and run over, the greater the degree of compaction. The thinner the layer of refuse, the more it will be crushed and flattened. The weight of the cover layer maintains a constant pressure. Moisture softens the refuse and destroys its resiliency, consequently a fill started in a dry season will shrink during a wet season.

ASCE Manuals of Engineering Practice No. 39
"Sanitary Landfill"
Headquarters of the Society, New York, 1959

A summary is given of the principles of the sanitary landfill method. A guide to proper planning and operation is included.

The subjects treated in the manual are preliminary considerations in selecting site, methods of operation, special operational considerations, equipment, public health and nuisance considerations, disposition and use of filled site, cost data, and administration of operation.

Gieser, F. E.
"Landfill Ends Refuse Disposal Problems"
Public Works, 90:131, March 1959

Sanitary landfill was initiated in Highland Park, Illinois, in 1952. The system was recommended after intensive study and personal investigation of methods used by other municipalities in the Chicago area. The site presently used was previously an open dump, and the switch to a sanitary landfill operation has eliminated the odor, fly and rat problems that plagued the city under the old system.

Five neighboring counties use the sanitary landfill site, but each has to do its own collection of refuse. At the site, trenches are dug 15 ft deep and two layers of refuse are filled into the pit. When the refuse reaches a height of 7 ft, a foot of earth cover is placed over the refuse. Another 7 ft of refuse is then placed upon the pile. This likewise is covered with a foot of earth. A number of service buildings have been built on completed fill areas, including a storage shed for refuse collection trucks.

The cost of disposal averages $0.08/cu yd of garbage, and $0.15/cu yd of uncompacted refuse.

Potthoff, E. H., Jr.
"Drained Canal"
The American City, 74:102, April 1959

The site of the operation is Niagara Falls, New York. An abandoned hydraulic power canal, 90 ft wide, 40 ft deep, and 4,400 ft long extends through the city's business district. The canal was drained, and a saitary landfill was begun in it. A 6-ft layer of heavy broken concrete was placed on the bottom of the drained canal to provide for drainage. Compacted 4-ft layers of random fill were alternated with 1-ft layers of dirt. The top 6-ft layer consisted of heavy rock and high-quality fill. The fill includes incinerator ash and noncombustible refuse.

The canal land belongs to the Niagara Mohawk Power Corporation. The city does the filling. It hopes to obtain the reclaimed land for use in a redevelopment program, park development, and completion of street pattern and parking.

Committee on Sanitary Engineering Research
"Refuse Volume Reduction In A Sanitary Landfill"
Proceedings of the American Society of Civil Engineers, Sanitary Engineering Division, Vol. 85, No. SA 6, November 1959

An investigation of refuse compaction and disposal in sanitary landfill has resulted in the following conclusions:

Sanitary landfill is an economical method of refuse disposal. Volume reduction (in-place volume reduction) was 25 percent of the original trucked refuse volume. An additional reduction of 25 percent is expected to take place in five years. Soil tube investigations showed that the extent of biological activity was greater in a one and one-half years old fill than that in two more youthful fills which were respectively one-half week and six weeks old. All the fill core samples indicated that much organic refuse remained for future decomposition.

Robertson, A. M.
"Income Defrays Costs At 'Sanitation Farm'"
The American City, 74:76, December 1959

In Xenia, Ohio, a switch was made from an open dump type of operation to one of the sanitary landfill type for the disposal of solid wastes. With the use of Warfarin rat poison, one million rats were killed in the process of cleaning up the dump. The city serves a population of about 20,000 and has 116 acres at its disposal for landfill.

The garbage is compacted and covered until a height of about 40 feet is reached. About 3/4 of an acre per year is utilized. The city charges $4.55 per quarter per residence for collection and disposal. It charges $0.35 and up for private dumping. Costs of operation are met by this income.

Dunn, W. L.
"Storm Drainage and Gas Burning At A Refuse Disposal Site"
Civil Engineering, p. 68, August 1960

Seattle is reclaiming swamp land adjacent to the University of Washington campus by means of sanitary landfill. Seventy acres are being used, and when they are reclaimed the University will use them for a golf course, and other light uses.

The article tells of a problem encountered in the fill. Seattle receives a great amount of rainfall. No provision had been made for draining off water entering the landfill. The problem was solved by the installation of French drains which were made of waste lumber. Excess gas from putrefication also has been a problem. The sanitation district now burns the gas (CH_4) as it comes through a corrugated pipe inserted in the French drain.

Vincez, J. J.
"Is Baled Refuse the Answer?"
The American City, 77:149, February 1960

The article suggests a new approach to the solution of the solid waste disposal problem — baling the refuse and disposing of it at sanitary landfill sites. The method involves three phases; viz.,

1. installation of a baler at the refuse transfer station to compress and bale refuse;

2. the use of a suitable trucking conveyance for hauling a large payload to the disposal site; and

3. stacking the bales side by side and on top of each other, using earth cover to provide a sanitary landfill.

The refuse must be greatly compacted, or the benefits will not be worth the trouble. The baling or binding material must be strong enough to retain the refuse in a compressed condition long enough to prevent any considerable loss during the handling process. Advantages of the process obviously include reduced hauling costs, longer term use of the disposal site, less blowing of paper at the site and a neater appearance. The main drawback to the process is the fact that no compressors have as yet been designed; and when they are, the costs will be high unless a large number of facilities adopt this means of disposal.

Anon.
"Size No Deterrent to Good Refuse Disposal"
The American City, 75:47, April 1960

In Farmville, Virginia (population 4,700) the sanitary-landfill method of disposal is used. The refuse is compacted and is covered each day to a depth of 4 inches with earth. The permanent cover is from 2 to 3 ft deep. The final level of the area will be raised from 15 ft to 18 ft.

Anon.
"Recommended Standards for Sanitary Landfill Operations"
U. S. Department of Health, Education and Welfare, Public Health Service, September 1961

The design of the sanitary landfill shall include one or more topographic maps. The geological characteristics of the site shall be determined. The soil used as cover shall be of such character that it can be compacted to provide a tight seal. Landfill operations shall be limited to areas where water pollution is not likely to occur. Suitable access roads shall be available. Provision shall be made for weighing all refuse delivered to the site. Suitable measures shall be taken to control fires. Access shall be limited to authorized personnel. Refuse shall be spread and compacted in layers not exceeding a depth of two feet. Individual lifts in sanitary landfills shall be no greater than eight feet. A daily cover shall be placed on each lift no later than one week following the completion of the lift. Sewage solids shall be disposed of at the site only if special provisions are made for such disposal. No garbage shall be burned at the site. Conditions unfavorable for production of vactors shall be maintained. The site shall be constructed as to minimize water runoff onto and into the fill. There has been established a suggested rating schedule for landfills based on these and other standards. A rate of 80-100 denotes a sanitary landfill, a rate of 60-79 denotes a modified landfill, and a rate of less than 60 denotes a dump.

Fleming, R. R.
"Solid Waste Disposal: Part I - Sanitary Landfills"
The American City, 66:101, January 1966

The production of urban refuse is almost 10^8 tons annually. Dumps are used by fifty percent of cities having a population greater than 2,500. The cost of dumps lies in the public health aspects, since dumps serve as breeding places for flies and rats, and as focal points for dogs. Dumps are odorous. Smoke comes from the burning trash.

APWA* lists the following requirement for a sanitary landfill:

1. Vector breeding and sustenance must be prevented.

2. Air pollution by dust, smoke, odor must be controlled.

3. Fire hazards must be avoided.

4. Pollution of surface and ground water must be precluded.

5. All nuisances must be controlled.

*(Municipal Refuse Disposal, APWA Research Foundation Project 104, Public Administration Service, 1313 East 60th Street, Chicago, Illinois.) The average city resident contributes about 3/4 ton of refuse annually. One yard of tractor bucket or bulldozer capacity is necessary for each 15,000 population. An APWA formula provides a means for estimating the necessary capacity:

$$V = \frac{FR}{D}\left(1 - \frac{P}{100}\right)$$

in which

V = Landfill volume per capita per year in cu yd;

F = A factor incorporating cover material; averaging 17 percent for deep fills and 33 percent for shallow fills, with corresponding F values of 1.17 and 1.33;

R = Amount of refuse in lb/capita/yr;

D = Average density of refuse in lb/cu yd;

P = Percent reduction of refuse volume in the landfill (0 to 90 percent).

Completed landfills are most suitable for parks and recreation areas. Structures must incorporate provisions for settlement and methane gas disposal.

Hernandez, G.
"Deep-Hole Method Extends Landfill Use"
The American City, 82:17, March 1967

The use of the trench method of disposal in the city of Lafayette, Louisiana, involves the excavation of a pit 40 ft deep. A Koehring dragline is used to excavate the pit. The spoil is cast to the windward side to serve as barricade to odors and windswept debris. A rubber tired Hough H-100A proved a much better compactor than the crawler tractor. The areal requirement has dropped from 1 acre/yr/10,000 people to 1/4 acre/yr/10,000 people.

Anon.
"Land and Recreational Development Through a Rock and Solid Waste Disposal System"
Report prepared for the Metropolitan Sanitation District of Greater Chicago by Bauer Engineering, Inc., Chicago, Illinois, September 1967

The preliminary report describes and illustrates the use of rock and solid wastes to construct useful and valuable recreational landscapes. The method is simple, practical, and economical. It can be implemented by using existing techniques of engineering and construction.

Dunn, W. L.
"Refuse Filling of a Swamp in a Fresh Water Lake"
Civil Engineering - American Society of Civil Engineers, 38:60, January 1968

Adjacent to the central University of Washington campus, 166 acres of swamp have been made into usable land by rubbish and garbage fill. When the work of recovery by means of refuse and landfill began in 1933, the swamp, much of it over 60 ft deep, generally had the consistency of a thick sludge. The total amount of fill is not known. An estimate of 7 to 8 million cu yd of wastes were deposited during the last 10 years. In late 1964, rubbish disposal was discontinued completely, and garbage disposal in 1966.

During the past 10 years the procedure was to place a timber and rubbish mat extending from shoreline out into the swamp, enclosing a portion of the area. The first layer of mats was a minimum of 15 ft thick. Earth was spread over the mats to sink them into the underlying peat. These partial dikes supplied a base for roadways and encircled the peat to retard displacement. After the areas were enclosed with dikes, a rubbish mat was placed over the peat. Garbage was then deposited, compacted, and covered in 6-ft cells on top of the rubbish. Depending upon the depth of the underlying peat and the desired elevation, the depth of garbage fill varied from 6 to 40 ft. Settlement was about 4 ft and tended to level off after 4 or 5 years.

Drains and canals were built to carry off storm water. Water quality studies of drainage water were made. Intense degradation of water quality was noted in the storm-drainage canal within the swamp and fill. Part of the deterioration is due to the organic load in storm drainage from an adjacent business area. There also was some evidence of transport of water through the refuse and into the drainage ditch. In a second zone around the periphery of the refuse fill, the water quality was improved over that in the drainage canal. Nearby Lake Washington has not been affected. Field observations indicate that it is almost impossible to get water to move into or through well-compacted household garbage. The reason is that it consists largely of paper and plastic materials.

Swamp land which has been reclaimed by filling with refuse will never become entirely stable. It is most suitable for open use such as parking, parks, and recreation.

Equipment

Anon.
"Go Heavy on Compaction"
The American City, 68:88, December 1953

In Dallas, Texas and Memphis, Tennessee the size of the equipment has been increased. The result is that the sanitary landfill sites now have much greater compaction than those in other sites where smaller equipment is used. Seven sites are operated in Memphis, Tennessee for the disposal of the refuse generated by its 450,000 people. Almost 600,000 tons of mixed refuse are disposed of each year. The area of the fill may vary from 5 to 150 acres, depending on the site. The layers vary from 20 to 90 feet in depth. Every fill is covered at night. The final earth cover is at least 18 inches deep.

The sites have been in operation for 15 years. It has been found that the most important factor in building a good fill is compaction. Each day the refuse is packed and covered with heavy equipment. Settlement has been less than 6 inches in ten years. The compacted fills have been used for ball fields, parks, roadways, and even for homes.

Dallas has followed a policy of replacing small equipment with larger and more mobile earth moving equipment. The refuse is sealed off each day with about 4 inches of dirt, and topped off with an 18 inch to 24 inch thick layer when the fill is completed. The land is used for parks, playgrounds, housing developments, and commercial projects.

Five sites are in operation simultaneously. The trench, ramp, or area fill is used as needed. The individual fills vary from 4 to 20 acres in size. Refuse is contributed by 500,000 persons. The fills receive 250,000 tons of refuse from the city and 100,000 tons of commercial refuse annually.

Johnson, W. F.
"One Man, One Machine"
The American City, 69:103, February 1954

One man operating but one crawler tractor can keep a sanitary landfill site running at peak efficiency. With a population of 15,800, the city of Emporia, Kansas, is reclaiming land with its refuse.

The city had been using the sanitary landfill method for eight years at the time the article was written, utilizing the trench method of disposal. Trenches are dug to a depth of six feet and to a width of ten feet, giving the tractor plenty of room to maneuver in it. The refuse is covered with 18 inches of earth. The tractor, a Caterpillar D-4 with a Traxcavator front-end shovel, spreads and compacts the refuse and spreads the final cover. It hauls 21,000 cu yd of refuse annually. The amount of settlement on the fill over the eight years of operation has been negligible. Completed areas have been used for farmlands, at greatly improved land values.

Anon.
"Questions and Answers About Sanitary Landfills"
Brochure by the Caterpillar Tractor Company, Peoria, Illinois, 1959

In the format of a question and answer pamphlet, this publication describes the operation of a sanitary landfill site. It begins by defining the term "sanitary landfill," and describes ways of converting an open dump to a fill operation. Two main types of sanitary fills are described, viz., the trench and the area types. The conversion of swamps to usable land is explained. Directions are given for obtaining good compaction at the fill site.

The problems of rain and frost on fill operations are considered, and a general list of operation practices that should be followed is given. The public health aspect of various disposal practices is discussed. The general consensus is that the landfill is as satisfactory a method as any other proposed. A description of necessary equipment follows, pointing out the good points of Caterpillar equipment.

388-400 O - 70 - 7

Anon.
"How Many Tractors Are Needed For Sanitary Fill?"
The American City, 74:40, March 1959

Data supplied by the Allis-Chalmers Manufacturing Company are as follows: a HD-6 crawler with 1-1/2 yd bucket will be suitable for a population of 30,000; a HD-11 tractor with 2-1/4 yd bucket, for a population of 30 to 75,000; and two HD-11 tractors for a population of 100,000. For more than 100,000 population, an HD-16 with a 3-yd bucket or an HD-21 with a 4-yd bucket would be needed.

Anon.
"One Unit Clears Landfill Site and Works It"
The American City, 74:32, August 1959

In East Pennsboro Township, Pennsylvania (population 8,500), 2,000 cu yd of garbage are disposed of weekly in a 25-acre landfill. An International Drott TD-15 4-in-1 unit was used for clearing the trees and shrubs from the site. It is used to rip shale material and to cover the fill.

Verden, J.
"One Bulldozer in a Trench"
The American City, 74:165, November 1959

In 1957 Victoria, Texas turned to the use of the sanitary landfill. A deep trench with daily cover method was selected as the best solution to the city's waste disposal problems. Garbage is picked up twice a week from residences, and trash once a week.

A bulldozer digs trenches 35 ft wide, 40 ft long, and 15 to 16 ft deep for the refuse. The same bulldozer compacts the refuse in the trench and covers it every night. The landfill site has 1,000 acres. In summer, the trenches are sprayed with insecticides to protect the area against flies.

McSpadden, W.
"Landfill Logistics"
The American City, 77:24, January 1962

Phoenix runs two sanitary landfill sites, located on opposite sides of the city. Before, when one site received too much rubbish, it took half a day to transport a bulldozer from the other site to help with disposal. A bulldozer with large rubber tires has been purchased. It can travel the 14 miles between sites in 45 minutes. This dozer greatly compacts the rubbish due to the tires — compacting 15 percent more refuse into the same space. This is especially important since the sites cost $4,000 to $6,000/acre.

The city serves 106,000 people. In the winter, when mud, sand, and silt accumulate on the streets of the hilly northern section of the city, the bulldozer is sent to clean up the debris, and yet be back to the landfill site in short time.

Sales Department of Caterpillar Tractor Company
"Fundamentals of Sanitary Landfill Operation"
Public Works, 95:88, December 1964

The article contains a description of methods of landfill. A list is given of the required equipment and estimates are made of the costs.

Kandra, G. A.
"Tire Failure No Longer a Problem"
The American City, 80:104, March 1965

Batavia, New York, a city of 19,000, began a sanitary landfill in 1962, spending $7,500 for 16.2 acres of abandoned gravel pit land, $21,788 for a 25,400 lb track-type tractor, and $1,674 for a chain-link fence. The city operates the landfill for all solid wastes except garbage, which is handled by a private contractor with his own disposal facilities.

Cuts 25 to 30 feet deep are filled in layers, each one 2 to 3 feet deep. These are covered at the end of each work period.

The tractor was unable to work sufficiently on windy days, and needed a complete track overhaul after 2,000 hours of operation. To solve the equipment problem, a rubber-tired loader was adapted for landfill use and turned over to the city for a pilot program by the Yale and Towne Company. It was operated for 1,300 hours between December 1963 and July 1964. The machine had seven tire failures due to punctures and two due to defective valves. Four of the punctures occurred during the last 300 hours of operation. Five tires were purchased at a cost of $1,020.50. Tire repairs cost a total of $204.05. Total downtime due to tire trouble was 20 hours.

The rubber-tired loader was more maneuverable, thereby making possible a reduction in shuttle time between the burrow pit and the working face of the fill. It did a more thorough job of compacting the refuse than did the original machine. The loader's ability to move anywhere in the city under its own power made it usable for snow clearing at night.

A cost comparison can be made from the data in the following table:

Item	Cost Per Hour Track-Type Tractor	 Rubber-Tired Loader
Track repair	$ 1.41	-
Tires	-	$ 0.75
Fuel	1.95	1.01

Koch, A. S.
"Sanitary Landfill Lives Up To County's Expectations"
Public Works, 96:70, July 1965

Liberal use is made of canyon bottoms as landfill sites. Refuse production in the county is 2,300 tons per day. The equipment consists of 12 D7E Caterpillar tractors, 2 Cat 619C tractor-scrapers, 1 Wagner dozer-compactor. Four of D7E's are stationed at each of the three landfill sites, two northern sites receive 90 percent of the rubbish volume. Because of this, one 619C works at each location.

Procedure: The fill is begun at the lower end of canyon and is then advanced uphill, with a bench formed on an average of every 50 ft. Individual cells are 50 to 60 ft long, and are filled to a depth of 15 ft.

Anon.
"Sanitary Fill Supermechanized"
The American City, 80:20, December 1965

A new machine developed by the D and J Press Company compresses refuse to less than 15 percent of the original volume it had in the compactor truck. The tightly packed package is extruded into a trench dug by its excavating section, which covers it in one pass without the aid of other equipment. The machine is operated by two men, and is powered by two 450-hp V-12 diesel engines. The machine measures 70 ft long, 22 ft wide, and 16-3/4 ft high. Refuse trucks dump their loads into a hopper attached to the side of the machine.

A machine has been purchased by North Tonawanda, New York. To date it has successfully handled several hundred loads of mixed refuse, including stoves, refrigerators, and other such bulky items.

Billings, C. H.
"Operation 'Big Squeeze' Takes on Refuse Disposal"
Public Works, 97:87, January 1966

D and J Press has constructed a machine which combines the various equipment needed for sanitary landfill into a single machine. This machine weighs 75 tons, is 23 feet wide, 70 feet long, 16 feet-8 inches high, and all on wheels. The typical cycle of operation begins with a truck dumping its refuse load onto a steel apron which lifts and transfers the load to a receiving cavity. The load is tucked away by a vertically swinging plate which closes the "mouth" of the machine. The load is compressed against a shear. At a predetermined pressure, the shear lops off a chunk, at the same time mangling long pieces of metal and wood. About three strokes of the shear occur in each cycle. Another platen shoves the chunks downward, compressing them further. The load is discharged from a chute located on the side of the machine opposite its "mouth." Compression is continued within the chute by another platen. The compressed load is extruded in a continuous mass 36 inches square in cross section and dumped into a trench previously dug by the machine. Compression is maintained while the refuse is covered with the earth that was dug out to form the trench. The compaction ratio varies with the type of refuse and is believed to range from 10:1 to 20:1.

The machine can dispose of a 5-cu yd load of refuse within an average of 3 minutes time in a manner that would result in the elimination of fly, rat, and odor problems. The operation is highly automated. Two men are required, each to survey the operation from opposite sides of the chassis.

Attig, G. K. and J. Clay
"Put Teeth Into Compaction"
The American City, 81:88, March 1966

Two new pieces of equipment in use at the sanitary landfill site which serves Eugene and Springfield, Oregon, have greatly increased the efficiency of the operation. A combination compactor-dozer, with gear-toothed compaction pads for tires, can place twice as much refuse in a given area without increasing depth as was before possible. A self-loading scraper provides the county with ample cover material. While the old setup was generally satisfactory, the new equipment has cut down on the number of men and machines required to compact and cover the refuse.

The disposal site is located between the two cities it serves, and is operated by the county. The county budget allocates $40,000/year to the operation of the landfill, which amounts to less than $0.32 per capita per year. Private contractors collect refuse from both communities. An average of 120 commercial collection trucks and 400 to 500 private vehicles come to the landfill site each day.

Hankila, M.
"Fill First, Then Compact"
The American City, 81:173, May 1966

Buchanan, Michigan, has a population of 5,500. Versatility is important for city equipment inasmuch as the city's rubber-tired loader spends only about 1/4 of each day covering refuse at the landfill. The refuse, already compacted in the collection vehicle, is dumped in the landfill to a depth of four feet. The loader dumps sand over the refuse before compacting it further. This protects the hard-rock lug tread tires from damage.

When the previous compaction vehicle, a crawler type, was in use, it required 45 minutes to load it onto a trailer and transport it to a landfill. The rubber-tired loader can drive to the landfill from the garage in 10 minutes. The loader also is used in backfilling excavations, loading sealcoating aggregate, and for removing snow.

Buchanan spends about $2,000/yr in addition to equipment depreciation to operate its landfill. Of this expenditure, the greater part is for labor. Only 1/5 is for the fuel and oil used by the machine in landfill operations.

Evans, H., Jr.
"A New Idea in Landfill Operation"
The American City, 82:114, March 1967

The new method involves the use of a "mole" to place pressure-compacted refuse. It is being tried in King County, Washington. Basically the method consists of hauling che refuse from transfer stations to the disposal site in specially constructed containers, emptying the containers into a new machine called a "mole," and compressing the refuse in the trench before covering it.

The Mole: The machine operates in a trench some 15 ft deep dug by a backhoe. Its hopper receives the contents from two containers. A hydraulic ram compresses the material to 1/10 its original volume, discharges it from back of the machine into the trench in a continuous extrusion line 9 ft square. A standard tractor with a dozer blade covers the material. The force of the horizontal ram pushing the refuse into the trench moves the mole forward.

(The machine was in the construction stage at the time of this writing.)

Use of Completed Landfills

Schneider, C.
"Sanitary Fill Reused Safely"
The American City, 68:83, October 1953

After only three years, New Orleans has reworked a sanitary landfill site, using the decomposed refuse as cover material. This was possible probably because of the large amounts of rainfall and high temperatures experienced in New Orleans. San Francisco and New York City could not use refuse from landfills after ten years of decomposition.

The landfill is at the site of an old open dump which was infested with rats and insects, the changeover taking place in 1948. Trash collections are made once each week, and garbage collections are made three times each week. The landfill costs about $0.90 per ton of refuse received; incineration costs about $2.80 per ton. Two incinerators dispose of about 45 percent of the city's mixed refuse, the rest is cared for at two landfills. Two other landfill sites are in operation — one of which is used only for commercial wastes. The second adjoins the Mississippi River. Its location results in the saving of many miles in hauling distances each year.

Schwalm, C. F.
"Do You Realize"
The American City, 69:105, February 1954

In the city of Hamilton, Ohio, an old open dump located on land next to a river has been converted to a sanitary landfill operation. The reclaimed land will be used as a playground.

The city bought a fleet of nine new collection vehicles over a three-year period. Daily waste collections are made in the downtown area, and twice weekly in residential sections. The costs of collection and delivery to the disposal site averages $1.02 per cu yd.

The site receives 9,000 cu yd of refuse each month. It costs an average of $0.17 per cu yd to dispose of it. Trenches 20 ft wide and 10 ft deep are dug. The dozer compacts the refuse as it is received. The compacted refuse is covered with 3 ft of dirt, thereby providing a ramp for the next day's operation.

Nedry, D. E.
"Temperature is a Test of Decomposition"
The American City, 69:29, March 1954

Sanitary landfill has been used at Coeur d'Alene, Idaho, not only as a means of refuse disposal but also as a method of reclaiming land in and around the city. At the time the article was written, property owned by a local yacht club was being filled for use as a storage space for boats and a parking lot for cars. Each layer of the fill is 6 ft deep and is covered by 2 ft of earth. Approximately 1/2 acre of area per year is used in the operation.

By testing the temperature of the ground, it has been possible to judge the extent of bacterial action in the refuse and to determine the degree of decomposition of buried refuse. Three months after burial, the temperature in the refuse is at least 20° warmer than that in the surrounding ground. From 2 to 3 years usually pass by before the refuse temperature drops to that of the surrounding soil. When this stage has been reached bacterial activity ceases to pose a problem.

The ramp system is used. The tractor pushes the refuse forward, grading it upward. The refuse is covered each night.

Parker, W. E.
"How to Build a Sanitary Fill in Swamplands"
The American City, 69:*, May 1954

Swamplands and open dumps are public nuisances and potential breeding places for disease, yet both can be converted to usable land areas by means of sanitary landfill. Successful endeavors of this nature have been made in Rochester, New Hampshire and in Seattle, Washington.

The face of the fill at Rochester is not sealed off each day, because the work has to be tailored so that it can be done from the top of the fill. However, enough cover is spread to effectively reduce the danger of rat infestation and development of nuisances. The fill is operated in fingers that are about 75 ft wide and which reach out into muck that may be as deep as 20 ft and have water depth of more than 4 ft. Sandy fill material is stockpiled on each side of a finger in a windrow, so that it may be easily accessible for use as cover.

Fill is placed in the muck and compressed with the use of the bucket of the tractor as thoroughly as possible. As the mucky underburden consolidates, the completed fill settles into the swamp, at times as much as several feet. This settling provides a second opportunity to build a fill on top of the settled fill, and thus further reclaim the swamp area. In this manner, Rochester is disposing of 36,000 cu yd of refuse annually.

Seattle has been reclaiming swampland since 1930. In 2 to 3 years the amount of settling has only been slight. The city has converted the reclaimed areas into parks, playfields, and into industrial property. In the operation, garbage is spread to a depth sufficient to support trucks. It is then covered with earth. Additional loads of garbage are spread on this base to form an 8-ft lift. The city maintains four separate fills, which serve 500,000 persons and cover a total of 120 acres. The refuse received exceeds 1,750,000 cu yd per year.

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Giles, J. H. L.
"Refuse Makes a Runway"
The American City, 69:*, July 1954

In two or three more years, Meriden, Connecticut will have an airplane runway at its disposal site. To accomplish this, the ground elevation must be brought to 30 feet in the course of the fill operation. Since the refuse is deposited only in 6 ft to 8 ft layers, settling should not be a problem. The refuse is spread over an area roughly 20 ft long by 50 ft wide and is compacted thoroughly. The compacted refuse is covered with a one-foot layer of sand and gravel. The top layer of refuse is covered with a two-foot cover.

The city has been able to dispose of the refuse at a cost of only $0.10 per cu yd of loose refuse. The city serves a population of about 45,000 people, and annually disposes of approximately 145,000 cu yd of refuse.

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Lancaster, R.
"More Cropland for Kearney"
The American City, 69:*, August 1954

Kearney has been reclaiming old gravel pits for use as alfalfa fields by means of sanitary landfill. Since 1946, the rate of reclamation has been about two acres per year.

From a population of 12,000, 3,000 cu yd of refuse are disposed of annually. An Allis-Chalmers HD-7 tractor is used. Only one man is required for keeping the fill in a good and sanitary condition. The abandoned gravel pits measure approximately 40 feet in depth and 300 feet in width. As refuse is pushed into the water, sand from alongside the pit is pushed in also. When the pit is finally filled to the waterline, the area resembles an inverted cone that measures 12 feet in depth at the center.

Area fill is used from then on, mixing the refuse with sand and dirt from outside the depression. The charge for services is $1 per month for single residences, $1.50 for duplexes, and an additional 25 cents for each additional unit. When a fill is completed it is leveled and is planted with alfalfa. The crop is irrigated by a well located on the property.

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Hopson, R. S.
"Sanitary Fills Provide More Playgrounds for Richmond"
The American City, 69:*, August 1954

Richmond, Virginia, switched to a sanitary landfill operation in 1947, and thereby transformed a smoky, open dump into a neat, insect-free, rat-free disposal area. As a result of the changeover, wastelands have been made productive, areas have been acquired for parks, swamp areas have been eliminated, and the important problem of disposing of the refuse contributed by nearly 250,000 people has been solved. The city runs as many as six fills at a time. Each year, an additional 25 acres of land are required for the disposal operation. The fills settle about 5 percent to 10 percent in five years. Decomposition is entirely complete in less than five years, when the fill is operated according to the procedure followed by the city. When necessary, the already decomposed refuse is excavated and used for cover material.

The entire cost of operation is about $0.14 per cu yd of refuse received.

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Dwyer, O.
"More Shoreline for Berkeley"
<u>The American City</u>, <u>69</u>:*, August 1954

By constructing sanitary landfills, Berkeley has reclaimed waste shorelines for business and industrial use. The area to be filled is enclosed by bulkheads built in the Bay. The area thus enclosed is dewatered according to the requirements of the California State Health Department.

The city maintains two separate fills; one fill receives only refuse collected by city equipment from the city's 115,000 people; the other fill receives refuse hauled by private collectors. The latter contains little organic garbage. The fills are constructed in sections that are 100 feet wide, 600 feet long and 14 feet deep. Two six-foot layers of refuse are compacted in each section, the first covered with one-foot of cover, the second layer with two-feet of cover.

Approximately 57,000 tons of refuse are dumped in the two fills each year. A settlement of 25 percent is expected before the fill becomes stabilized. After settling comes to an end the land is used for whatever construction the city may require. (Note: To date (1968) the amount of construction has been negligible.)

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Anon.
"Badlands Become Good Neighbors"
<u>The American City</u>, <u>69</u>:*, October 1954

Two cities in the Central United States have been able to convert nuisance lands into good usable land.

Madison, Wisconsin began to use the sanitary landfill as a means of refuse disposal when Wisconsin passed a law prohibiting the use of garbage for feeding hogs. The city uses 57 acres of tax-delinquent land adjacent to an existing high school for its disposal site. An Allis-Chalmers HD-5G crawler tractor with a 1-yard front-end shovel is used to do the work. The unit digs the trenches and compacts the garbage, covering it with a two-foot layer of gravel purchased and delivered to the site.

Seminole, Oklahoma used land on the outskirts of the city for a land-reclamation sanitary landfill site. The land was badly gullied and was decreasing in value prior to the initiation of the rehabilitation program.

Refuse trucks deliver the trash to convenient points at the head of the gully. A bulldozer is used in compacting the refuse and in covering the refuse with soil removed in excavating the trench for the next day's fill.

The city plans to put the completed land to use as pasture in order to prevent any further soil erosion.

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Dunn, W. J.
"Sanitary Landfill Extends University Campus"
The American City, 74:97, March 1959

The fill is located at the campus of the University of Washington in Seattle. The landfill is operated at the Union Bay swamp on Lake Washington. To date, about 28 acres of fill have been converted into parking area and a playfield. Operation during wet weather is beset with difficulties, and the extensive settling is a problem. No objections to the operation have been raised by nearby residents.

Luce, R.
"Sanitary Landfill Pushed Back the River"
The American City, 74:92, December 1959

The city of Topeka has three sites along the Kansas River where floodlands are used for sanitary landfill. Jetties are constructed out into the river. The settling pools thus created quickly fill with sediment. The area is then available for fill. Only one of the sites is used for garbage and refuse from municipal collection.

The charge for collection is $1.35 per month per single residence for twice weekly collections. Residences equipped with a garbage disposal receive an exemption of 60 cents per month. Although garbage must be separated from other material, it is picked up in the same truck as is the rubbish. Daily collections are made at all commercial stops.

Anon.
"County Landfill Reclaims Marshlands"
Public Works, 94:117, March 1963

The Bergen County, New Jersey, sanitary landfill serves 52 of the county's 71 communities, i.e., a population of 600,000 and a collection of highly developed commercial and industrial complexes. Through the disposal of 400 truckloads of all types of refuse per day, low-value tidal marshland is converted into potential recreation sites at the rate of 60 acres per year. Over 14,000 cu yd of compacted material are placed in the dump weekly. Since a wide variety of type and size of material is handled, a single lift up to 15 feet thick is more feasible than multiple shallower lifts. A modified trench and cover system is used. The trenches are 35 feet wide and from 25 to 30 feet long. Because of the deep fills, a given work face remains open two to three days before being covered.

The total landfill site covers nearly 800 acres of county-owned marshland. It is broken into a dozen individual sites by a network of local roads and expressways crisscrossing the section. Haul roads are made of crushed rock to prevent miring.

Anon.
"How To Use Your Completed Landfills"
The American City, 80:91, August 1965

A survey of counties that used sanitary landfill for their solid waste disposal showed that 48 percent of the 208 which responded to the survey did not have any structures on the completed landfill sites, 21 percent had built on one or more sites, and 31 percent had not as yet completed any landfills. Settlement or gas production or both have adversely affected many of the structures constructed on completed sanitary landfills.

The article describes the responses from many counties throughout the nation. In general, the consensus was that buildings must have adequate protection from settling and gas seepage. One city initiated the following requirements: a monolithic, self-supporting foundation slab, keyed and sealed foundation walls, a plastic seal under the interior floor, and a 24-inch wide rock-filled trench around the foundation to collect gas. Golf courses, playgrounds, parks, and picnic areas are suitable uses for completed landfills, although gases produced by the decomposing refuse often makes it difficult for grass and other flora to grow.

Dunn, L.
"Reclamation of Union Bay Swamp in Seattle"
Quarterly Journal of the University of Washington, College of Engineering, April 1966

A waste-fill procedure is described which added 166 acres, formerly a part of the lake, to the University of Washington campus in Seattle. Land suitable for parking lots, playfields, open storage, and certain kinds of structures was reclaimed in the form of rubbish and garbage cells covered with earth. General conclusions are made concerning the effect on the water quality of the lake and concerning refuse-fill methods that perhaps would be applicable elsewhere.

First, M. W., F. J. Viles, Jr., and S. Levin
"Control of Toxic and Explosive Hazards in Buildings Erected on Landfills"
Public Health Reports, 81:419, May 1966

The principal hazard involved in construction on refuse-filled land arises from the anaerobic production of combustible gases. Gas-tight construction over landfills is difficult if not impossible to achieve because of the gas pressures resulting from biological gas production.

During investigations of gas levels in a housing development constructed on sanitary landfills, the concentration of methane was found to be at an unsafe level in a high proportion of the buildings. A concrete slab laid on top of the fill did not prevent gases from penetrating into the buildings. Several sealants (Flintkote C-13-A asphalt emulsion; Flintkote No. 70 asphalt emulsion; sodium silicate; water) were found to be inadequate for the purpose.

Results of periodic sampling over several years in the sub-basement spaces of a number of buildings indicated that organic fill located around and under the heated buildings became completely degraded in approximately five years, releasing CH_4 at a proportionately rapid rate. A situation such as this can constitute a serious explosion hazard unless suitable methods of aerating and ventilation are employed. Continuous mechanical aeration at a rate of one or two air changes per hour adequately reduced the methane concentration.

References given in the article are:

1. Eliassen, R., "Decomposition of Landfills," Am. J. Public Health, 32:1029, 1942;

2. Eliassen, R., "Why You Should Avoid Construction On Refuse Landfills," Engin. News Record, 138:756, 1947;

3. Merz, R. C. and R. Stone, "Factors Controlling Utilization of Sanitary Landfill Site," University of Southern California, Los Angeles, 1963.

Sowers, G. F.
"Foundation Problems in Sanitary Land Fills"
Journal of Engineering Division, American Society of Civil Engineers, 94:103-116 (SA 1), Proceedings Paper 5811, February 1968

In the past, marginal or otherwise useless lands have been used for sanitary landfill operations. The growing scarcity of building sites close to cities as well as the steady increase in the volume of wastes being generated make it imperative that completed sanitary landfills be used as sites for future building. Unfortunately, the fills are weak, compressible, and are characterized by a continuing process of chemical and biological deterioration. Building foundations are weakened by break-throughs into the fill and by constant settling. Decay and decomposition result in the formation of noxious and explosive gases. The construction of foundations extending through the fill is difficult and expensive.

A more effective utilization of completed fills would be possible if they were planned and operated with the possibility of future building kept in mind. In line with such an approach, material of the highest density and resistance to breakdown should be segregated for disposal in future building sites. This material should be heavily compacted and possibly surcharged to increase its structural strength and decrease its compressibility. Building structures must be designed to compensate for settlement, or to be supported on piles or on piers. Their sub-structure must be designed to resist the corrosion and care for the gas production characteristic of fills.

Anon.
"HRVC Commends Yonkers Plan for Park on Warburton Landfill Site"
HRVC Newsletter (Hudson River Valley Commission), 2:2, April 1968

The City of Yonkers, New York plans to construct a riverfront park on a half-mile, 7.5-acre site that the city had been using as a dump for incinerator refuse. The site is 80 ft above the Hudson River. The project is expected to cost upward of $7.5 million dollars. The central area, which would be built first, would include a three-level social sitting area, pedestrian walks, landscaping, and a multi-level playground. North of that area would be a small parking lot for about 40 cars and a quiet sitting area with reflecting pools and a waterfall fed by a recirculating pump system.

Economics

Mailey, H. V.
"Landfill from Eyesore to Asset"
Public Works, 95:95, November 1964

The site of the operation was at Wilkes-Barre, Pennsylvania. Six villages joined to operate the landfill. The locale of the fill was an abandoned coal stripping area. The annual expenditure (5-day week) is estimated at 39 cents per capita per year for a contributing population of 93,000. An unexpectedly large revenue is obtained from commercial haulers and commercial and industrial establishments. For example, in June 1964, a total of 3,745 vehicles (of which 687 were municipal trucks, 1,440 small pickups, 1,618 commercial haulers) came to the site.

Cost of preparing the site was $2,000. The present cost to Wilkes-Barre is $25,257 per year. (When an incinerator was used, the cost was $60,798 per year.)

Fahy, V.
"A Firm Price for Six Years of Service"
The American City, 81:106, May 1966

A track-type loader previously had been used in the sanitary landfill operation at Minot, North Dakota. The downtime with the machine was extensive. Repairs to the amount of $20,000 had to be made over the past 5 years. To predict machine repair costs over future years, the following stipulations were placed in a bid for a new machine:

1. It had to meet the specifications of the city.

2. The total net price had to include the unit price, minus trade-in, plus a guaranteed maximum cost of repairs for 10,000 hours, or six years.

3. The bid had to include a guaranteed resale price at the end of 10,000 hours, or six years.

4. All bidders had to be bonded against default of the guaranteed repair cost and resale price items.

The city provides residential pickups twice a week. This results in the delivery of an average of 160 cu yd of material to the fill each day. Eight private hauling firms serve the commercial and industrial establishments — adding approximately 150 cu yd to the daily load.

The city charges $1.25 per month for each residence. Multiple-residence units are charged an additional $1.00 for each additional kitchen unit in use. The 1964-65 budget allocated $111,000 for refuse collection and disposal — $91,000 for hauling and $21,000 for operating the landfill. This does not include depreciation of capital goods. Average yearly cost is $4.26 per ton, or $1.17 per yd for hauling, and $0.94 per ton or $0.26 per yd for disposal.

The unit price was $22,665, less a trade-in of $2,090, or a net of $20,573. The guaranteed repair cost for six years or 10,000 hours was $6,100. The guaranteed trade-in value after six years or 10,000 hours is $9,000. The actual cost for six years of usage is $17,675.

Reynolds, W. F.
"Abandoned Strip Mines Studied for Solid Waste Disposal"
Public Works, 98:74, May 1967

The study is expected to demonstrate the potential in the use of abandoned strip mine areas for waste disposal.

The location of the operation is in Allegany County (near Frostburg, Maryland). A three-year program is to be completed in 1970. It will include a determination of unit cost and mine capacity, of ground and surface water quality changes, and the making of an inventory of all abandoned mines in the state.

Research (Leaching, Seepage, CO_2 Travel, Fly Emergence, etc.)

Anon.
"Investigation of Leaching of a Sanitary Landfill"
Report by the California State Water Pollution Control Board, Publication No. 10, Sacramento, California, 1954

The following are comments and excerpts from the "Summary of Conclusions:"

1. "A sanitary landfill, if so located as to be in intermittent or continuous contact with ground water, will cause the ground water in the immediate vicinity of the landfill to become grossly polluted....

2. "Local increase of mineral elements to concentrations varying from 20 times those found in the unpolluted ground water of the area in the case of common minerals up to 10,000 times in the case of ammonia nitrogen are possible.

3. "It may be expected that continuous leaching of an acre-foot of sanitary landfill will result in a minimum extraction of approximately 1.5 ton of sodium plus potassium, 1.0 ton of calcium plus magnesium, 0.91 ton of chloride, 0.23 ton of sulfate, and 3.9 ton of bicarbonate. Removals of these quantities will take place in less than one year.

4. "Where the pollutional load on a ground water is light by reason of a sanitary landfill being in intermittent and partial contact with the underlying ground water, the most serious impairment of the ground water as little as a half-mile downstream from the landfill will be an increase in hardness, and then only in the upper portions of the aquifer.

5. "Anaerobic conditions with the production of combustible gas will exist within a landfill in approximately one month following deposition of the fill."

Black, Ralph J. and A. M. Barnes
"Effect of Earth Cover on Housefly Emergence"
Public Works, 87, March 1956

An uncompacted layer of soil as deep as 60 inches did not serve as an effective deterrent to the emergence of houseflies. When compacted at 8.5 percent moisture (dry basis) the soil cover prevented fly emergence at a depth of only 1-1/8 inches.

Two phases of fly control are of importance in the operation of sanitary landfills:

1. the prevention of oviposition by thoroughly covering all exposed refuse each day; and

2. the prevention of fly emergence by compacting the cover at or near the optimum moisture content.

Black, R. J. and A. M. Barnes
"Effect of Earth Cover on Fly Emergence from Sanitary Landfills"
Public Works, 89:91, February 1958

Laboratory results in a previous experiment showed that a compacted earth cover on refuse was effective in preventing fly emergence. During the summer of 1956, a field investigation was undertaken to test the laboratory findings under established operating conditions at several sanitary landfill operations in California.

At each landfill site, 25 emergence traps were placed 4-6 inches apart in two rows of eight and one row of nine. The traps were placed only over refuse infested with fly larvae so that negative results would indicate control of emergence, rather than a lack of larvae in the refuse. The six landfill sites used for the investigation were Oakland, Watsonville, Monterey, Lodi, Santa Cruz, and San Rafael. The article describes the specific operation at each of these sites.

To prevent fly emergence, four essential facts must be considered:

1. the soil must be compactible;

2. suitable equipment for compacting the soil must be on hand;

3. there must be a suitable range of soil moisture;

4. the cover must be sufficiently thick.

Engineering-Science, Inc.
"Effects of Refuse Dumps on Ground Water Quality"
The Resources Agency of California, State Water Pollution Control Board, Publication No. 24, Sacramento, California, 1961

The flow pattern of pollution in ground water depends greatly on local geologic conditions.

The principal processes involved in the introduction of pollutants to the ground water through the agency of refuse dumps are infiltration and percolation, refuse decomposition, gas production and movement, leaching, and ground water travel.

The amount of water which enters a refuse fill will be governed by rate of water application, nature of the refuse cover, and climatic conditions. In southern California, refuse dumps having unirrigated soil covers do not seem to transmit surface-applied moisture in quantities great enough to cause noticeable pollution. In areas of higher precipitation, the percolation of rainwater through refuse has definitely been observed, and estimated water balances indicate that heavy irrigation and occasional years of high precipitation may produce substantial percolation through permeable dump covers even in southern California. The appearance of percolation even under such adverse conditions may be delayed for years because of the high moisture-retaining capacity of combustible rubbish, and because heat liberated in the decomposition of the refuse may accelerate evaporation.

Refuse contains mineral and organic substances in quantities capable of seriously damaging underground water supplies. Carbon dioxide produced in the breakdown of organic matter can seriously degrade underground water by dissolving Ca, Mg, Fe, and other substances which are undesirable at high concentrations.

Decomposition processes and rates are believed to be closely connected with the circulation of air and gases of decomposition through refuse fill. Gas movement can occur by displacement when there is a net production or uptake in the refuse, and by convection due to differences in gas density. Density variations may arise when portions of the refuse atmosphere receive heat liberated in the decomposition process, and when the gas produced has an average molecular weight different from that of air. However, the most effective transfer mechanism is molecular diffusion; the diffusivity of a porous medium is relatively independent of the particle size, so that gases may diffuse readily through some materials of low permeability. Therefore, in preventing CO_2 from moving into the underground, methods which involve its removal to the atmosphere by encouraging draft or ventilation may be more effective than coatings to decrease permeability of the disposal pit surfaces.

The substances most likely to prove objectionable if percolate enters a ground water with inadequate dilution are: hardness, Fe, NO_3, and total dissolved solids. Sulfides and organic matter may also cause problems if the leached substances are pumped out too soon after entering the ground water.

The lateral dispersion and consequent dilution of carried materials is more effectively accomplished by nonconformities in the water-bearing strata than by random velocity variations through the pores of the sand.

Apparently only three basic mechanisms are available by which solid refuse can impart undesirable qualities to the ground water:

1. direct horizontal leaching of refuse by the ground water;
2. vertical leaching by percolating water;
3. the transfer of gases produced during decomposition by diffusion and convection.

Doty, R. E. and A. M. Barnes
"Effect of Earth Cover on Emergence of the Vinegar Fly, *Drosophila melanogaster* Meigen"
California Vector Views, 8:7, February 1961

Studies of the effect of soil cover on infested media for fly breeding were made with the vinegar fly as the test organism. The tests were designed to explore three variables: soil moisture, depth, and compaction of soil.

The article describes the method of placing the larvae in tubes buried in soil. The larvae emerged and attempted to burrow through the soil. The first four trials indicated that the vinegar fly adults did not emerge through a 2-inch uncompacted covering of dry soil (0.9 percent moisture). Only 0.5 percent of the flies actually survived to emerge from their pupal cases. This was attributed to the desiccation of the breeding medium by the soil layer. In three sets at 6 percent soil moisture, 32 percent emerged from the pupal cases, and 25 percent emerged through the 2-inch soil layer. At the same moisture level but with a 4-inch soil layer, 26 percent emerged from the pupal cases, but none emerged through the soil.

The percentage of flies that were able to emerge from the pupal cases varied directly with the soil moisture content. The emergence of the vinegar fly can be prevented by as little as a 4-inch uncompacted soil cover.

Merz, R. C. and R. Stone
"Landfill Settlement Rates"
Public Works, 93:103, September 1962

The study involved the construction of six test cells, each 50 ft^2 by 20 ft deep. The purpose of the study was to determine the optimum means by which the maximum amount of waste could be packed into the available space, and at the same time make it possible to predict shrinkage. Among the summary statements and conclusions are the following:

1. In conventional landfills having 4-ft lifts, the density of refuse can be increased about 20 percent by adding water to bring the moisture content to 40 percent.

2. With the use of 18-ft lifts, the density can be increased by 35 percent through the addition of water and the provision of good compaction.

3. The in-place density of refuse in a 20-ft lift is from 5 percent to 15 percent greater than that in a 9-ft lift.

4. In the landfill in which aerobic conditions were maintained, the lifts set at 18 ft, and to which water was added, an active composting environment was maintained, temperatures were high, and the settlement rate was three times higher than that in the anaerobic fills. (A fire hazard did exist.)

5. Shrinkage during the first month was greatest in the 20-ft lift. After the third month, shrinkage was quite small in all of the lifts.

Merz, R. C.
"Determination of the Quantity and Quality of Gases Produced During Refuse Decomposition"
University of Southern California, Los Angeles, Engineering Center Quarterly Reports, USCE Report 83-3 30 September 1962; 89-6 30 July 1963; 89-7 30 September 1963; 89-8 31 December 1963

The volume of gas production is related to the moisture content. Gas production generally was higher in drums receiving water, and was highest in the drum containing saturated refuse. Volume of gas production also is related to aeration and to the composition of the refuse. Variations from 0.023 cu ft per lb of dry refuse to 0.176 cu ft per lb of dry refuse were observed. Carbon dioxide and nitrogen were the major gases; no methane was found.

Merz, R. C.
"Determination of the Quantity and Quality of Gases Produced During Refuse Decomposition"
Final Report, University of Southern California, Department of Civil Engineering, Los Angeles, July 1963

In laboratory experiments in which were used eight 55-gallon drums filled with garbage, paper, and grass, researchers at the University of Southern California measured the quantity and determined the composition of the gases produced by the decomposition of the material in the drums over a nine to eleven month period.

Results of the experiments showed that the volume of gas production definitely is related to the moisture content of the refuse. Gas production generally was higher in drums which received the larger amounts of water. The volume of gas production also varied with the amount of grass and garbage in the refuse. Aerated drums produced more gas than did those not aerated.

The greatest percentage of the gases was in the form of CO_2 and N_2. The amount of CO_2 production increased in volume as the tests continued. Methane was not found in measurable volumes in the drums.

Merz, R. C. and R. Stone
"Factors Controlling Utilization of Sanitary Landfill Site"
University of Southern California, Department of Civil Engineering, Los Angeles, 1964

The report was the first progress report made by the investigators to the Department of Health, Education, and Welfare for the year 1964. Four test cells of various sizes were constructed at the Spadra Landfill, Walnut, California. The landfill cells which were constructed had been undergoing decomposition for as long as six months. Comprehensive conclusions from the collected data could not be made, although it was possible to arrive at some general conclusions.

Cells A, B, and C had bottoms measuring 50 ft on a side, and tops measuring 70 ft x 130 ft, and a depth of 20 ft. Cell D had a bottom measuring 24 ft on a side, and a top measuring 35 ft x 65 ft, and was approximately 11 ft deep. The portion used for research purposes was that mass rising vertically from the bottom area.

At the center of each cell, an access well was constructed to provide outlets for gas collection lines, leach collection lines, and electrical leads, as well as access for the researchers. As the cells were constructed, half sections of 55-gallon steel drums were located within cells A, B, and C, two with open end up for the collection of leachate, and two with closed end up for the collection of gas. Thermometers and thermistors were installed for the recording of the temperatures inside the cell.

Studies were made concerning amount of settlement, moisture content, gas produced, and temperature within each cell. Cell C was interlaced with air lines to provide air for decomposing the refuse aerobically. (Settling was much faster in the aerobic cell than in the anaerobic cells.) Various types of cover were used for tests concerning the ability of covers to hold moisture and to maintain grass. Moisture content was varied in the cells by watering down the material. Moisture content was varied in those studies concerned with determining the effect of moisture content on degree and rate of settling.

The gases produced were mainly CO_2 and N_2. In the anaerobic cell having the highest moisture content, the CO_2 content was considerably higher than in those having lower moisture contents. The N_2 was replaced to a large extent by CH_4 in this cell. The aerated landfill had the greatest shrinkage. The rates of settlement of the anaerobic cells were generally less than 0.05 ft per month; that of aerobic landfill, 0.24 ft per month. Temperatures within the anaerobic cells reached 120°F; in the aerobic cell mass it climbed to a high of 177°F.

Merz, R. C. and R. Stone
"Gas Production in a Sanitary Landfill"
Public Works, 95:84, February 1964

Among the statements and conclusions listed in the paper are the following:

1. Gases produced within the anaerobic test landfills consisted chiefly of CO_2 and N_2. The concentration of CH_4 depended upon the moisture content, and varied from little more than a trace in the landfill to which no water was added to constituting the major component (greater than 50 percent) of the gas produced in a saturated landfill. Hydrogen was present only in very small amounts.

2. Gases produced in the aerobic fill consisted chiefly of CO_2 and N_2. Oxygen did not exceed 10 percent.

3. Production of CH_4 was markedly increased by surface irrigation of the fill.

4. Gases within the four landfills appeared to be under positive pressure and diffused laterally and vertically downward into the surrounding earth as well as upward through the top cover.

5. Small concentrations of O_2 were frequently found in all fills.

6. Initial peak temperature was reached in three months and occurred at various depths. Temperature peaks reached during the latter stages of the decomposition were never as high as the original peak.

7. Initial temperatures in the aerobic fill greatly exceeded those in the anaerobic fills.

LeGrand, H. E.
"System for Evaluation of Contamination Potential of Some Waste Disposal Sites"
Journal, American Water Works Association, 56:959, August 1964

The article describes a system for evaluating the contamination potential of any source of pollution, including refuse disposal. It is a point count system in which certain environmental factors are given values. The suitability of a given site depends upon the total value of the points. Point values are assigned to: water table, water table gradient, sorption, permeability, and distance to point of use. The article presents charts and scales for giving point values to each of the factors as based on its relationship to the other factors.

Each factor tends to have a direct or inverse relation with each of the other factors. It applies to natural conditions. Quantitative studies have been drawn upon for preparation of the system. However, the scheme is empirical and is designed to give an approximate evaluation. It works best for a one-medium site (wells and disposal sites both in loose granular materials) and fair to good for two-media sites.

Merz, R. C. and R. Stone
"Factors Controlling Utilization of Sanitary Landfill Sites"
University of Southern California, Los Angeles – First Progress Report to Department of Health, Education, and Welfare, National Institutes of Health, USPHS, Project No. EF-00160-04, 1 March 1965

The purpose of the study was to determine the optimum means by which the most waste can be put into the available volume and at the same time permit a realistic prediction of shrinkage.

Procedures used in the landfill construction in which water was added and compaction provided resulted in densities 100 percent greater than those of the refuse as discharged from the truck. Shrinkage occurred in the cells within the first month following their completion. Rates of settlement after six months were 0.24 ft in the aerobic cell and 0.05 ft in the anaerobic cells. Gases produced in the "wet" landfill were CO_2, N_2, and CH_4. The temperature within the anaerobic cells reached as high as 120°F. The temperature in the aerobic cell after several months rose to 177°F.

Merz, R. C. and R. Stone
"Sanitary Landfill Behavior in an Aerobic Environment"
Public Works, 97:67, January 1966

An aerobic landfill cell was constructed and was provided with an access well in which could be located outlets for gas collection lines, leach collection lines, and electrical leads. It also served as a means for human access in the placing of equipment and taking of data. A system of piping to admit air also was installed. To prevent the air from being forced through the earth cover and into the atmosphere, an impervious polyethylene membrane was stretched one foot below the surface. The total rate of settlement over 344 days was 1.66 ft, a shrinkage 4 to 6 times greater than that occurring under anaerobic conditions. The chief components of the gas taken at the top and bottom levels were N_2, CH_4, O_2, and CO_2. At times H_2 was detected. The temperature was higher and had a greater range in the aerobic cells than in the anaerobic cells. In the former, it ranged from 113° to 193°F at the 10-ft level. Gases discharged from both aerobic and anaerobic cells had an objectionable odor.

Burchinal, J. C. and H. A. Wilson
"Sanitary Landfill"
Sanitary Landfill Investigation Progress Report, Project EF 00040-01, 02, and 03 to the USPHS, 1967

Refuse fills are capable of seriously damaging underground water reservoirs by causing an appreciable increase in hardness, iron, solids, and in various forms of nitrogen and sulfur. The principal means of ground water pollution are percolation and movement of CO_2 through the aquifers.

Hydrogen, oxygen, nitrogen, carbon dioxide, and methane are the major gases in a landfill. The hydrogen concentration of the gas produced in a test fill was found to be 20.6 percent between the first and second week. It dropped to about 1 percent after one month. The final CO_2 concentration was 40 percent. At first the nitrogen decreased to as low as 10 percent. Later it rose to 70 percent. Methane production was small (N.B., the pH was 5.2). Acetic acid production was significant during the first few days. The most significant compound accumulated in the fill was n-butyric acid.

Refuse in a landfill contains aerobic and anaerobic, and mesophilic and themophilic microorganisms. Decomposition of the refuse is limited by moisture, aeration, and nutrients. Of these factors, aeration is perhaps the most important, inasmuch as decomposition of organic material is more rapid under aerobic than under anaerobic conditions.

Engineering-Science, Inc.
"In-Situ Investigation of Movements of Gases Produced from Decomposing Refuse"
Final Report prepared for California State Water Quality Control Board,
Publication No. 35, April 1967

Over 90 percent of the gas produced by refuse decomposition in large landfills is CO_2 and CH_4. Both CH_4 and CO_2 were found in concentrations up to 40 percent at distances up to 400 ft away from the edge of the fill. An equal concentration of CO_2 can be found in the soil under a landfill if the soil is homogeneous and not impervious. Methane poses less of a threat to ground water quality because it is only slightly soluble in water. Moreover, since it is lighter than air, it will tend to rise through the landfill rather than diffuse into the ground water.

Refuse gases pose more of a hazard to ground water than do leachates because gases are always produced; whereas the leachate problem is one of external water passing through the refuse. The leaching problem is readily avoided through the proper location and maintenance of the fills.

A workable and effective CO_2 gas barrier membrane was developed. (Using such a membrane would increase the cost of landfill operation by 10 percent or less.) Methane production in pits constructed to test the effectiveness of an asphalt barrier was not great enough to permit a conclusive determination of the effectiveness of this type of barrier. A more effective gas control procedure would be one in which the gas is vented and burned.

Miscellaneous

Weaver, L. and D. M. Keagy
"The Sanitary Landfill Method of Refuse Disposal in Northern States"
Public Health Service Publication No. 226, 1952

This is a report of the studies undertaken by the North Dakota State Health Department, in cooperation with the city of Manden, North Dakota, and the U. S. Public Health Service. The report is of special interest to northern communities exposed to severe winters, inasmuch as the city of Manden was able to carry on its landfill operations at two different sites for two years without encountering any problems, even though the temperature dropped to -44°F at times.

One of the sites was about one mile outside the city. The trench method was used. Windblown paper proved to be a nuisance. It could have been eliminated by surrounding the disposal site with a strong wire fence from 10 to 12 ft high. The extent of compaction of the refuse deposited during the winter months was greater than that buried during the remainder of the year.

Vincenz, J. L.
"Development of the Sanitary Landfill in California"
Paper for the Conference on Municipal Refuse Collection and Disposal, University of California, Berkeley, February 1953

The first sanitary landfill operation in California was begun in Fresno in 1934. Berkeley and San Francisco had prior landfill operations, but in these latter operations the refuse was neither compacted nor covered regularly. In Fresno the refuse was compacted and covered, at times with a covering layer as thick as 30 inches. The deep cover was added so that the land could be reused for agriculture. Several papers describing the sanitary fill operations were published, yet no other cities adopted the practice at the time.

In 1942, was begun the establishment of sanitary fill operations at all war department camps and airfields not having incinerators. The operation proved so successful at the sites that many bases with incinerators adopted the method. The U. S. Public Health Service inspected and approved the operations, and published an article on sanitary fills which gave a considerable impetus to the spread of these operations. The State of Texas Health Department urged many small Texas cities to practice the sanitary fill method of disposal.

The importance of compaction was borne out by the fact that New York City experienced great difficulties with settlement of uncompacted refuse; while Santa Monica and Fresno, California, and Winnetka, Illinois had excellent results with compacted fills.

Anon.
"A Report From Two Midwestern Cities"

The American City, 69:*, September 1954

Hutchinson, Kansas, developed an innovation in the ramp method of sanitary landfill, while Lansing, Michigan, was forced by public pressure to build a fill. Hutchinson took out the waste motion in its landfill operation by building a ramp-type fill through the development of a specially built blade. The tractor levels the refuse when in forward motion and pushes dirt when in reverse. The blade is a standard 18-inch ripper installed on the rear of a tractor. Hutchinson has been using the sanitary fill method as a feature of its service since 1944. One dollar per household per month defrays the costs of operation. The city has reclaimed more than 45 acres of wasteland and was working on a 50-acre site at the time of this article. The fill receives approximately 150 tons of refuse per day and will raise the final level of the land by 13 feet.

Lansing was practically forced to adopt the sanitary fill method of disposal because of the public uproar at the open dumps run by the city and a few private entrepreneurs in the city. Since 1952 the city has operated the fill, and by 1954 had reclaimed 110 acres with the refuse from 93,000 residents. Trenches are used which are 100-ft long, 30 to 40-ft wide and 6-ft deep. Refuse consists only of rubbish and manufacturers' wastes. Garbage is collected by the city and ground and disposed of with the sewage sludge.

*Page number is missing on our copy of the paper.

Anon.
"It Made a Big Difference"
The American City, 73:107, January 1958

People in Mitchell, South Dakota, are gradually becoming accustomed to the new sanitary landfill disposal site that replaced the old open dump. Tires in the old, cancerous dump have been snuffed out and the formerly abundant population of flies and rats has been eliminated. Mitchell now has a housing development within two blocks of the landfill site. The landfill site is 35 acres in extent. The city is now depositing its second layer of fill at the site. As yet no settling problems have been encountered. With deposition of the two layers, the level of the land has been raised 35 feet.

Anon.
"Dayton Buries Non-burnables"
The American City, 73:29, April 1958

Dayton, Ohio, operates three sanitary landfills for the disposal of non-burnable material such as glass, cans, and ash. Serving a population of 283,000, approximately 550 cu yd of fill per day are required for the disposal of the nonburnable objects. Materials to be used in the fill are collected every two weeks by the municipal sanitation department.

Black, R.
"Sanitary Landfills Serving California Communities in 1957"
California Vector Views, 5:27, May 1958

The report concerns 51 sanitary landfill sites in California. It contains four pages of charts, listing 21 different aspects of each of the landfill sites.

Of the 51 sites, 21 were area-fills, 19 were cut-and-fills, seven were area-fills utilizing moving ramps, 2 were of the cut-and-fill type utilizing moving ramps, 1 was of the moving-ramp fill type, and 1 was a combined operation — using the area method for rubbish disposal, and the cut-and-fill method for mixed refuse. Some of the sites were run by public agencies, some by sanitation districts, and some by private contractors.

Charts give a very complete picture of each of the sanitary landfill sites in the state.

Gieser, F. E.
"Highland Park Landfill"
Municipal Construction, 3:82, June 1958

The landfill method of refuse disposal was initiated in Highland Park in 1952. It was started by completely overhauling the previous open dump. In the new operation, trenches are dug, filled with wastes in 6-ft lifts, and earth is spread over each lift. The trenches are 15-ft deep. More than 13,000 cu yd of refuse are disposed of each month. The cost is $0.08 per cu yd of garbage and $0.15 per cu yd of rubbish.

The fill is being used to reclaim low-value land. It also serves as a source of income, inasmuch as nearby cities are allowed to use it on a cost basis.

Anon.
"Refuse Volume Reduction in a Sanitary Landfill"
Journal, Sanitary Engineering Division, American Society of Civil Engineers, (SA6) 85:37, 1959

An engineering investigation was undertaken to ascertain the extent of refuse volume reduction that can be achieved initially and after a long period of storage in a sanitary landfill. The tests were conducted at Monterey Park, California, where the soil consists of fine sandy-silt-clays. The tests were run Nov-Dec 1957. During this time, the skies were overcast during only a few days. On these days a minor amount of rainfall occurred.

Results of the tests, and the conclusions to be drawn are as follows:

1. In-place volume reduction achieved at the sanitary fill site under test-operating conditions was 25 percent of the original trucked refuse volume.

2. After five years, an additional 25 percent in-place reduction of volume occurred.

3. Soil tube investigations indicated that the intensity of the biological activity in the fill after 1-1/2 years was greater than that in the first few weeks after the fill was begun.

4. In a typical landfill operation homogenous materials actually may expand as a result of fracturing and matting, or of poor compaction.

Hall, R. E.
"We Rework Our Sanitary Landfill"
The American City, 74:153, September 1959

Having only 40.3 acres to use for sanitary landfill, Charlottsville, Virginia, has decided to rework the land, although it has already been completely utilized for waste disposal. The site was reused after no more than six years, with no foul odors noticed. Except for some paper and rags, all of the matter had been decomposed by the time the fill was reworked.

Collection by the city is twice a week. The collection and disposal operations cost the city $4.50 per person per year. The expenses are paid by the city's general fund.

Eliot, George F.
"Garbage Is A Nasty Word"
Suburbia Today, May 1961

From a community of 30,000, 34 tons of refuse must be collected and disposed of each day. Two courses may be followed in disposing of it. The refuse can be burned or can be buried. A landfill operation requires one acre of land per year per 10,000 people, and costs about $1.00 per ton of refuse to accomplish it. Rats do not breed in landfills, rubbish does not catch fire in them, and odors are at a minimum. With the proper use of landfills, wastes can become an asset instead of a liability.

About 75 percent of the total refuse can be burned in a modern incinerator. Only from 5 percent to 15 percent of the original mass remains, and that in the form of inert ash. Principal disadvantages accompanying incineration are the high capital costs, expensive operation, and the production of air pollutants.

Sanitary landfill is the method to be preferred for refuse disposal by the average community, provided, of course, that sufficient fill area is available to meet present and future needs.

Rinehart, J.
"A City Dumps Its Dumpsite"
Public Works, 93:117, March 1962

Until 1962, Logansport, Indiana, had its refuse disposed of by open dump, open burning, and hog feeding. Because of the many health hazards associated with these methods, it decided to switch to sanitary landfill. A deal was made in which the city purchased a 50-acre landfill site in a hilly wasteland within a mile of the city limits. Jurisdiction over the operation of the site within the specifications of a contract with the city was left to the winning contractor. The interesting feature is that the new contract (collection plus disposal) is $29,000 per year less than it had been with the old objectionable method of disposal.

Booth, E. J.
"Buried 25 Years and Still Legible"
The American City, 80:26, July 1965

In the process of constructing a new highway near Bismarck, South Dakota, an old landfill area was cut through. Inspection of the exposed material showed that little decomposition of paper had occurred. The print was still legible. Metal items also were in good condition. There was little evidence of settlement, and no evidence of gas production or of rodents.

Anon.
"No Cover Material Needed For Converted Refuse"
The American City, 81:18, February 1966

The Bullingdon Rural District Council at Wheatley, Oxfordshire, England, recently installed a refuse conversion plant which separates the refuse into a peat-like product and rejects material such as tin cans, rags, plastics, and rubble. The product is used to cover rejects at the landfill. It has a density of approximately 2-1/2 cu yd per ton when discharged from the plant. Bacterial activity at the fill reduces the volume by about 20 percent. Settlement takes place evenly.

The plant consists of a 20-ft long by 8-ft diameter drum which rotates at 11.5 rpm. Water is added to the refuse until it acquires a moisture content of 40 percent. With the moisture content at this level, it is easy to breakup the fibrous material by the tumbling action. After 45 minutes of tumbling, the broken up material is screened and separated. The drum has a rating of 50 to 60 tons of refuse per day, and is operated by two men.

Anon.

Public Works, 97:151, February 1966

The article contains extracts from a model ordinance proposed by the New Jersey Department of Health covering the disposal of refuse by sanitary landfill.

University of California
"Survey of Sanitary Landfills from 1952-1966 (Parts A and B)"
University of California, Berkeley, Sanitary Engineering Research Laboratory
Solid Wastes Project, 1966

The survey presents a chart compiled by the task force of the Solid Wastes Project as a part of its literature search. The survey consists of two sections or parts. In Part A is listed the references (author, journal, etc.); and in Part B is given a summary of information under the headings: location, population served, daily cover, amount of land available, economic aspects, number of collections per week, disposal plant owners, special features.

Hockensmith, E. H.
"The Stream Pollution Problem at Sanitary Landfills"
University of California, Berkeley, Department of Sanitary Engineering Seminar
In Solid Wastes Disposal, CE 298, May 1966

A sanitary landfill can bring about a serious pollution of ground and surface water if it is improperly located, designed, or operated. A rational approach to the problems encountered in operating a fill indicates that a number of factors must be considered, including water table elevation, soil characteristics, geological formation, stream flows (both surface and underground), beneficial water uses, drainage patterns, material handling problems, and fire prevention problems. From the public health standpoint, bacterial contamination and chemical leachates are two of the most serious pollutants that could come from an improperly located, designed, or operated landfill.

An outline of problems to be expected and dealt with is presented along with some case histories of water contamination from landfills.

Armogida, S. A.
"San Mateo County--Solid Wastes Situation"
Private Communication, 1967

This folder contains six communications, personal and public, concerning the problem of waste disposal in San Mateo County, California, and particularly that coming from the acquisition of the Green Valley and Ox Mountain sites for landfill. The basic problem is the limited availability of landfill sites and the search for alternatives to landfill. A communication by S. A. Armogida states that the current rate of refuse production is 7 lb per capita per day, and that at 4 lb per capita per day 26 million tons of waste would have to be disposed of by the year 2000.

Hughes, G. M.
"Selection of Refuse Disposal Sites in Northeastern Illinois"
Environmental Geology Notes Published by the Illinois State Geological Survey, Urbana, Illinois, No. 17, September 1967

Geologic environments in northeastern Illinois were evaluated in terms of results of studies on refuse disposal and ground water contamination made elsewhere. The geologic environments commonly considered safe for refuse disposal in this area are those with materials of low permeability, and those that are relatively dry. A third type of environment, one which is hydrologically protective, also should be considered for disposal purposes.

Zemlansky, J.
"New Jersey Reviews Training Program and Long-Term Evaluation of Sanitary Landfill"
Refuse Removal Journal – Solid Wastes Management, 10:22, November 1967

New Jersey produces approximately 12,600 tons of household garbage per day and 7500 tons of industrial and commercial refuse. About 1000 tons per day are brought in from New York and Philadelphia. The area of the state is 8000 sq miles. At present, a survey of disposal facilities is being made by the state. At the time of this article information had been collected on landfills with respect to location, size, ownership, costs of collection and disposal, landfill potential, manpower, etc. The information includes facts concerned with the availability of cover, with drainage, composition, air pollution, odors, and other factors. A similar study on incinerators is in progress. A study also will be made on population change, developmental changes, changes in quantity and quality of solid wastes, rate and growth patterns, and recreational development.

Braun, Peter
"A Regional Refuse – Disposal Solution"
The American City, 82:96, December 1967

The township of Sparta, New Jersey, is starting a landfill capable of providing a long-term solution to solid waste problems of the surrounding region. It will provide for the needs of 17 of the 24 municipalities in Sussex county for a 25-year period. All 17 communities are within a 10-mile radius of Sparta. A study showed that the site could take care of a total annual population of 80,000 persons.

Gershowitz, H.
"Council to Present Model Landfill Contract"
Refuse Removal Journal – Solid Waste Management, 11:54, May 1968

The National Solid Wastes Management Association will soon present its model "sanitary landfill contract" and "model instructions" to bidders in the government's Solid Wastes Program.

In preparing the models, the aim was to prepare one whereby a city would be sure to get a true sanitary landfill if it contracted for one. One safeguard is a provision that the contractor shall have some degree of experience in landfills. A second requirement is that the bidder have adequate equipment. Landfills in operation should be subject to periodic inspection. No contract shall be awarded to any bidder who has an unsatisfactory record of performance. Certain specifications of performance are spelled out. Among them are a requirement that the cover be of loam, clay, sand, or other inert matter; that a minimum depth of 6 inches of compacted cover and final spread be kept on all inactive faces at all times; that the final cover be at least 24 inches deep and of compacted material; and that the maximum degree of slope on banks shall not exceed the ratio of four-to-one or two-to-one to be determined by the terrain of the site. All salvage operations are to be operated in a sanitary manner remote from the operating face of the fill.

INCINERATION

Design – General

Goodrich, W. F.
"The Economic Disposal of Town's Refuse"
London: P. S. King and Son, (New York: J. Wiley and Sons), 340 pp., 1901

The book is an interesting text on incineration, which also includes a revealing chapter on open dumps, and another on dumping at sea. It contains many bits of information which when taken together show that until within the last few years, the advance made in refuse management and technology has been far from spectacular. For instance the idea of generating steam with the waste heat from incinerators (called "destructors" at that time) was widely broached. The following are two quotations which illustrate the concern with steam generation and air pollution. "As late as 1888, it was only claimed that a low temperature cell dealing with about 5 tons of refuse per day could provide steam for 6 indicated horsepower as a maximum. With the forced draught cells, it is seen by reason of the greater quantity of refuse burned per cell and the higher temperature secured, as much as 30 indicated horsepower per hour could be obtained from one cell." "Mr. Charles Jones, M.I.C.E. of Ealing, who erected the first destructor in the vicinity of London in 1883, was the first to grapple to any extent with the trouble caused by the 'Jones Fume cremator.' The cremator was an independent furnace consisting of a reverberatory brick arch, with rings of firebricks placed in the direction of the gases traveling from the destructor cells. The gases were deflected to the red hot mass of fire beneath. The next step was to design the destructor (incinerator) such that high temperatures could be obtained at which the gases would be burned in it. This was done by applying a forced draught. Thus, the minimum temperature, 1250°F, claimed to be necessary for good burning, was readily attained."

In his discussion of tipping, Goodrich states: "Here again, the 'economic' triumphs over the demand for sanitary disposal ... Dr. Fraser's report where he says: 'The only argument in favour of tipping is its antiquity.'"

The book contains chapters on laws concerning refuse collection and disposal. It discusses the design of incinerators and the status of the practice. A section is devoted to a discussion of the state of refuse disposal in the U. S. "About 1200 tons of civic waste are now produced every day in Greater New York, which has a population of nearly four million." (0.1 lb/capita/day.) The Thackeray Incinerator (capacity 700 tons/day) built in San Francisco in 1897 is described.

The following are tables concerning wastes composition and production copied from the book. They are of value in studies concerned with trends in waste generation.

AVERAGE COMPOSITION OF ASHBIN REFUSE

Item	Percentage of Weight
Breeze and cinder	50.0
Paper, straw, fibrous material, and vegetable refuse	13.0
Coal	0.7
Bones and offal	0.6
Rags	0.4
Coke	0.3
Ash	12.0
Dust and dirt	20.0
Bottles 1%; tins 0.7%; metal 0.2%; crocker 0.6%; broken glass 0.5%; a total of	30.0

AVERAGE HEATING POWER OF COMBUSTIBLE REFUSE

Item	Calorific Values/lb of Combustibles (btu)	
	Dry	Moist
Coal	14,000	9,354
Coke	12,000	8,000
Bones and offal	8,000	5,334
Breeze and cinder	6,000	4,000
Rags	5,000	3,334
Paper, straw, fibrous material, and vegetable refuse	3,800	2,534

Authorities Component Parts	New York Craven % Weight	Total	London Maxwell % Weight	Total	Codrington % Weight	Total	Berlin Hering % Weight	Total	Boston O'Shea from 140,000 people
Coal	16.1		0.8		0.15		0.2		
Ash { Breeze cinder	12.1	80.5	3.7	84	28.8	81.6	2.6	53	} 75.6
Fine ash	52.3		19.5		52.6		50.2		
Garbage									
Vegetable and animal matter	12.2	12.2	4.6	4.6	14.2	14.2	32.5	32.5	20.5
Paper	5.46		4.28				4.26		
Rags					0.43		1.15		
Clothing, etc.	0.89		0.39						
Refuse									
Carpets	0.24								
Bottles	0.18		0.96		0.30				
Metals	0.15		0.21		0.37		0.20		
Tins	0.10		0.79				0.58		
Leather	0.13								
Rubber	0.01								
Barrels (whole)	0.10								
Bones			0.48		0.25		0.53		
Wood							0.40		
Glass	0.03		0.47				1.27		
Crockery			0.55		2.90		6.10		
Straw, fiber, etc.					2.90				
Other saleable material	0.04								
Totals	100	7.33	100	11.35	100	4.25	100	14.49	3.93 100

Hirsch, P.
"Incinerator Will Solve Many Refuse Problems"
Public Works, 88:119, April 1957

A new refuse incinerator was completed in Evanston, Illinois, in 1957. Its capacity is 180 tons per 24 hours; it has two furnaces, hydraulic stoker bars, and a large capacity to permit a low burning rate and low gas speed, as well as space for maximum fallout in the combustion and subsidence chambers. The subsidence chamber can be operated both wet and dry-bottomed. Fly ash is removed by a "vacuum cleaner" system. A centrifugal separator removes the collected ash. The chimney is 175 ft high and 8 ft in internal diameter. The cost was $745,000.

From a population of 75,000, Evanston collected 9,820 tons of mixed refuse and 101,886 cu yd of noncombustible refuse.

Meissner, H. G.
"A Simplified Method of Incinerator Design"
The American City, 72:135, September 1957

Paper, cartons, and crates are wood or wood products. The heat value of wood is known. Moisture content can also be determined. With this information, incinerator design can be based on heat transfer calculations. Furnace grates must be large enough to release heat at the rate of 20,000 btu per cu ft per hr. Furnace volumes must be great enough to release heat at the rate of 20,000 btu per cu ft per hr.

An example of the calculation of air and gas weight is given in the article. These are the bases for a size calculation. Total heat produced is used in calculating the amount of water needed for fly ash control.

Raisch, W.
"Innovations in Refuse-Incinerator Design"
Paper, ASME Annual Meeting (ASME Paper No. 57-A-220), New York, New York, December 1957

The 500-ton municipal refuse incinerator located in Oyster Bay, Long Island, New York, was designed by the author to direct all components to the central purpose of refuse incineration. This plant contains four furnaces of 125 tons per 24 hr capacity, each equipped with semi-automatic stokers. Semi-automatic operation is preferred to complete automation, because it enables the crew to regulate the rate of burning to keep the temperature within a predetermined range and to provide better control of the organic content of the ash. Optimum temperature for the plant is 1800°F to 2000°F at 200 percent excess air.

Ashes fall directly from the furnaces into an enclosed hydraulic sluiceway, and are carried by water to a large underground ash tank. Waste heat supplies steam for the generation of power for the incinerator and other township buildings at the same site, as well as for pumping water for the plant. Fly ash is removed in expansion chambers which have troughed water bottoms, a deflecting damper, a water-spray, and low pressure steam at the head end of the chambers. Radiant heat in a portion of the charging floor increases worker comfort. Dust in the storage pit is controlled by air inlet ports at the top of the pit. Fly ash in the stack-discharge averages 0.296 lb of particulate matter of 1-micron size and larger per 1,000 lb of flue gas discharged.

Anon.
"A Dust-Free Incinerator"
The American City, 73:*, January 1958

The location of the incinerator is in Oyster Bay, Long Island, New York. Its capacity is 500 tons per day.

Air Pollution Equipment: Fly ash is removed in two troughed-water-bottom expansion chambers equipped with a deflecting damper and a water-spray arrangement with low pressure steam at the head of the chamber. Fly ash in the stack-discharge averages 0.296 lb particulate matter of 1-micron size and larger per 1,000 lb of flue gas discharged.

The costs amount to $1,699,000 plus legal fees and administration.

Design Features: The storage-pit dust is intercepted by inlet ports along the top which draw air across the pit and carry away the dust. Radiant heating of part of the air charge is provided. The incinerator has a hydraulic ash collection and removal system. About 13,000 lb of 250 psi steam are produced each hour to generate 400 kw of electricity for the plant and other town buildings. Waste heat also is used in operating a 60 hp deep-well pump of 500 gpm capacity. The plant has four 125-ton furnaces equipped with semi-automatic stokers.

*Page number not shown on our copy.

Anon.
"Engineering Design of Refuse Incinerators"
U. S. Department of Health, Education, and Welfare, Manual for the National Park Service, June 1958

This manual is a guide for National Park Service personnel to assist them in preparing specifications and in designing refuse incinerators. However, it is useful for other agencies. Factors influencing the design of a refuse incinerator, including site selection, equipment, design, and operation, are discussed in Part I. Engineering design is discussed and examples of calculations are given in Part II of the manual.

Heaney, F. L.
"Choosing the Right Incinerator"
Civil Engineering, p. 651, September 1958

No one formula can be applied in determining which type of incinerator installation would be best for all communities. Each type must be investigated. Studies must be sufficiently thorough to determine the proper operating methods, to decide upon the best available site, and to decide upon the most satisfactory method of financing. Construction costs alone make it evident that the selection should not be made by amateurs. In this field, as in many others, careful planning is the first requisite to economy, efficiency, and a good installation.

Anon.
"Incinerator Design Criteria"
The American City, 73:36, December 1958

Samuel M. Clarke of Greeley and Hansen suggests that incinerators should be rated on tons of refuse per week instead of per day, since plants are shutdown weekly for cleaning, and therefore capacity depends on storage facilities as well as on rate of furnace operation. BTU's per pound of refuse varies from 2,500 to 6,000 depending on ash and moisture content.

Anon.
"Municipal Incinerator Design — A Survey of Engineering Practices"
U. S. Department of Health, Education, and Welfare, Public Health Service, 1959

The considerable variety in the construction and operational characteristics of municipal incinerators are indicative of a need for further research and development to assure more efficient design parameters. A definite trend toward further mechanization has been noted in the survey data. An apparent need exists for the more careful training of technical and other personnel concerned with municipal incineration. The problem of air pollution arising from incineration is gaining considerable recognition and demands additional investigation.

The results compiled in this survey are the responses to questionnaires sent to 230 cities in the U. S. Replies were received from 110 cities. It covers trends in construction, type of refuse incinerated, design data, and personnel and maintenance costs.

Taylor, M. G., Jr.
"You Don't Need a Tall Stack"
The American City, 75:74, December 1960

The location of the plant is in Winchester, Kentucky. Its capacity is 100 tons/day.

Air Pollution Equipment: Incinerator gases pass through a breaching into a chamber in which cooling is accomplished by water spray and dilution with excess air. The stack temperature of the gases is 350°F.

Design Features: The incinerator plant consists of two furnaces, which are ram-shaped and have neither storage pit nor crane. The design temperature of the primary combustion furnace is 1600°F, and that at the incinerator exit, 1200°F. The plant has a two-man staff, but apparently one man would suffice.

National Coal Association, Washington, D. C.
"Modern Dust Collection for Coal-Fired Industrial Heating and Power Plants"
Fuel Engineering Data, Section F-2, September 1961

This publication is intended as a general guide to dust collection equipment for managements considering installation of a new plant or modernization of an existing plant. It describes currently available types of equipment and their application to the several methods of burning coal. However, because of the

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empirical nature of dust collection technology, it is recommended that equipment selection for a specific installation should be made on the advice of an experienced consulting engineer and in accordance with the recommendations of equipment manufacturers.

Anon.
"New Incinerator Design Group"
The American City, 76:27, November 1961

A new ASME committee has been formed to study incinerator design and air pollution. The ASME team believes that an answer to air pollution from stack gases lies in the design of new plants which capitalize on a more thoroughly understood knowledge of the combustion process in an incinerator.

Nickelsprn, H. B.
"Factors in Incinerator Design"
Public Works, 93:123, March 1962

The density of refuse varies from 250 to 750 lb per cu yd – depending upon the amount of compaction. Computations and ratings for plant design should be based on weight, not volume.

According to the paper, there are four essentials to complete combustion:

1. Sufficient air to permit complete incineration – an insufficient amount of air results in high temperatures, which, in turn, reduce the life of the refractory.

2. Mixing air with refuse to start oxidation.

3. Sufficiently high temperature so that the refuse can be heated to its ignition point and ignition be sustained. Furnace temperatures range from 1200-1800°F, and should be kept around 1500°F.

4. Sufficient time to complete combustion. The time requirement can be reduced by providing sufficient furnace draft. The draft should be great enough to result in a negative pressure when the furnace door is opened (0.25-inch water column). The latter requirement is a function of safety in working conditions.

The following are the recommmended ratings in pounds of refuse burned per sq ft of grate surface per hour: Herringbone stationary grates (hand stoked), 40; inclined tilting grates (mechanically stoked), 60; round grates (mechanically stoked), 70. Traveling grates are rated on the basis of 300,000 btu per hour per sq ft. The normal heat release in furnaces operating under draft conditions is 20,000 to 35,000 btu per cu ft volume. An accepted figure of 25 cu ft per ton of rated capacity has been used for the combined volumes of furnace and combustion chamber. Most municipal refuse has a combustible content similar to that of cellulose ($C_6H_{10}O_5$). The theoretical air requirement is 5 lb air per lb of combustible material fired. In practice it is desirable and practical to provide 100 percent excess air. Moist garbage needs less air per lb.

In general, the greater the furnace height, the better the design. Sample design calculations are provided.

National Coal Association, Washington, D. C.
"Layout and Application of Overfire Jets for Smoke Control in Coal-Fired Furnaces"
Fuel Engineering Data, Section F-3, December 1962

This publication applies to the design, construction, and application of overfire jet systems to prevent smoke from hand and stoker-fired furnaces. It contains factors for determining the size, spacing and disposition of the tubes for introducing overfire air into furnaces, as well as recommendations for construction of overfire systems to obtain maximum effectiveness.

Fox, E. B., Jr.
"49 Municipalities Join in County-Wide Incineration Plan"
Public Works, 94:100, February 1963

Delaware County has 49 separate municipalities and a population of over half a million. Land area available for landfill is scarce. The output of refuse is 200,000 tons annually. The Delaware County Incinerator Authority was formed in 1954, and was absorbed by the Delaware County Commissioners in 1958. Three incinerator plants have been constructed. The first was completed in 1960. Operating costs are $2.26 per ton, and capital costs are $1.46 per ton (25 years at 3.2 percent interest). Descriptions of all three incinerators as given in the article include grate design, furnace construction, air supply, ash handling, and instrumentation. Sewage effluent is used for process water in incinerator Plant No. 2 in Darby Township. Incinerators No. 1 and No. 2 have fly ash chambers. The chamber has a dry bottom in No. 1, and a wet bottom in No. 2. Incinerator No. 3 also has a "wetscrub" fly ash eliminating system. It uses effluent from the Radnor-Haverford Sewage Plant.

Hayden, J. L.
"Incinerator Model Convinces Public"
Public Works, 95:94, July 1964

A 400 ton per day incinerator has been constructed in Lowell, Massachusetts. It is a pit and crane incinerator designed to operate in two shifts, five days per week. The capacity is predicted on the basis of a projected 100,000 population of Lowell by 1980. After weighing 500 trucks loaded with refuse, it was concluded that refuse is generated at the rate of 2.84 lb per capita per day. One-third of the refuse is collected privately, and the remaining two-thirds by city forces.

Design Specifications: The receiving pit is 26 ft wide, 81 ft long, and 26-1/2 ft deep. The incinerator bridge has a 4-ton capacity, and is equipped with a 2-1/2 cu yd bucket. The plant has two drying grates (8 ft by 20 ft), two burning grates (8 ft by 25 ft). The combustion chamber is designed to operate at 1800°F. The gases are cooled to 600°F in spray water chambers. Other specifications also are given in the article.

Costs: The total cost of land and construction was $1,500,000. The bid for construction was $1,238,676.

A scale model of the incinerator was used to improve public receptivity to the incinerator.

Easterline, J. D.
"Complete Combustion with Minimum Excess Air"
The American City, 80:99, February 1965

Scrubber wash water is being successfully recycled in the No. 1 incinerator of Broward County, Florida. Large amounts of quite moist yard trash are burned and a good residue is produced. The incinerator has a low stack particulate emission rate. The plant has two ram-fed furnaces, Detroit stokers built on a tandem design, charging hoppers that can be loaded by crane or truck, and stationary crane controls. The total capacity is 300 tons per day. In normal operations, the test value for particulate emission is 0.96 grain/cu ft. The construction cost was $1,309,000. A water seal controls underfire air. A second plant was built in 1964 at a cost of $1,194,000.

Gruenwald, A. and J. A. Reynolds
"Less Than $3,000 Per Ton"
The American City, 80:99, October 1965

By using a simple design, a 250 ton per day incinerator could be built in Ewing Township, New Jersey, for less than $3,000 per ton of capacity. A low air velocity in the combustion chamber allows a lazy flame, which according to the article would minimize air pollution. Operating costs have been about $2.50 per ton. The incinerator is operated only on one shift per day. Additional shifts and perhaps even an extra furnace will be added as the population increases from its present 32,000 to an ultimate of 55,000, and after industry moves in.

Apparent per capita refuse production is 5.2 to 6.1 lb per day.

Cerniglia, V. J. and A. Friedland
"Smile — Your Incinerator is on TV"
The American City, 81:110, April 1966

The addition of a second furnace in Oyster Bay, Long Island, New York, did not necessitate an increase in the work force, since the old incinerator was rehabilitated to include labor-saving devices. The most important of the additions was the installation of a closed circuit television. Two cameras monitor a view of the furnace, and two monitor the refuse storage bin through the charging floor of the incinerator. An independent compressed-air cooling system protects the cameras from the intense furnace heat. The use of television allows the operators to spot problems before they occur, i.e., large incombustible objects which may slip by the crane operator.

An Elliott self-cleaning strainer in the water recirculation pipeline reduces problems arising from the recovery and reuse of water used to quench the residue and control stack emissions. All equipment on the charging floor is dustless. There are intercom and alarm systems. A bay for the storage of nonburnable materials and a supply-receiving bay are located at one end of the bin. Demountable construction on the expansion chamber enclosures and on the rear portion of the plant, as well as similar constructions on the east end of the plant, make the future installation of new air pollution devices as well as future expansion relatively inexpensive.

Anon.
"$25-million Incinerator Will Be Britain's Largest"
Refuse Removal Journal, 10:16, 7 July 1967

The capacity is 700 truckloads per day, i.e., 2,880,000 tons per yr (1/5 London's output). The incinerator will handle domestic and commercial refuse. The article describes the design and operation of the plant. The plant will have a single horizontal gas-flow plate electrostatic precipitator. Its boiler incorporates a steam rising unit of the single-drum water-tube type with a partially water-cooled combustion chamber. The temperature of the flue gases will be reduced by a tangent tube-walled radiation shaft above the combustion chamber. The optimal route for collection vehicles was found to be 12 miles. Any route less than 8 miles long would be unprofitable.

Eggen, A. and O. A. Powell, Jr.
"Feasibility Study of a New Solid Waste System"
Division of Urban Science and Technology, School of Engineering, University of Hartford, Hartford, Connecticut, DUST/TR-6701, November 1967

The "best guess" system is composed of 3 separate subsystems: the auto shredder, the power production system, and the material production system. The auto shredders would be constructed according to existing technology, and would be operated by the existing scrap industry. The power production system essentially would consist of a shredded refuse burning gas turbine. The power production systems would be operated either by utilities or by large power users. Technology development would be required in 3 areas: the development of a high-pressure refuse "pump," of a high-intensity, high-temperature shredded refuse burner, and of a high-efficiency, low-pressure-loss separator.

The most attractive specific system at this time is based on a modified Pratt and Whitney Aircraft FT 4 gas turbine (i.e., existing burners replaced by gas collector and distribution manifolds); on combustion in a separate burner (separator) of a new concept, and on two Hammermills, Inc. 6060 shredders; the range in power generating costs would be from 0.4 to 3.3 mills/kw-hr.

Material production will include the manufacture of shredded scrap/ceramic composites. One-half of the scrap should be effective in carrying tensile loads. Estimates of the total costs of producing such materials are given, as well as the uses to which they can be applied.

Michaels, Abraham
"What Good Incineration Means. Part I - History"
The American City, 83:83, May 1968

This is the first of a three-part paper on incineration.

The first incinerator plant was built in 1885 for an army installation. Although a few plants were constructed during the next 15 years, the idea of using incineration in the disposal of municipal refuse did not gain any appreciable degree of acceptance. Even in the 20th century, the acceptance of incineration progressed quite slowly. Thus, in 1952, Bowerman and Ludwig (The American City, 67, March 1952) reported that of the 175 cities that had operated incinerators, over one-third (i.e., 60) had abandoned their plants.

Changes in American living habits which took place after World War II brought about the pressures needed to improve incinerator design to a level at which incineration could be practiced without placing an intolerable burden upon the environment. "Prior to 1950, the manufacturers actually designed most incinerator furnaces and their appurtenances to meet performance specifications loosely defined by the tonnage of the refuse to be handled. Invariably the incinerator manufacturer used an existing furnace configuration as the basis for design.... An architect or engineer would then design a structure to house the incinerator equipment."

Today's engineering contract generally contains a list of criteria designated by the municipality as being essential in the designing of the plant. Examples of the criteria are:

1. the quantity and characteristics of the waste to be burned;
2. the air pollution requirements of the plant;
3. the quality of the residue;
4. the type of manpower to be used for plant operations;
5. the plant site;
6. the money available for construction.

Determination of the heat value of refuse generally is based upon the assumption that combustible refuse generally is cellulosic in nature. However, since the percentage of plastic is increasing, its high heat value (up to 19,000 btu) should be considered in new designs.

Design — Special Applications

Popovich, M., M. Northcraft, R. W. Boubel, and G. E. Thornburgh
"Wood Waste Incineration"
Reprint No. 70, Engineering Experimental Station, Oregon State University, from Technical Report A61-3, R. A. Taft Sanitary Engineering Center, Public Health Service

A creditable job in consuming waste products with only a minimum discharge of smoke and cinders has been done by tepee burners in some installations. However, the great quantities of smoke and cinders produced in most operations cause hazardous visibility conditions for automobile and air travel, and create a nuisance and fire hazard to property owners in surrounding areas. Measurement methods and results on steel waste-wood incinerators are presented for exit gas temperature, exit gas analysis, exit gas velocity, burner draft at base, smoke density (visual), and cinder discharge.

Kaiser, E. R., J. Halitsky, M. B. Jacobs, and L. C. McCabe
"Modifications to Reduce Emissions from a Flue-Fed Incinerator"
Technical Report 552.2, College of Engineering, New York University, New York, 1959

The emissions of particulate matter, noxious gases, smoke, and odor from flue-fed apartment-building incinerators contribute to the air pollution of cities and are a nuisance in neighborhoods. Existing installations in three 16-story apartment buildings were modified, and major reductions in emissions were demonstrated. The modifications tested in 38 cases were overfire air jets to aid combustion by providing: turbulence in the furnace, a luminous-flame gas burner equipped with overfire jets in the incinerator chamber; for the passage of all gases through a nichrome wire screen at the entrance of the flue (Werner principle); a Hartmann device which includes a gas-fired stainless steel secondary combustion chamber in the incinerator furnace; a Peabody gas scrubber; and the locking of the service hoppers during combustion. Costs, evaluation tests, and descriptions of all modifications are presented. The article includes tables, illustrations, graphs, and references.

Kaiser, E. R., J. Halitsky, M. B. Jacobs, and L. C. McCabe
"Performance of a Flue-Fed Incinerator"
Air Pollution Control Association Journal, 9:85, February 1959

The flue-fed incinerator is a convenient means for the disposal and reduction of domestic rubbish and garbage in apartment buildings. A single flue and incinerator can serve an entire building. Approximately 11,000 flue-fed incinerators are in use in New York City. They consume an estimated 600,000 tons of refuse annually. The main disadvantage in their use is air pollution.

An investigation was made of a single apartment house incinerator. The apartment house was a 128-unit building housing 299 occupants. The daily refuse production amounted to 430 lb per day, i.e., an average of 1.44 lb per occupant. Had newspapers been added to the material to be burned, the incinerator charge per person per day would have been 1.7 lb.

The flue-fed incinerator reduced the apartment refuse to about 37 percent of its original weight and to 10 percent of its original volume. The bulk density of the refuse averaged 4.1 lb per cu ft in the incinerator. The residue had a bulk density of 15.4 lb per cu ft in the ash cans. The residue averaged 64 percent metal and glass over 1/4 inch in size, 12 percent ash, 16 percent combustible, and 8 percent moisture, excluding quench water.

The air supplied to the furnace was 10-20 times the theoretical requirement necessary for complete combustion. This resulted in a reduction of furnace temperatures. The peak furnace temperatures varied from 970-1200°F during the period of rapid burning. The average temperatures ranged from 668-463°F. These latter are lower than the temperature at which burning of organic compounds volatilized from the refuse is complete.

The emissions of particulate matter to the atmosphere via the flue gases ranged from 0.85 to 1.55 percent of the refuse weight. Emissions of eight noxious gases totaled 0.9 to 3.0 lb per 100 lb refuse.

Black, R. J. and L. B. Near
"Controlled Burning on Refuse Dumps"
California Vector Views, 6:55, September 1959

According to the article, there are three types of controlled burning dumps:

1. Single lift fill: This would be used where low level ground could be improved by filling. Roadways and bank with safety berm are constructed so that completed fill fits the contours of the surrounding land.

2. Trench fill: A trench is excavated in level ground. The excavated material is used for fill. Costs of excavation make it the most costly of the three methods.

3. Canyon site: Two shelves are cut along the side of a canyon. The upper level is used for burning. Ashes are bulldozed to the lower level for permanent landfill. The lower level limits the dumping area and facilitates salvage.

The operation must meet five requirements:

1. It must be sufficiently isolated.

2. It must provide a caretaker to supervise dumping and police the operation.

3. A clean, level roadway and safety berm must be provided.

4. A bank approximately 15 ft high with a 45° slope must be erected.

5. The dump face must be of a length suitable to permit a proper segregation of materials.

The refuse is segregated into five types of materials. The first class consists of household rubbish, mixed refuse, paper products, cans, bottles, toys, and similar materials. After metals are salvaged, the rest can be burned with the production of very little smoke. The second class of refuse is composed of stoves, refrigerators, washers, drums, beds, and other large items. These items are almost totally salvable.

In the third class belong tires, ground rubber, roofing paper, linoleum, other heavy smoke-producing materials, concrete, brick, and other rubble. Salvable items are removed and the remainder are buried.

The fourth class consists of lawn clippings, and brush and tree trimmings. These items must be thoroughly dried before being burned. Dirt and ashes make up the fifth class. By providing a separate storing area, these materials can be used for cover material.

Where local soil conditions are not suitable for sanitary landfill, or volumes of refuse are too small, the controlled burning method may be a satisfactory temporary solution.

Kaiser, E. R. and J. Tolciss
"Incineration of Automobile Bodies and Bulky Waste Materials"
Paper presented at the Annual Meeting of American Public Works Association, New York, New York, 17 August 1960, Technical Report 764.1, New York University, College of Engineering

A questionnaire survey of 24 municipalities over 400,000 population indicates the following practices in the disposal of large items of refuse.

The open burning of demolition lumber on building sites and dumps is still practiced in many large cities. Burial in sanitary landfills is also common, but shredding for burning in municipal incinerators is rarely practiced.

1. While some tree branches are incinerated, with or without shredding, tree trunks and stumps are sometimes burned at dumps, but usually are buried in sanitary landfills.

2. Open burning at dumps, and sanitary landfilling without burning are the general methods of disposal of mattresses, old furniture, crates, and other large combustibles.

3. Bulky metallic refuse not salvaged by junkers is usually buried in sanitary landfills.

4. Open burning is a recognized source of air pollution, but is practiced as an economy measure to extend the life of disposal areas, and to save on hauling costs by burning waste lumber at demolition sites.

The use of conical, steel, refuse burners for burning bulky wastes and miscellaneous refuse at landfill operations has been demonstrated. The investment is low and the use of such burners is a marked improvement over open burning. Air pollution is produced, but the use of gas scrubbers to minimize it appears to be economically feasible. Refractory furnaces for the smokeless burning of bulky wastes at landfill areas would consume such wastes economically without prior shredding. Fly ash emissions could be kept at acceptable limits by keeping the burning rate low.

The smokeless burning of automobile bodies for the salvage of steel in large conveyor-fed furnaces with either afterburners or electrostatic precipitators has been demonstrated as being possible. A smokeless, economical firebrick auto-body burner for capacities up to 30 bodies in 8 hours is being developed.

Kaiser, E. R.
"Unsolved Problems with Flue-Fed Incinerators"
Air Pollution Control Association, 11:254, May 1961

Incinerators in the basements of multi-story apartment buildings greatly simplify the problem of waste disposal by reducing the weight of refuse to 35 percent of its original and volume to 10 percent. One operator can tend 10 incinerators in a group of as many buildings housing a total of 3,000 persons. Since the incinerator chimney or flue also serves as the refuse chute, residents can deposit refuse into the charging hoppers at any time convenient to them. Gravity transports the refuse to the incinerator.

The typical single-chamber incinerator furnace receives refuse from a flue that extends above one rear corner of the furnace roof. The refuse accumulates in a sloping pile whose top often reaches the flue. When this happens, the furnace capacity is not properly utilized. In installing new units, it is recommended that the flue be centrally located. Since the refuse can roll away in all directions from the apex of the pile, the furnace would thereby be more fully utilized, and the clearance between the apex and the flue would be increased. In computing furnace size, it is advisable to allow for 1 lb or 0.25 cu ft of refuse per occupant between late afternoon and early the following morning.

"Gassing-out" at the hopper is manifested by smudging on the walls above the hoppers, by burnt odors, and as discomfort while charging refuse. "Gassing-out" may be caused by the plugging of the spark arrestor with paper carried up by the flue gases, resistance to the flow of flue gas by roof settling chambers, and by negative pressures due to exhaust fans within the building, as well as to leakage from the hoppers of double-flue incinerators.

A by-pass flue allows the use of a multiple-chamber incinerator with a single flue. Air from below helps burn refuse having a high percentage of noncombustibles.

Various techniques of which our knowledge is increasing are concerned with hopper locking, auxiliary gas firing, overfire air jets, and the use of flue-gas scrubbers.

The amount of particulate matter trapped in the chambers beyond the bridge-wall of the multiple chamber incinerator is significant but probably low in proportion to the total solids carried by the gases. A paper trap protects the spark arrestor. Commercial scrubbers are efficient, but the exhausting of gas is a problem in a basement installation due to cooling and condensation of moisture onto a flue that is at building temperature.

McAskill, J. D.
"A Residential Incineration Program"
The American City, 76:*, June 1961

To cut garbage collection and disposal costs, automatic gas incinerators were installed in the residences of five new subdivisions of Saskatchewan, Canada at a cost of about $110 per installation. Homes having the incinerators have a noncombustible garbage pickup on a four-week basis. Those not using the home incinerators have a weekly service. The citizens generally accepted the new system. The average cost for gas consumption per month ranged from $0.86 to $1.10 with an average of $1.06 in Regina, and an average of $1.04 in Yorktown.

*Page number not given.

Kaiser, E. R. and J. Tolciss
"Smokeless Burning of Automobile Bodies"
Technical Report 764.2, College of Engineering, New York University, New York, June 1961

Burning is a practical way of cleaning auto steel, and is necessary in the production of the grade desired for remelting. An economical furnace for doing the job without causing air pollution has been sought by both auto wreckers and air pollution control officials.

Designs and tests are presented for a furnace which can burn two car bodies at a time and up to 28 bodies per day. Air pollution is controlled by an oil-fueled afterburner. Projected cost of the recommended design is from $16,825 to $22,050 depending on local conditions. Based on a throughput of 6,048 bodies a year, the total cost for burning will be close to $3.76 per body, or $6.83 per ton of steel over the cost of open burning.

Mortenson, E. W.
"Description of a Two-Compartment Trench System of Refuse Disposal"
California Vector Views, 9:21, April 1962

When a sanitary landfill is not practical and when only small amounts of refuse are collected, burning is not objectionable in a two-compartment trench system. A trench 300 to 400 ft long, 4 to 8 ft deep, and 15 to 20 ft wide is divided into a receiving pit and a storing section. All of the refuse is placed in the receiving pit and is burned periodically. A bulldozer pushes the residues and noncombustibles into the storage area where it is compacted and covered. By means of this system the amount of exposed refuse is reduced to a minimum, and makes possible a rapid and complete burning of combustibles.

Anon.
"Covered Plant to Burn Sludge"
The American City, 77:8, September 1962

Lynwood, Washington, will be the first community to have installed the Dorr-Oliver FS Sludge Disposal System. The plant is part of a $1,892,000 project which includes construction of sewers and pump stations. The FS unit is capable of disposing of the entire output of a plant intended to serve a population of 60,000 in 1975. The FS system burns the sludge to a fine ash in a closed system with which is eliminated nuisances, air and water pollution accompanying the burning of sludge.

Calaceto, R. R.
"Sludge Incinerator Controlled by Cyclonic Scrubber"
Public Works, 94:113, February 1963

Detroit disposes of its sewage in four multiple-hearth furnaces, each capable of handling 12 to 16 tons of material per hour. Fly ash is controlled by a cyclonic scrubber. Gases discharging from the upper end of the furnace proceed throught a brick-lined breeching section and down through a precooler to the inlet of the cyclonic jet scrubber. Gases are reduced to the saturation temperature in the precooler by applying approximately 125 gpm of spray water at 100 psig. In the cyclonic jet scrubber an additional 240 gpm at 100 psig is employed. Fly ash collection efficiency during tests was 95.9 percent. The scrubber reduced the average grain loadings of 3.5 per cu ft (approximately 1,800 lb per hr) to 0.145 grain. The requirements of the city of Detroit that fly ash discharge should not exceed 0.3 grain per cu ft (adjusted to 50 percent excess air and 500°F) are met. Emissions now are reduced to steam tailing from the short stub stack. The tailings persist for possibly 30 ft in warm weather and possibly 100 to 200 ft in the winter prior to complete disappearance. No characteristic tan-colored separation exists after steam separation.

Simplicity of design resulted in a maintenance-free operation for three years.

Peskin, L. C.
"The Development of Open-Pit Incinerators for Solid Waste Disposal"
Paper - 59th Annual Meeting of the Air Pollution Control Association, San Francisco, California, June 1966

The open-pit incinerator was originally developed at duPont for the safe destruction of chemical wastes which present an explosive hazard in a conventional type of closed incinerator. The incinerator described has an open top and an array of closely spaced nozzles which admit a screen of high velocity air over the burning zone. Very high burning rates, long residual times leading to complete combustion, and high flame temperatures are achieved. Visible smoke is readily eliminated and fly ash can be contained by suitable screening. It is estimated by Elmer Monroe, Senior Consultant for duPont, that for specific industrial materials emissions of less than 0.25 grain of dust per cu ft have been achieved. Oversized wastes and plastics, which generate problems in the conventional incinerator, are readily destroyed in the open-pit incinerator. Both installation and maintenance costs are low.

The Thermal Research and Enginering Corporation is undertaking to build open-pit incinerators. The design for a municipal plant to be constructed in Canada is presented.

Meland, B. R. and R. W. Boubel
"A Study of Field Burning Under Varying Environmental Conditions"
Paper - 59th Annual Meeting, Air Pollution Control Association, San Francisco, California, June 1966

A field study on grass field burning was conducted in the Willamette Valley of Oregon during the summer of 1965. Approximately 230,000 acres of grass fields are burned in the valley during August and September, resulting in serious air pollution problems. The relationship between certain variables were computed both by computing a matrix of correlation coefficients and by stepwise linear regressions. The independent environmental variables were from time of harvest to time of burning, time of day, air temperature, relative humidity, soil and straw moisture, wind speed and direction, and fuel density. Dependent variables which were measured were particulate emission and size distribution, combustion temperature, burn rate, amount of ash, percent of organics in the particulates, and smoke appearance. Suspended particulates correlated significantly with percent organics in common (annual) ryegrass. Other variables did not correlate significantly.

Operation and Performance

University of California, Berkeley
"Municipal Incineration — A Study of the Factors Involved in Municipal Refuse Disposal by Incineration"
Technical Bulletin 5, I.E.R. Series 37, Sanitary Engineering Research Project, October 1951

Incineration should be considered as an intermediate step in the disposal process inasmuch as there remains an ash residue to be buried and large volumes of gases to be dispersed into the atmosphere. Also, it is not economically competitive for disposing of municipal refuse when short-haul, semi-isolated land areas are available for extended landfill operations. Hence, incineration usually finds application in large cities or in small towns which are a part of a highly-urbanized metropolitan area.

Designing municipal incinerators for continuous 24-hour operation and adequate refuse storage is essential for proper and economical performance. Whenever possible incinerators should be located with the following criteria in mind:

a. Centrally located for economic haul,

b. Adjacent to an industrial area for an outlet of salvable products and waste heat,

c. Minimum nuisance from vehicles, noise, ash, odor, etc.,

d. Land at reasonable cost,

e. Two-level topography for minimum construction cost,

f. Ash disposal within economic haul,

g. Satisfactory meteorological environment,

h. Compliance with regulations, e.g., zoning laws, air and water pollution control laws, etc.

A municipal incinerator is an expensive facility which requires constant technical supervision to maintain optimum performance. Improper supervision will result in unnecessary and excessive costs for operation and repair.

University of California, Berkeley
"Municipal Incineration — A Field Study of Performance of Three Municipal Incinerators"
Technical Bulletin 6, I.E.R. Series 37, Sanitary Engineering Research Project, November 1951

In 1950, tests were made on three California incinerators — Signal Hill, Beverly Hills, and Pasadena. The purpose of the study was to develop methods for obtaining performance data on municipal incinerators, to examine existing criteria, and to suggest new criteria for interpreting performance data on municipal incinerators. Fuel value of refuse, moisture, and excess air, temperature, gas analysis, heat and mass balances, and stack discharges were studied. Also of concern were utilization of waste heat, auxiliary fuels, stack discharges, and operation of incinerators. Measuring techniques and actual performance of each incinerator are discussed.

Anon.
"Bridgeport Incinerator Utilizes Sewage Plant Effluent"
The American City, 74:82, January 1959

The Bostwick Avenue Incineration Plant in Bridgeport, Conneticut, has operated on an average of 90 percent capacity five days per week since its opening in 1958. No bad effects from a 29 percent overload were noted, even though it was designed to handle only a 25 percent overload. The rated capacity of the incinerator is 300 tons.

The plant uses effluent from a sewage treatment plant for residue quenching, fly ash control, and other plant uses not requiring potable water. It has two 150-ton furnaces, each with 150 sq ft of grate area. Operating temperatures are between 1400°F and 1800°F.

Total cost, including roads, paving, fencing, but excluding engineering and legal fees, came to $1,170,000.

Anon.
"400 Tons Per 8-Hour Shift"
The American City, 74:98, October 1959

Glasgow's new refuse incinerator, the largest in Great Britain, serves a city of over 1,000,000 inhabitants with its 400-ton per 8-hour shift capacity. The plant is divided into four independent sections, each having a capacity of 100 tons per 8-hour shift. Trucks enter the second floor, are weighed, and then dump the refuse into hoppers. The refuse proceeds to primary rotation screens to separate out screenings under 1-1/2 inches in size. Salvageable materials are separated on sorting belts. Baling equipment prepares tin cans and other scrap metal, paper, and textiles for salvage. The remainder, called tailings, are fed into incinerators. Mechanical suction units prevent the dissemination of dust at the reception hoppers. The furnaces each have five hydraulic grates. Air pollution is controlled by grit collectors, incorporating an induced draft fan, centrifugal, primary, and secondary collectors, and grit settling tanks.

The two chimneys are 220 feet high.

The cost was $5 million.

Weber, C. C.
"Incinerator Inspection: What to Look For"
Public Works, 98:133, May 1967

General rules of thumb are given devising a program of incinerator inspection. The inspection should include a determination of compliance with regulations, an investigation of complaints, a gathering of information, a determination of the extent of the compliance of the construction with approved plans, a plant efficiency estimate, suggestions for improving the operation, and a determination of the need for plant modification or equipment replacement.

Heat Recovery (Steam, Power, etc.)

Anon.
"The Swiss Don't Miss Incinerator Thrift"
The American City, 75:32, February 1960

Recently in Berne, Switzerland, an incinerator was constructed which converts its waste heat into steam for use by two factories and a 1,200-bed general hospital, a 120-bed children's hospital, a dental institute, and a school. The plant burns 30,000 tons of refuse per year, and from this produces 30,000 tons of steam, resulting in an annual coal savings of 5,000 tons. Annual operating costs are 650,000 Swiss francs, wages are 360,000 francs, and income, mainly from the sale of heat, is about 560,000 francs.

Flaherty, J. F.
"Boston's Incinerator is a Steam Producer"
The American City, 75:104, June 1960

Boston's new 900-ton incinerator serves 360,000 persons, or about 1/3 its area and 1/2 its population. Waste heat generates steam for the Boston City Hospital, thereby reducing the city's fuel and power bill by $115,000 annually. The plant has six 150-ton furnaces equipped with mechanical stoking grates. The three boilers generate 75,000 lb of steam per hour at 250 psi gauge. The chinmey is 175-ft high by 10-1/2-ft inside diameter. Fly ash is controlled by six cyclone fly ash arrestors plus a spray cooling system to cool the gases when the waste heat boilers are not in use.

The total cost was $5,500,000. The estimated operating cost, including amortization, maintenance, and deducting income, is $783,000 per year. Cost of disposal under previous methods plus the cost of operating the hospital steam-generating plant was $784,000 per year.

Gerhardt, P., Jr.
"Incinerator to Utilize Waste Heat for Steam Generation"
Public Works, 94:100, May 1963

An incinerator having a capacity of 1200 tons per day was designed for Chicago, Illinois. Its air pollution equipment includes a wet bottom in the combustion, subsidence, spray, and drying chambers. Water sprays are used. The plant is designed to generate steam (50,000 lb per hour) at 225 psi. Steam sales should bring from $125,000 to $150,000 annually.

Shequine, E. R.
"Steam Generation From Incineration"
Public Works, 95:92, August 1964

The installation of a boiler in an incinerator plant not only provides energy at a comparatively low fuel cost, but also simplifies problems of air pollution control by automatically cooling the products of combustion so that a standard commercial dust collector may be used. A continuous feed process results in far greater efficiency than a batch feeding process. It is believed that 450 psi and 725°F are respectively the maximum pressure and temperature which should be considered for the fuel under discussion.

Industrial plants often need steam, and they generate refuse which must be disposed of. In the past, most municipal incinerators have been located in areas where there was little possibility of using steam. It is believed that in the future more incinerating plants will be located so that the steam-generating potential may be utilized, as this potential becomes more familiar.

Anon.
"Swiss Engineers Explain Incinerator Income"
Newsletter, Sanitary Engineering Division, American Society of Civil Engineers, p. 5, July 1966

In Switzerland, as well as in the greater part of Europe, water walls and boilers are employed in incinerators to transform combustion chamber heat to steam. The steam thus generated, is supplied to nearby industry, which pays for the steam at a cost comparable to that from other sources of heat and power. Officials deliberately choose the sites for incinerators with respect to the proximity of industry, so that a market for the steam will be assured.

The water walls were previously placed above the combustion chambers. However, experience has shown that the best results come from placing the water around the chambers, nearer the source of heat. Electrostatic precipitators are commonly used in Europe, despite the dearth of air pollution laws. Although expensive, the precipitators remove over 90 percent of the particulate matter, a far greater removal than can be encountered in any operation in the United States.

Ten Swiss engineers, visiting the U. S. to study refuse disposal and water pollution control, explained the European system at a conference in New York City.

Anon.
"Navy to Incinerate Rubbish for Power"
Refuse Removal Journal, Solid Wastes Management, 10:19, April 1967

The Navy will build at Norfolk, Virginia, the first steam generating, water-walled incinerator to be built in this hemisphere. The cost will be 2.2 million dollars. The incinerator will have a capacity of 180 tons municipal refuse. The hope is to save $47,000 annually in terms of steam. A reciprocating grate stoker will be installed. About 50,000 lb of steam will be produced per hour at 275 psig. In a year's time, the amount of steam produced at this rate would be equal to that generated through the burning of 5,000,000 gallons of fuel oil. The flue gas will be cooled to 600°F before being passed into a cyclone dust collector for removal of fly ash. An electrostatic precipitator also will be used.

Pertinent facts are as follows:

1. The heat value of refuse is 5000 btu per lb.

2. The heat value of 2-1/4 lb of refuse equals that of one pound of coal.

3. The cost of constructing incinerators for power production has increased from $10,000 to about $13,000 per ton capacity in the U. S.

4. From 85 to 100 lb of refuse can be handled per sq ft of grate surface per hour.

5. Forty-five percent of the latent heat of refuse is needed to support burning process, 10 percent lost through equipment, and 45 percent out of the stack.

6. The burning of one pound of refuse can produce 1.8 lb of steam.

Among the installations are the following:

1. Atlanta sells steam generated as part of incineration at $140,000 per year. Proceeds from the sale paid for the incinerator in 12 years.

2. In three years' time, 150,000 lb of steam per hour were produced by the plant at Oceanside, Long Island, New York. Heat generated by the plant is used in the distillation of the sea water to produce the water it uses in its operation.

3. In the Issy-les-Moulineaux (Paris) plant, 450,000 tons of refuse are burned in the production of 90 million kw-hr electricity. Similar plants are located in Dusseldorf, Munich, Frankfurt, and Hamburg in Germany. A 9.4-million dollar incinerator which is equipped to provide 300 kw from 2,205 lb refuse has been built in Switzerland.

Anon.
"Combustible Rubbish Contents Favors Using Heat Recovery"
Refuse Removal Journal, Solid Wastes Management, 10:32, November 1967

According to A. Rogus, American refuse has 3500 to 5000 btu per lb. If burned, this could yield 1.4 lb steam — enough to generate 0.10 kw-hr of electricity. (Coal has 13,500 btu per lb, and oil, 18,000.) The incorporation of steam and electric generators would increase the capital cost of an incinerator plant by 25 percent, or from $10,000 per ton capacity to $12,500 per ton. In New York, a 25 percent to 40 percent saving could result in incineration cost through the sale of electricity. Rogus criticizes the practice of dumping furniture, mattresses, construction lumber, and other such bulky items in landfills.

Anon.
"Incinerator Uses Trash as Fuel in Rotterdam"
Refuse Removal Journal, Solid Wastes Management, 10:6, November 1967

In 1966, an incinerator built in Rotterdam produced 80 million kw-hr, of which 8 percent was used in the operation of the plant. Revenue from the sale of the power did not meet the cost of producing it. (The population of Rotterdam is 750,000.) The cost of burning the refuse was about $3.33 per ton. The construction cost was about 10 million dollars. In 1966, 275,000 tons of refuse were burned at a total overhead of about $840,000. Other income came from the salvage of tin cans and metal – about $5.00 per ton. Clinkers were sold for use in road building, land reclamation, and other purposes.

Design: The incinerator has four furnaces arranged in two symmetrical pairs. On the yearly average, three furnaces run for 126 hours per week. It has an electrostatic precipitator (98.6 percent cleaning efficiency), and a 300-ft chimney. Other details also are given in the report.

Manpower: Fifteen men per shift are required. The men work from 7:15 a.m. to 5:00 p.m., 5 days per week. An additional incinerator is under construction.

Anon.
"Three Contractor Owned and Operated Incinerators Service Metropolitan Chicago"
Refuse Removal Journal, Solid Wastes Management, 11:12, May 1968

Facility 1 – Incinerator, Inc.: Incinerator, Inc. was the first contractor-owned plant in the U. S. It was founded in 1958 by 52 private haulers. After the plant had been in operation for about 2 years it was adapted to incorporate a steam-generating system. The original projected costs of the conversion and steam production proved to be too low. For example, the original projections called for the use of $25,000 worth of fuel after the first year; the actual cost was $135,000. The main problem with the steam project was the dirty quality of the refuse fuel. Fly ash coated the tubes and prevented the uniform conduction of heat through them. It cost over 1.25 million dollars to install a boiler as contrasted to the $600,000 originally projected. To date over $200,000 has been lost. Steam-producing facilities have been in operation since 1963. Since the last negotiation of the power contract, the plant is beginning to run in the black. Maintenance of the entire facility is from $150,000 to $200,000 per year. Daily processing amounts to 500 tons per day. In 1967, it handled 155,000 tons on a 7-day-a-week, 24-hour per day basis.

The company also has a contract for the sale of the tin cans collected – $10.50 per ton. Metal containers are separated from the general refuse automatically by a rotary screen which has one-inch holes. The collected metal goes to the end of the drum, where it is shredded and then automatically conveyed to boxcars.

The plant is staffed 16 hours per day by four employees.

Plastics present a problem. Some are fireproof, while others melt and congeal around pumps or in the sewers.

The plant uses a sizeable amount of water per day. In dry months, the water bill may be as high as $7,000. The plant has a contract to supply one million pounds of steam per day.

Facility 2 – Vandermolen Disposal Company: The facility is a 450-ton per day plant, currently being expanded to accommodate another 250-tons per day. Bulky materials are incinerated along with other refuse with no apparent malfunctioning. At the incineration process, tin cans are salvaged by a magnet. About 75 cu yd of compacted tin containers are removed daily, as well as 100 cu yd of burned sheet steel.

The facility is run 7 days per week, 24 hours per day. The staff consists of 16 employees, scheduled on 4-man shifts. Residue is used as "night" landfill cover (i.e., the initial 6-in. seal on a deposit area).

Facility 3 — Land Filling and Improvement Company: This facility began operation in 1959. The incinerator is a 250-ton per day plant. It operates on the counter flow method. Hot gases and fires are driven over the incoming refuse to predry and preignite it. The plant processes residential, commercial, and industrial wastes.

Air Pollution and Control

Anon.
"0.72 cu ft of Fly Ash Per Ton of Refuse Burned"
The American City, 73:36, December 1958

An incinerator having a capacity of 500 tons per day has been built in Cincinnati, Ohio. For air pollution equipment it has an expansion chamber and a baffle of "Thinsulite" construction. Approximately 0.72 cu ft of fly ash per ton of refuse is burned.

Anon.
"Incinerator Will Have Short Stack, Dust Collector"
The American City, 74:40, March 1959

In Belmont, Massachusetts, an incinerator was built and was equipped with a 144-tube Hagan aerostatic centrifugal mechanical collector for air pollution prevention. About 95 percent of the fly ash is removed. The stack is only 20 ft in height.

Powell, Thomas
"Air Pollution and Incineration"
Compost Science, 1(No. 3):35, Autumn 1960

Air pollution has become an urgent problem in metropolitan areas and inefficient incinerators contribute greatly to this problem. The present trend in waste disposal is toward burning because of the disadvantages found in other methods of waste disposal. Smoke, dust, and gases may be discharged by incinerators. Contamination of air in the U. S. is estimated to cost from $1.15 billion to $4 billion per year. Air pollution also causes damage to health and sometimes results in death. (Editor's note: Only a small fraction of this pollution comes from incinerators.) Since 1950, more than 20 states have adopted or strengthened air pollution legislation. Some cities, notably Detroit and Los Angeles, include incinerator control measures in their codes. The Air Pollution Control Association is establishing minimum requirements for the design and operation of all major types of incinerators.

Composting probably will gain more widespread use in the future as more and more people realize two important facts — valuable organic matter soon must be returned to the soil to preserve our resources, and incinerators can be a cause of danger to health.

Edlin, M.
"A Refuse-Sewage Treatment Works"
The American City, 75:89, August 1960

An incinerator constructed in New Albany, Indiana, has a stack which is 175 ft high, 7-1/2 ft in internal diameter, and is equipped with stack sprays. The plant is a combination sewage disposal plant and mixed-refuse incinerator. Waste heat is used to flash-dry the sludge. The sludge is incinerated at times.

Anon.
"Incinerator Fly-Ash Meter Under Development"
The American City, 80:21, April 1965

The Illinois Institute of Technology Research Institute is developing a monitoring device to measure particulate matter in incinerator stack gases. The instrument consists of an isokinetic sampler, a cyclone, and interlocking flow system, and a tape recorder.

Johnson, H. C., J. D. Coons, and D. M. Keagy
"Can Municipal Incinerators Meet Tomorrow's Regulations?"
Paper - Annual Meeting, Air Pollution Control Association, San Francisco, 1966

The starting assumption is that the Los Angeles and the San Francisco Bay Area regulations are the most stringent in the United States. A table of emission allowances in Los Angeles and the Bay Area is given:

EMISSION ALLOWANCES IN LOS ANGELES AND THE BAY AREA

	Los Angeles	Bay Area
1. Particulate	0.3 grain/SCF*	0.2 grain/SDCF
2. Visible Plume		
(a) Ringelman	< #2	< #2
(b) Opacity	< 40%	< #2 eq.
3. Organic Compounds	None	< 50 ppm C_2 - C_6*
		< 50 ppm carbonyls*
4. Oxides of Nitrogen	None '66	None '66

*Subject to certain correction factors.

Notes:

1. Differences in test methods and correction factors bring the particulate allowances closer than is indicated by the table.

2. Los Angeles design standards and permit requirements would lead to organic compound emissions lower than those in the Bay Area allowances.

Except those on the West Coast, only a few incinerators can meet the grain loading and opacity requirements given in this table. (Editor's note: There are no functioning incinerators on the West Coast at this time.) Incinerators which continuously maintain temperatures above 1400 to 1500°F and provide adequate turbulence and residence time can meet the requirements regarding dark smoke and organic materials. Control of plume opacity caused by the presence of submicron particles of condensed metallic salts and oxides is the most difficult problem. Adequate control presently is expensive and needs further development. There are no existing standards for NO_x. More stringent requirements pertaining to organic compounds than those stipulated in San Francisco will be needed in an increasing number of areas. The requisite technology already is available. Factors needing attention and evaluation are particulate grainloading, visible plume, and NO_x control.

Anon.
"Burn Away the Odors"
Public Works, 97:84, March 1966

Fume incineration, a new approach to sewage treatment plant odor control, has been incorporated in the design of San Diego's new Point Loma plant. Odor problems are abnormal, primarily because of sulfides generated at an outfall drop structure where a 15-ft drop occurs over a 120-ft weir. The estimated concentrations of H_2S in trapped air at the various sources are up to 200 ppm. The gases are collected at the points of generation and piped to the incinerator.

d'Anjou, R.
"Opportunities in Reducing the Volume of Flue Gas to be Cleaned from Large Incinerators"
University of California, Berkeley, Course CE 298, May 1966

The generation of steam in boilers fired by municipal refuse indirectly improves the prospects for reduced air pollution. Less flue gas is produced which in turn permits economies in gas cleaning. These economies will become especially important as the demands for high efficiencies in dust collection become more insistent. Further improvement in this direction will come when equipment is developed with which refuse can be burned with excess air of about 50 percent.

U. S. Department of Health, Education, and Welfare
"Air Pollution Aspects of Tepee Burners Used for Disposal of Municipal Refuse"
Public Health Service Publication No. 999-AP-28, September 1966

This report covers an evaluation study of air pollution emissions based upon an extensive literature search and on field trips to 15 tepee burners in six states. Smoke as a function of composition and rate of charge was observed, and the effect of burner charging methods, construction, and operational procedures on smoke emissions was recorded.

None of the tepee incinerators observed in operation meet the normal visible emission limitations of air pollution control ordinances of most municipalities. Nuisance problems from fly ash fallout can be expected within distances of up to 1,290 feet downwind from an operating tepee. Based upon the results of the study, the Public Health Service does not consider the use of tepee refuse burners as a suitable method for the disposal of municipal refuse.

Wegman, L. S.
"The Cleanest Incinerator Stack Gases of any Incinerator in the Nation was Mandatory in this Unusual Incinerator Installation"
The American City, 82:89, May 1967

In the article is discussed the design of an incinerator to be located near a high-standard residential area on Long Island in New York. The plant will contain 3 furnaces, each having a capacity of 200 tons per 24 hours. Twelve trucks will be accommodated simultaneously. The flow diagram of the operation will be as follows: refuse → furnace → residue of little or no combustible material and gases → settling and expansion chamber → spray chamber → air-cooling chamber → cyclones → induced draft fan → large flue → 265 ft stack. Furnace controls include an under-grate air control, a furnace temperature control, and a furnace draft control. Air pollution controls are a research-cottrell cyclone collector control, a gas temperature control by spray water cooling, and an additional gas temperature control by air cooling.

The use of silicon-carbide and air-cooled walls in the furnace will reduce slagging and extend the life of the furnace. To date stack effluent should be within present and anticipated air pollution control standards.

McLean, N.
"Gas Cleaning Equipment"
Public Cleansing, 58:167, April 1968

The majority of gas cleaning equipment (air pollution control) installations fall into one of the following categories: inertial separators, impingement separators, and electro-precipitators. The inertial separators can be subdivided into settling chambers and mechanical collectors; and the impingement separators, into gas scrubbers and fabric filters.

The simplest method of controlling pollution is the gravity settling chamber. It is essentially a large chamber between the source of ash and the stack. It is designed to reduce gas velocity and allow the settling out of some of the suspended solids. The chamber may be equipped with baffles, and these baffles may be wetted. The dimensions generally are large, and the application of the chambers generally is limited to particles larger than 100 microns. Efficiencies in fine dust removal generally are less than 50 percent, and may be as low as 10 percent.

Mechanical collectors are those in which removal of dust and grit is brought about by utilizing forces resulting from changes in the direction of the gas flow. The separating force usually employed is the centrifugal force when the gases are made to spin in a vortical motion (cyclone collectors). Cyclones are not generally considered economical for particles below about 5 microns.

The principle involved in the design of impingement separators is that when dust-laden gas impinges on a solid or liquid body, the gas will be deflected around the body. The dust particles, due to a greater inertia, tend to collide with the body surface and be subjected to a retaining force. Examples are self-induced spray scrubbers, tower scrubbers, venturi scrubbers, fabric filters, and gravel bed filters.

Gas scrubbers operate at relatively high efficiencies ranging from 80 percent for the self-induced spray scrubber with a pressure drop of 4 to 6 in. w.g. to over 99 percent for the venturi scrubber, which requires a pressure drop of some 40 to 50 in. w.g.

The gravel bed filter works in continuous operation at temperatures up to 600°F and at efficiencies in excess of 99 percent. These filter beds consist of one or more layers of abrasion resistant material, such as gravel through which the dusty gas is passed. The dust caught in the filter bed is removed by a vibrating screen.

In an electro-precipitator, the dust-laden gas is passed between curtains of earthed collecting plates and a series of high voltage discharge or ionizing wires. Electro-precipitators can be designed for any volume, have low maintenance costs, and the draft loss usually is less than 0.5 in. w.g. Gases normally must have a temperature lower than 600°F, and must be humidified before entering the chamber. The velocity of the gas must be reduced to 3 to 5 ft per second and distribution must be uniform. Thus space requirements are high. Collecting efficiencies are in the range of 95 to 99.7 percent. The collection efficiency can be expressed by the following empirical formula:

$$\text{Overall Efficiency} = (1-e^{-wA/V}) \times 100(\%)$$

in which e is the Naperian Logarithm base; A, the surface area of collecting electrodes; V, the gas volume; and w, the effective particle migration velocity.

Economics (Costs – Capital and Operating)

Waldschmidt, M.
"Incinerator Solves Burnable Waste Problem"
Public Works, 88:96, February 1957

A 100-ton per day refuse incinerator was placed in operation in South Euclid, Ohio, in 1955. It is located adjacent to a residential and business section. The cost was about $200,000. The plant has two direct-charged furnaces, mechanical stoking and grates. During May 1956, 668.37 tons of waste refuse were incinerated at a total cost of $1.81 per ton, exluding depreciation, electricity, gas, and water costs.

Mick, K. L. and E. L. Scott
"An Examination of Sewage Solids Incineration Costs"
Water and Sewage Works, 104:479, November 1957

Additional dewatering of sludge beyond that of normal concentration is necessary for sustained combustion. This is commonly accomplished by vacuum filtration. The sewage treatment plants at Buffalo, New York City, Cleveland, Detroit, and Minneapolis-St. Paul were selected for comparison of cost data because they all operate incinerators, publish extensive annual data, and are of similar magnitude. It is necessary to compare the entire systems, since the components are not the same, and in fact the systems themselves reveal differences. Four tables of data and references are presented.

Wegman, L. S.
"Binghamton's Incinerator After One Year"
Civil Engineering, American Society of Civil Engineers, 28:41, June 1958

Binghamton, New York, has a 300-ton municipal incinerator. A large settling chamber was adequate for controlling fly ash. The single chimney is 145 ft high, and has an inside diameter of 10 ft. During 1957, a total of 28,474 tons were handled. The total cost for wages and plant superintendence was $67,776, or $2.37 per ton. Other recurring costs totaled $6,300. Repairs came to $2,700. The cost of labor in 1958 was $2.08 per ton. The total construction cost was $887,761.

Stack effluent was generally less than Ringleman No. 1/2. No air pollution nuisance has been reported.

Leake, J.
"Incineration Costs at Louisville, Kentucky"
The American City, 74:157, April 1959

For the calendar year 1958, the gross operating cost at 24-hours per day, seven days per week, was $1.80 per ton. Income from salvaged cans reduced the net operating cost to $1.33 per ton. Further gains are expected from the drying and sale of sewage sludge from the Louisville Jefferson County Sewage treatment plant. Preventive maintenance and replacement of equipment are carefully planned.

The incinerator presently has a 750-ton capacity, but is designed for expansion to 1,000 tons. The buildings, stacks, can-reclamation system, and refuse storage bins are designed for a 1,000-ton per day operation. The total cost was $3,815,000.

Burning is complete and no air pollution problem has been detected.

Wheeler, C. F.
"Direct-Charge Incinerators Can Do A Good Job"
The American City, 74:197, May 1959

The four 150-ton furnace plant in Durham, North Carolina, has been rebuilt and two new 170-ton furnaces have been added to it, thereby increasing its capacity from an original of 600 tons per day to a new of 880 tons per day. The total cost involved five contracts and amounted to $363,133 ($386 per ton of total capacity). Estimated cost of a comparable new plant is $1,500 per ton. The furnaces are of the beehive type and are directly charged through an opening in the dome. Operation costs are less than $1.00 per capita per year. Beehive furnaces require little mechanical equipment. A table of design data is given.

Clark, S. M.
"Incinerating Plant Costs"
Public Works, 93:122, September 1962

The per ton cost of incinerator construction varies with location, time, foundation, and site preparation, construction materials, enclosure of the tipping floor, and unusual structures or equipment. Data are presented for six medium-sized incinerators. The per ton cost varies from $3,152 to $5,500.

Fox, E. B.
"49 Municipalities Join in County-Wide Incineration Plant"
Public Works, 94:100, February 1963

Facing the problem of refuse disposal, the 49 municipalities of the county of Delaware, Pennsylvania, established the Delaware County Incinerator Authority in 1954. Three plants, each with a capacity of 500 tons per day, were completed by 1962. The contract cost of the three plants was approximately $5,730,000. A fourth plant is planned. Operating costs are amounting to $2.26 per ton. Based on trash tonnages and 25 years of interest at 3.2 percent for county bonds, the capital costs total $1.46 per ton.

The three plants are described in some detail.

Sebastian, F. P.
"San Francisco's Solid Wastes Crisis"
Civil Engineering, American Society of Civil Engineers, 37:53, October 1967

Lack of land for sanitary landfill, and a clean-air ordinance which prohibits traditional means of burning, are leading to a solid wastes crisis in San Francisco. The solution may be found in two recent European innovations, namely, electrostatic precipitators to clean the stack gases and waste heat recovery.

A committee established by the San Francisco Chamber of Commerce to study the problem evaluated 10 alternative methods of waste disposal: Incineration on land or at sea, composting, burial at sea, sanitary landfill, hog-feeding, open dumping and burning, salvage, use of nuclear energy, and railway transfer to the desert. None were considered satisfactory for solving the San Francisco problem. Consequently, the committee turned to incineration as the solution.

The Bay Area air pollution standards are: not more than 50 ppm C_2-C_6; not more than 50 ppm carbonyles; not more than 0.20 grain of particulates per dry cu ft of gas; and a value of 2 on the Ringleman scale in opacity. In Europe, 15 plants are in operation in which particulate removal is greater than 99 percent.

Estimated cost for a new, clean incinerator plant:

Site (7-10 acres at $2/sq ft)	$ 850,000
Site preparation	50,000
Engineering and planning	700,000
Incineration equipment	7,300,000
Building	2,000,000
Office, waterhours, and shop	250,000
Ash-handling equipment	500,000
Steam-handling facility	750,000
Site finishing (paving and landscaping)	250,000
Contingencies	850,000
	$13,500,000

Miscellaneous

Rogus, C. A.
"Refuse Incineration--Trends and Developments"
The American City, 74:94, July 1959

The ash and garbage content (northerly states) of refuse has dropped by about 40 percent and 70 percent, respectively. The quantities of refuse are increasing, but the amount collected is only 70%-80% of that produced, since self-disposal by industry, commercial establishments, and apartments is on the increase for reasons of economy and convenience. The thermal content has increased from 3,500 btu per lb a decade ago to a present level of 4,500 btu per lb.

Modern furnaces no longer require segregated refuse, so that the expense of separate containers and collection is no longer necessary.

Incineration of refuse uses up 1/3 to 2/3 of its thermal value. The excess could be utilized.

Truck scales are valuable for planning operations. Capacity ratings should be in tons per week, since density and pattern of operations vary with location.

Foster, W. S.
"When to Build an Incinerator"
The American City, 75:118, March 1960

Of 175 cities that have built incinerators, 60 (34 percent) have abandoned them for other methods of disposal. Alternatives to incineration are the open dump and the sanitary landfill.

1. Flies, rats, and dogs abound in open dumps. Uncontrolled fires are common. Such dumps are both unsightly and unhealthful.

2. A properly operated landfill is sanitary and cheaper than an incinerator, but enough land for the next 25 years must be available.

If no storage pit is at hand, an incinerator must have the capacity to burn the peak refuse load within about six hours. If cold refuse is to be dropped directly onto the fire bed, the grate area should be 0.8 sq ft per ton of rated capacity, and the furnace and combustion chamber 30 cu ft per ton of rated capacity. Air pollution becomes a problem whenever the furnace is overloaded.

An incinerator should be built when sites for landfill are about to become nonexistent, when haul costs exceed $1.50 per ton of refuse, and the distance to the fill is 10 to 15 miles longer than to an incinerator site.

Goff, C. D.
"Only One Answer: Incineration"
The American City, 75:94, April 1960

In a study on the solid waste disposal problem in Milwaukee, it was concluded that incineration is the only long-range answer. It was noted that the open dump and hog feeding practices are becoming less common. The use of the sanitary landfills involves the costs of increasingly longer hauls to the disposal site. The use of garbage grinders — commercial and domestic — is increasing. The practice is resulting in a reduction of the size of the wet garbage fraction from 65 percent of the total refuse in 1952 to 10 percent in 1960

At present, salvage is not being done at incineration plants. Experimental attempts are being made to use incinerator heat to generate steam for cleaning and heating.

The alternatives to incineration available to the city of Milwaukee would be:

1. to fill in the shallows of Lake Michigan;

2. to haul the refuse to some far-off site by way of large trucks or railroad gondolas;

3. to burn and crush refuse at the landfill site to extend the life of the fill.

The best solution is to resort to incineration, using an incinerator equipped with a mechanized furnace. The use of such a furnace results in better burning and the production of less smoke and of a better residue than could be produced without a mechanized furnace. Heat recovery would be a possibility.

Conclusions reached in the study were:

1. The disposal costs per ton of refuse decreased with increase in plant size and length of operation time.

2. A good design, proper operation, and careful maintenance are necessary.

3. Eventually the county will have to build and operate a large incinerator to handle municipal, commercial, and industrial combustibles on a fee basis.

Fox, E. B., Jr.
"Three Incinerators Solve Refuse Problem"
The American City, 76:102, August 1961

In Delaware County, Pennsylvania, three separate incinerators were built, each with a capacity of 500 tons per 24 hours. Incineration was chosen over landfilling because:

1. the largest available sites were too far removed from the population centers to be economical;

2. many of the sites lay in watershed areas of reservoirs supplying drinking water;

3. expensive flood control measures would be necessary prior to use of swampy lowlands adjacent to the Delaware River;

4. landfills would soon consume available land.

The population was 550,000 in 1960. Forty-nine municipalities are concerned.

Garbage grinders are not permitted due to inability of sewerage facilities to handle the additional load.

Rogus, C. A.
"Refuse Collection and Disposal in Western Europe -- Part IV: Refuse Disposal by Incineration"
Public Works, 93:71, July 1962

High-temperature incineration of municipal refuse was developed nearly 100 years ago in England, and by 1920 over 200 plants were in operation in Britain. Incineration lagged on the Continent. However, in the 1890's, a large 270-ton per day plant was constructed in Hamburg. Subsequently, many other plants were constructed. Most of them were equipped with steam boilers and electric power generators. By 1940, over 250 refuse incinerator plants had been built in the U. S. The individual capacities of the U. S. plants ranged up to 750 tons per day. Following World War I, rising labor costs, emphasis on salvaging, cheaper sources of utility power, and nuisances created by the still-not-perfected design of incinerators led to a revised use of incinerators. However, the nearly complete mechanization, higher and more even burning temperatures, and the bulk and high content of non-decomposable synthetics in today's refuse are bringing about a return in the popularity of the incinerator as a refuse disposal device. Incineration accounts for about 35 percent of refuse disposal in America and for 12 percent to 85 percent in Europe, with a median of about 40 percent in Western Europe.

Separation of salable components and incineration of the tailings, or remainder, is done most extensively in England and Scotland, but only to a negligible extent elsewhere. Recovery of waste heat for steam and electric power generation is practiced extensively on the Continent. The use of incinerators as an intermediate disposal process to reduce the volume of refuse before final disposal by landfilling or other methods is not used much as yet, but it may become more attractive due to the increasing bulkiness, burnability, and plastics content of modern refuse. Complete incineration, in which the refuse is burned so thoroughly that the residue contains no putrescibles and its volume is reduced to 5 percent to 12 percent of the original input is most popular in the U. S., but seldom practiced abroad. Throughput time is no longer than for intermediate disposal.

The Volund and the De Roll systems of incineration are described. Comparative cost data for incineration in Europe and the U. S. are presented. A table of data for steam and power generation in Paris, Hamburg, and Zurich also is provided. A median figure for pounds of steam per pound of refuse seems to be around 1.40 for modern refuse and recent plants.

Fuel briquettes can be manufactured from refuse by sorting out noncombustibles, grinding to secure greater uniformity, drying, and extruding the briquette under pressure. An average heat output of 7,500 btu per lb can be produced without any noticeable smoke.

Modern plants in Europe are honestly functional in their architecture. Several special features of European incinerators are noted:

1. Exhaust stacks seem to be higher than those in the U. S.

2. Fixed crane cabs with air conditioning and glass enclosures, centrally located, give good visibility and control of crane and pit operations.

3. The provision of large storage pits with up to 48 hr of operating capacity is the usual practice.

4. Eccentrically-shaped metal charging hoppers reduce or eliminate clogging and bridging of refuse.

5. Hydraulically operated horizontal shear-gates in vertical metal feeding chutes insure closure and give positive protection against backdrafts and backfires.

6. Airtight sheet metal casings for furnaces coupled with elimination of stoking doors and only nominal use of inspection doors guard against emergence of furnace dust and the intake of unwanted excess air.

7. Pulling in combustion air from tipping floor and storage pits so as to produce a slight vacuum in these areas effectively reduces dust.

8. The successful use of orange-peel type crane buckets in handling refuse destroys the myth that only clam-shell buckets work well.

American Society of Mechanical Engineers
"Incinerator Topics for Study and Research"
Incinerator Committee, Process Industries Division, 21 January 1964

The committee and subcommittees will make their contributions to progress by informing the profession and the public through published technical papers and books which they may inspire or prepare. Specifically, the subcommittee will probably contribute most directly in six important ways by:

1. building a library collection of incinerator technology for use by the profession and the public;

2. soliciting technical and economic papers for presentation at meetings;

3. publishing through ASME and possibly other channels;

4. discussing topics and problems, later summarized in print, which map the advanced state of the incinerator art, and which will serve as the necessary background for further investigations;

5. outlining the needs and opporutnities for research codes and standards, and the encouragement thereof;

6. financing and guiding research through the established ASME research procedures.

Eighteen research topics are listed.

American Society of Mechanical Engineers
"Proceedings of 1964 National Incinerator Conference"
Incinerator Committee, Process Industries Division, 18-20 May 1964

The Table of Contents of the report is as follows: 1. Planning a New Incinerator. 2. Specifications and Responsibility for Incinerator Plant Performance. 3. Electrostatic Fly Ash Precipitation for Municipal Incinerators--A Pilot Plant Study. 4. Lexicon of Incinerator Terminology. 5. Monolithic Refractories in Municipal Incinerators. 6. Refuse Composition and Flue-Gas Analyses From Municipal Incinerators. 7. Furnace Configuration. 8. Incinerator Refractory Enclosures. 9. The Incinerator Crane. 10. Trends in Charging Refuse Into and Conveying Residue From The Furnace. 11. Incinerator Buckets and Grapples. 12. Combustion and Heat Calculations for Incinerators. 13. Steam Generation from Incineration. 14. Waste Heat Utilization at Hempstead-Merrick Refuse Disposal Plant. 15. Metallurgical Aspects of Incinerator Construction. 16. European Practice in Refuse Burning. 17. Modern Incineration of Community Wastes. 18. Fly Ash Control Equipment for Municipal Incinerators. 19. The Effect of Furnace Design and Operation on Air

Pollution from Incinerators. 20. Health Aspects of Air Pollution from Incinerators. 21. Problems Encountered in the Operation of a Large Incinerator Plant. 22. An Investigation of Combustion Air for Refuse Burning. 23. Incinerator Operating Personnel. 24. Essentials of Good Planning. 25. Roof Damper Operation for Apartment House Incinerators. 26. Incinerator Testing Programs. 27. Instrumentation of an Incinerator. 28. Incinerator Temperature Measurement--How, What, and Where. 29. Flue Gas Cooling.

Anon.
"Municipal Incineration of Refuse: Foreword and Introduction"
Journal, Sanitary Engineering Division, American Society of Civil Engineers, 90(SA3):13, June 1964

The use of incinerators for the disposal of large quantities of municipal refuse has long been favored, since the costs and difficulty of obtaining land for sanitary landfills continue to increase. Methods of disposal other than landfill and incineration have been tried, including depositing in water, dumping on land, reduction, piggeries, grinding, domestic incineration, and composting, but sanitary fills and incineration are the only two methods by which almost any municipal refuse can be handled with the maintenance of satisfactory health standards. Of the latter two, incineration seems to be the better answer for the future, as well as for the present for waste disposal.

Sanitary landfill is the only disposal method by which all solid waste, irrespective of size, moisture, or other characteristics, can be disposed of. However, as cities grow in size, available land becomes more and more scarce and costly, and hauling costs to areas outside the city negate any savings over the costs of operating a municipal, centrally located incinerator. "Incineration is complete," leaving only 20 percent to 25 percent by weight to be disposed of at sanitary fills. The major disadvantages of incineration are the higher initial costs of construction, high operation and maintenance costs, and the problem of the final disposal of residue.

The paper goes on to relate the history of incineration in the United States, and points out the factors to be considered when deciding upon the capacity of a plant. Approximate costs of construction and operation of an incinerator are discussed, and the areas in need of research in the field of incineration are pointed out.

Winkler, T.
"Incinerator Serves Suburban Communities"
Public Works, 96:74, December 1965

A 500-ton per day incinerator designed to serve a population of 366,000 has been constructed in Wayne County, Michigan. The total cost, including landscaping, was $2,036,334. The plant is intended to serve five communities near Detroit. The ultimate capacity of the plant will be 750-tons per day. Presently, it has two 250-ton per day incinerators. A storage pit holds two days' collection. A truck-weighing scale is at hand.

American Society of Mechanical Engineers
"Proceedings of 1966 National Incinerator Conference"
Incinerator Committee, Process Industries Division, 1966

Contents of the report are: 1. Municipal Incinerator Design Practices and Trends. 2. The Incineration of Bulky Refuse. 3. Meeting the Challenge of Solid Waste Disposal. 4. The Incinerator Crane and its Application in the Building. 5. Incineration vs. Air Pollution - A Necessary Divorce. 6. Characteristics of Furnace Emissions from Large, Mechanically-Stoked Municipal Incinerators. 7. Municipal Incineration and Air Pollution Control. 8. Chemical Analyses of Refuse Components. 9. What Price Incineration Air Pollution Control? 10. Specifications and Legal Responsibility. 11. Public Relations Considerations in Incinerator Plant Location. 12. Record Keeping for Incinerator Plants. 13. An Appraisal of Refuse Incineration in Western Europe. 14. European Practice in Refuse and Sewage Sludge Disposal by Incineration. 15. Survey of European Experience with High Pressure Boiler Operation Burning Wastes and Fuel. 16. The Use of Electrostatic Precipitators for Incinerator Gas Cleaning in Europe. 17. Instrumentation Specification - The Key To a Good System. 18. The Measurement of Air and Gas Flow and Pressure as Applied to Modern Municipal Incinerators. 19. A New Incinerator Control Meter is Needed. 20. Smoke Density Measurement in Municipal Incinerators. 21. Closed-Circuit Television and its Application in Municipal Incineration. 22. The Nature of Incinerator Slags - X-Ray Spectrographic Analysis of Incinerator Slags. 23. Silicon Carbide Refractories in Incinerators. 24. Kodak Park Waste Disposal Facilities. 25. Three Industrial Incineration Problems. 26. General Overall Approach to Industrial Incineration. 27. New Developments in Industrial Incineration. 28. Incinerator Testing Programs 1966. 29. Auxiliary Gas Burners for Commercial and Industrial Incinerators. 30. Fly Ash Control Equipment for Industrial Incinerators. 31. Prefabricated Chimneys. 32. A Salvage Fuel Boiler Plant for Maximum Steam Production. 33. Progress in Municipal Incineration Through Process Engineering.

Fleming, R. R.
"Solid Waste Disposal: Part II -- Incineration and Composting"
The American City, 81:94, February 1966

Delaware County, Pennsylvania, (embraces 49 municipalities) would have needed 1,000 acres of landfill over the next 20 years. However, sites were rapidly becoming unavailable. Therefore, county officials built a 500-ton incinerator at a cost of $6,900,000 to serve the whole area.

Metropolitan areas in the North, Central, Eastern, and Southern United States are rapidly running out of suitable landfill sites. A decade ago, municipalities in Los Angeles County operated nine incinerators, but now none are in operation due to air pollution regulations. More than one-third of the 175 cities which had incinerators have abandoned them in favor of other methods of disposal. Even well-designed incinerators will smoke when overloaded, and planning and enlarging of capacity is necessary to prevent future nuisance. Electrostatic precipitators can remove up to 98 percent of particulate pollutants. A lazy flame lowers chamber velocity and particles can be precipitated in the expansion chamber without the need for additional air pollution equipment.

Sanitary landfill costs range from $0.50 to $2.00 per ton, while incinerator costs are around $3.00 to $6.00, of which about $0.70 represents capital investment. Incinerator residues commonly total 5 percent to 20 percent of the initial refuse volume, or about 3/4 cu yd per ton of refuse burned. This residue is used in European cities and a few American cities as a subbase material for roads. Most of the American cities dispose of it in landfills. In Europe, provision usually is made for using the waste heat. In the U. S. this is done only at Atlanta (steam heat for commercial buildings), Boston (for hospital heating), Miami (for heating a hospital and pumping water), and New York City (for heating its new $22,000,000 public works garage). The new plant in Oceanside, New York, supplies steam to power a desalting plant.

Composting has not been popular in the United States due to lack of demand for the finished product. One competitive plant, although experimental, is in San Fernando, California. Others are in Elmira, Phoenix, Houston, and the Virgin Islands. (Editor's Note: The plants in San Fernando and Phoenix, and one of those in Houston are no longer in operation.)

Anon.
"Big Incinerator Nears Completion"
The American City, 81:21, April 1966

The Montgomery County Incinerator in Rockville, Maryland, will contain three furnaces, each with a capacity of 350 tons per 24 hours. The furnaces are among the largest in the country and will feature the largest traveling-grate stokers ever installed in a municipal plant.

Bennett, C. G.
"Huge Incinerator Planned for City"
New York Times, 19 June 1966

New York City is planning to build a $30 million incinerator capable of handling 3,200 tons of refuse per day. The incinerator may provide usable steam as a by-product, and will utilize advanced devices for the prevention of air pollution. The designs are to be ready by 1968, and the plant is expected to be built by 1971 or 1972.

The city presently has eleven incinerators, three of 1,000-ton capacity and all under the supervision of the Department of Sanitation. All refuse will be brought to the new incinerator by barge; one-third of the total will come from the Bronx, and the remainder from the other four boroughs.

The use of boilers as gas coolers for the production of vast amounts of hot water or steam is being looked into. In a similar arrangement, Atlanta, Georgia, is providing steam for several adjoining buildings. At the Naval Base at Norfolk, Virginia, an incinerator will soon be providing steam not only for surrounding buildings but also for ships tied up at berths.

Hume, N. B.
"History of Efforts at Incineration in the Los Angeles Area"
Paper - Annual Meeting of the Air Pollution Control Association, San Francisco, California, 20 June 1966

Until 1943 Los Angeles operated an incinerator adjacent to the municipal boundary in the municipality of Vernon. The aging of the incinerator and the rising production of rubbish led to the formation of a City-County Committee in the mid-forties to formulate an incinerator construction program for the metropolitan area. The committee recommended the construction of five incinerators within the city, including the replacement for the old one. A $2,100,000 bond issue was placed on the ballot for the construction of four incinerators.

The Lacy Street incinerator was of the rotary type and was based on experimental work done at the previous site. It had a fly ash control problem, and operation was discontinued after the formation of the Los Angeles County Air Pollution Control Board. Other incinerators were constructed in Alhambra, Santa Monica, Pomona, and Signal Hill during the late forties and early fifties. The Lacy Street Plant was remodeled to use water-cooled grates, and a Gaffey Street incinerator was built to service the Harbor area. In 1954 it was discovered that none of these incinerators met the minimum pollution requirement of 0.4 grain of matter per cu ft of emission gas. Since landfill was a good deal cheaper than the cost of adequate incineration, Los Angeles switched to landfill operations for waste disposal, and now only one incinerator is in regular operation.

Design specifications are given for the Gaffey Street and San Fermando Road incinerators.

Fox, R. A., Editor
"Incineration of Solid Wastes"
Metropolitan Engineers Council on Air Resources. Collection of papers presented at the MECAR Symposium, New York, New York, 21 March 1967. (Library of Congress Catalog Card No. 67-25957.)

The contents of the publication include: 1. Composition and Combustion of Refuse. 2. Refuse Fires Steam Generator at the Navy Base, Norfolk, Virginia. 3. New Incinerator at Munich, West Germany. 4. An Incinerator with Refractory Furnaces. 5. Economics of Solid Waste Incineration. 6. Burning Industrial Wastes. 7. Air Pollution Control Equipment for Incinerators.

Sebastian, Frank
"The Worldwide Rush to Incineration"
The American City, 82:40, December 1967

The author (who is promoting an incinerator of his own design) claims that clean incineration is the answer to the world's sewage, sludge, and solid waste disposal problems. He gives examples of modern incinerators:

1. Paris: The Paris plant has a capacity of 1400 tons of refuse per day. Television cameras monitor all important plant operations. Electrostatic precipitators are used.

2. Dusseldorf: This plant has a capacity for handling 960 tons of municipal and industrial refuse per day. It uses excess heat to generate steam to produce electricity. It is equipped with electrostatic precipitors. Its stack gases read less than Ringleman No. 1 – never more than No. 2. Metallic scrap is magnetically separated from burned residues, and is baled for sale at $12.50 to $25 per ton. The balance of residue is screened and sold for fill at 10 to 20 cents per ton. The city receives $3.45 per ton or $700,000 per year.

3. Leverkusen: Here, refuse is burned in a rotary kiln. Steam is produced and is transported 2 miles for use.

4. London: A 1600-ton per day plant is being built. It will generate steam worth $1,400,000 per year. Reclaimed residue per year will be worth $280,000. The gas discharger will have 0.05 grain per cu ft of dust.

5. Osaka, Japan: Two new plants are being built by this city. Both will produce steam. Tokyo has a 100-ton per day sludge incinerator.

6. Kyoto, Japan: Sewage incinerators are burning sludge next door to farmers who can't be bothered with using sludge. They use chemical fertilizers instead.

Anon.
"Plastics Pose a Solid Waste Disposal Problem"
Environmental Science and Technology, 2:89, February 1968

At present the disposal of plastics by incineration does not seriously affect the overall solid waste disposal problem according to a report prepared by the Battelle Memorial Institute for the Society of Plastics Industry, Inc. About 1.5 percent of the total wastes is in the form of plastics. This amounts to 3.25 billion pounds. The percentage may double in the next decade. However, if the amount of plastics subjected to incineration were increased significantly, plastic disposal could create a problem, particularly from hydrogen chloride and other hydrogen halides. The problem derives from the incineration of hydrogen-bearing plastics, such as polyvinyl chloride which accounts for one-third of the total plastics, and other polymers containing flame inhibitors. The concentration of HCl in incinerator stacks may approach toxicological limits under certain conditions.

Anon.
"Film on Incineration Shows Foreign Accomplishments"
Environmental Science and Technology, 2:230, March 1968

A privately produced color movie highlights incinerator development in several parts of the world. A 13-minute, super-8 mm, color film "Solid Waste Worldwide - A Burning Issue," is available to consulting engineers, municipalities, and government agencies. Among the plants shown in the film are the Castle Bromwich (Birmingham, England), the plant at Dusseldorf (which produces steam, electricity, salable residual ash, and magnetically separated scrap), Yao City (Osaka, Japan), the Mannheim, Essen, and Frankfurt plants in Germany, and the Issy les Moulineaux plant (Paris, France).

Requests for borrowing the film can be made to Frank P. Sebastian, BSP Corp., P. O. Box 8158, San Francisco, California 94128.

Fleming, R. R.
"Frank Answers to Some Hot Incinerator Questions"
The American City, 83:97, May 1968

The article is a series of questions and answers concerned with practical reasons for the successes and failures in incineration operation. The subjects range from reasons for premature failures to opinions on performance type specifications for incinerator construction.

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COMPOSTING

Design and Methods

Anon.
"Make Compost in 14 Days"
Phamphlet by Organic Gardening and Farming, Rodale Press, Department C, Emmaus, Pennsylvania

Instructions are given for making compost on a "backyard" scale. The instructions cover ten categories, viz., location of operation, collection and assemblage of materials, use of power equipment, operation without power equipment, improvement of the value of compost, the watering and turning processes, mistakes to avoid, how to use compost, and sheet composting. A list of some common materials that make excellent additions to the compost heap is given. It contains instructions on how to use compost.

van Vuren, J. P. J.
"The Manufacture of Compost from Municipal Waste"
Pamphlet GPS No. 32167, Department of Public Health, South Africa, 1942

Composting was carried out in pits. Town waste and night soil were used as the source of organic material. The success of the process depends chiefly on two factors, viz., thorough aeration and the drainage of excess liquid. All surplus liquids from the pits drain into a main channel having a sump at the lower end. This liquid is used for moistening the contents of the pits.

The method of charging the pits is very important. An essential requirement is that a correct ratio be provided between the quantity of dry refuse and that of the night soil. Dry refuse is screened and used as the first layer in the pit. Night soil is spread on top of the dry material, with care being taken not to add too much liquid. Subsequent layers of dry refuse and night soil are added until the pit is filled. The topmost layer should be a dry one. It is needed for soaking up most of the liquids and for preventing drainage difficulties.

On the fifth day after starting the composting, the material is turned, primarily to destroy the fly larvae. The temperature of the material at this stage should be about 130°F. The material is turned again on the tenth day. By this time the night soil has been stabilized and no longer is distinguishable. The temperature should be 150° to 160°F. The third and fourth turns are made on the 15th and 20th days, primarily for aeration.

The compost is "ripened" by removing it from the pits and allowing it to stand in heaps for three or four weeks.

General observations: 1. If the contents of a compost pit give off unpleasant odors and do not heat up, it is an indication that an excessive amount of night soil has been used, causing bad aeration. Turn the contents immediately and very thoroughly. 2. On exactly the fifth day after a pit has been filled it should be in a sufficiently dry state to be turned thoroughly. In turning, the material is shaken loose and lightly heaped so as to cause optimum aeration. This results in a quick rise in temperature. If the temperature does not rise within 24 hours the turning was not done efficiently and the contents must then be turned again immediately. 3. The temperature of the material will not rise if the channels are blocked, if too much or too little moisture is present, and if the material is too compactly pressed. 4. The presence of an abnormal number of flies or larvae indicates that bad aeration is causing unpleasant odors to which flies are attracted;

or that the laborers did not charge or turn the contents thoroughly. 5. Excessive drainage indicates that too little dry material was used in proportion to night soil. 6. Instead of using disinfectants to counteract the smell of night soil in sanitary buckets, a thin three-inch layer of compost is placed in the bottom of the pail. Prior to removing the bucket, another layer is placed on top. This will not only allow the composting process to start while the night soil is being collected, but will eliminate most of the smell and consequently the fly attraction. It is not only cheaper but also more efficient to use compost instead of disinfectants.

Several experiments are to be started to study the further simplification and effectiveness of the whole process.

Truman, H. A.
"Municipal Composting at Dannevirke"
Journal of the New Zealand Branch of The Royal Sanitary Institute, No. 43 (Volume X - No. 3), December 1949

A description is given of the composting procedures at Dannevirke. It is summed up as follows: 1. Municipal composting provides a sound and hygienic method for the disposal of organic wastes difficult to handle. 2. Controlled tipping as a method of refuse disposal is usually preferable to incineration. Composting has advantages over both of the methods. 3. The general policy of burying, burning, and piping away to the sea or to rivers huge quantities of agriculturally useful materials is unsound. 4. Composting is a sound and logical method for the disposal of liquid sludges since it contains the moisture essential for composting. Sludge disposal by other methods which yield a useful fertilizer, necessitates costly methods of dehydration. 5. Municipal composting makes it possible to return to the land by way of an organic manure both town refuse and town sewage. This return should be the aim of all those charged with the responsibility for disposing of these organic wastes. 6. Municipal composting can earn a return for the ratepayers both in cash and in soil fertility.

Leatherhead Borough Council (England) has been operating a municipal composting scheme for the past eleven years. The operation has resulted in a saving of an 8 pence rate in the pound.

McGauhey, P. H. and C. G. Golueke
"Composting of Municipal Refuse"
Unpublished Paper, Sanitary Engineering Research Laboratory, University of California, Berkeley, 1953

The article devotes three pages to the historical development of the art of composting and to a description of the different methods of composting practiced throughout the world. It then explains the fundamental aspects of the composting process, which are: 1. Segregation: Noncompostable materials are separated from the refuse. 2. Grinding: Refuse is shredded to pieces about 1-inch in size to make the material homogenous, more susceptible to bacterial invasion, and to give it a beneficial initial aeration. 3. Stacking: Refuse is stacked in windrowed piles trapezoidal in cross section, 8-10 ft at the base, 5-6 ft in height. 4. Turning: Aeration is provided by turning to bring about uniform decomposition. (A recommended turning schedule is given in the article.) 5. Final Grinding: For sake of appearance, the refuse is ground to a particle size small enough to pass through a 3/8-inch screen.

The biological aspects of the process are described, as well as economic considerations. It is doubtful that composting will make refuse disposal profitable.

Production costs of composting selected garbage with sewage sludge by the Frazer Process are reported to be $15 to $20 per ton. Estimates on the use of the Dano grinder indicate a cost of $9 to $10 per ton of raw refuse. The present price of compost sold to specialty gardeners and nurserymen--reportedly $68 per ton--is more than large-scale farmers in California would pay. Estimates of what farmers would pay range from $10 to $15 or more per ton. (Editor's Note: In reality, the California farmer has expressed no interest at all in using the material.)

Burnap, R. L.
Second Report (no title)
The Compost Development Corporation, 520 Fifth Avenue, New York, New York, 1953

A description is given of the problems of large-scale composting, of the methods, and of the categories of research pertaining to these problems. The research was divided into four-interrelated categories, viz.; 1. Economics, 2. Mechanics, 3. Biology, and 4. Utilization.

Phase I. Initial Research and Development: This phase consisted in describing the organizations which carried out the four major areas described above.

Phase II. Pilot-Plant Stage. 1. Mechanics: In this stage the operation of a pilot digester is tested in order to perfect the process. Research and development of more adequate grinding equipment are of concern. 2. Biology: A careful study is made of the pilot plant operation. Compost is sampled at various stages to establish the rate and nature of the decomposition taking place. Laboratory studies of the decomposition process are made with the objectives of making the compost operation more efficient and capable of producing a better product. The study should include that of the decomposition of various wastes available as, for example, coffee grounds, wool waste, paunch manure, sewage. 3. Economics: A study is made of the probable costs of large-scale production as based on operation of the pilot plant. 4. Utilization: Tests on the value of compost should be made to include its value as a fertilizer, as a soil conditioner, and as a carrier of added inorganic minerals.

Phase III. Full-Scale Plant Stage. 1. Mechanics: This stage involves the construction of a full-scale compost plant for "separated" garbage. In this stage, improvement of the full-scale production plant is made through removal of operational difficulties. Research and development of equipment for automatic separation of compostibles from noncompostibles are carried on. Research is conducted to determine whether or not specific materials require special handling. 2. Biology: Laboratory and pilot-plant work with the objective of improving the end product or the efficiency of the process is performed. Further testing of various waste materials, both in the laboratory and at the pilot plant are made. (Industries with disposal problems will be invited to cooperate in composting experiments in which their wastes would be the raw materials.) A study of "night soil" decomposition should be made with the objective of developing a practical and sanitary compost process for areas relying on human feces for soil fertility. 3. Economics: A careful study of full-scale plant operation is made to obtain an accurate cost breakdown of the process. 4. Utilization: Tests to determine value of compost are continued. Long-term test plots are established with which the value of compost under various methods of application and in various mixtures with other materials will be tested.

Phase IV. Practical Development and Promotion of Large-Scale Composting. 1. Mechanics: Design and engineering of garbage treatment plants of various sizes are of concern, as are the design and engineering of pilot plants for various waste materials. 2. Biology: The study on the utilization of different wastes and improving the end product is continued. 3. Economics: A study is made of production costs for plants of various sizes, and of the costs of composting different wastes at pilot plants. 4. Utilization: Greenhouse tests, long-term field tests, including tests of the nutritional quality of foodstuffs produced with and without compost are continued. Comparisons of nutritional value will be made both by feeding tests and by spectrographic analysis.

Continuing through each phase will be a constant inquiry into the work being done by other researchers and organizations, so that the Corporation can keep informed of the latest developments in waste disposal and utilization, composting, and soil management.

Valuable notes are ammended to each Phase section.

McGauhey, P. H. and C. G. Golueke
"Reclamation of Municipal Refuse by Composting"
Technical Bulletin No. 9, Sanitary Engineering Research Laboratory, University of California, June 1953

The report describes research on composting extending from laboratory to field scale. The latter involved composting municipal refuse from the city of Berkeley at its sanitary landfill site. As a result of the research, many of the hitherto empirical approaches to composting could be placed on a rational basis, and many of the prior misconceptions of various phases of the process could be rectified.

Among the many important facts and conclusions listed in the section SUMMARY AND CONCLUSIONS are the following:

1. Successful European methods are not directly applicable to the U. S. because of the dissimilarity in the nature of refuse to be composted.

2. The practice of composting throughout the world has been largely an art rather than a science. In the U. S., fundamental studies of the decomposition of organic matter had been made but their engineering applications to the composting of municipal refuse were unexplored.

3. The factors fundamental to composting are those fundamental to any aerobic biological process: initial population of microorganisms, available nutrients, temperature, pH level, moisture, and aeration.

4. Microorganisms are indigenous to municipal refuse in such great numbers as to make inoculation entirely superfluous. Neither of two commercially produced inoculums tried improved the process.

5. Facultative and obligate aerobic bacteria, actinomycetes, and fungi are most active in the composting process. Apparently thermophilic bacteria play a major role in decomposing protein and other readily broken down organic material; actinomycetes in decomposing cellulose and lignin compounds. Fungi, being limited by temperature, play a lesser role.

6. Normal city refuse contains nutrients sufficient for rapid aerobic composting. (Editor's Note: This no longer holds true – nitrogen has become limiting.)

7. The rate of decompostion is a function of the C:N ratio of the refuse. For rapid composting without loss of nitrogen through volatilization of ammonia, a C:N ratio of 30:1 to 35:1 is needed. A C:N ratio above 50:1 slows the process. At C:N ratios less than 30:1, nitrogen is lost. The C:N ratio of mixed Berkeley refuse averaged 33:1.

8. A maximum temperature of 73° to 75°C was attained during the composting process.

9. The hydrogen ion concentration is not limiting in the composting of combined municipal refuse.

10. The fundamental steps of a rapid composting process include segregating, grinding, stacking, turning (or mechanical aeration), stacking, turning, and regrinding.

11. Grinding of refuse is necessary for rapid aerobic composting. No special size requirements need to be met with respect to particle size. However, material having a high garbage content must not be pulped lest it become too soggy to compost.

12. Ground refuse may be composted in windrows. The maximum height of a pile should proabably not exceed 5 or 6 ft to avoid compaction. The minimum height to maintain good insulating properties is about 4 ft. The maximum width of a pile should be about 10 ft, although it is not critical and may depend upon the method of turning to be used.

13. Turning compost accomplishes aeration, insures uniform decomposition, and exposes all pathogens and insect larvae to lethal temperatures inside the pile. Turning should be done on the third day after grinding and repeated thereafter, depending on the moisture content and structure of the material. If a compost becomes anaerobic, it should be turned daily until aerobic conditions are restored.

14. The moisture content for good composting depends upon the nature of the material. For municipal refuse, it lies between 40 percent and 65 percent. The moisture content of mixed Berkeley refuse after grinding averaged 49 percent. Excessive moisture content may be reduced by daily turning or by the addition of straw, soil, paper, etc.

15. The course of a normal compost is characterized by a rapid rise in temperature, followed by a leveling off and slow decline without appreciable fluctuations, and a progressively darkening in color of the material.

16. A compost is nearing completion when its temperature begins a steady decline. Finished compost is characterized by: 1) a dark gray or dark brown color; 2) a neutral, slightly musty, or earthy odor; and 3) a C:N ratio of 20:1 or less, or more if carbon is in a difficulty available form.

17. The time required for composting varied from about 12 days for a C:N ratio of 20:1 to about 21 days for a C:N ratio of 78:1.

18. Municipal refuse composts readily with raw and digested sludge and with cannery wastes.

19. Any appreciable production of compost in California would presumably have to be marketed to large-scale agriculturalists and there is little evidence by which to estimate their requirements. Agricultural acceptance of compost will depend upon the economy with which it can be purchased and applied to the soil.

A formula suggested by a New Zealand research group for estimating the carbon content of refuse is as follows:

$$C = \left(\frac{100 - \%\ \text{ash}}{1.8}\right) .$$

In the Berkeley studies it was found that the results of this method approximated the more accurate laboratory determination of carbon within 2 percent to 10 percent.

Golueke, C. G. and H. B. Gotaas
"Public Health Aspects of Waste Disposal by Composting"
American Journal of Public Health, 44:339, March 1954

Composting is the production of a relatively stable humus suitable for agricultural soils by means of biological decomposition. It is used most extensively in Asia, Europe, and South Africa, lands in which the population is dense and the need for food production is most urgent. Known since antiquity, composting was first systematized by Lord Howard in the Indore process, which has since become widely accepted in South Africa. Mechanization of composting led to the appearance of a number of patented devices in the decade 1920-1930. Composting has not been successful in the U. S.

In composting ordinary municipal refuse there are four important steps: grinding, stacking, aeration by turning, and regrinding. Turning is not necessary until the third day if the initial moisture content is below 70 percent; subsequent frequency of turning is determined by the moisture content. Within 24 hours after grinding and stacking the internal temperature of the pile rises to about 50°C and subsequently continues to rise less rapidly until a maximum of 70° to 75°C is reached. This may persist from 3 to 6 days until the supply of readily available nutrients diminishes because of the breakdown of organic matter, and then the temperature declines. When a temperature of 50° to 55°C is reached again, active decomposition is over and the material is sufficiently stabilized for agricultural purposes. With mixed municipal refuse the entire process lasts from 10 to 21 days, depending on the C:N ratio. The highest temperatures do not extend to the surface of the pile, and turning is required for complete decomposition of all the refuse.

Sewage sludge may be safely treated by composting. Thermophilic temperatures obtained in aerobic composting is sufficient to destroy pathogens and parasites, as well as fly eggs.

Special care is necessary when night soil and sewage sludge are added to the compost in order to safeguard the health of the workers. Sufficient standby equipment should be available to prevent an accumulation of refuse in case of a breakdown.

Snell, J. R.
"High Rate Composting"
Consulting Engineer, 4:49, August 1954

Description of Plant on Michigan State Campus: Garbage is ground and taken by bucket conveyor to the top of a digester having eight levels. A slowly revolving shaft turns plows mounted on the crossarm of each of the eight decks. The rotating plows aerate and mix the refuse and gradually push it to an opening in the deck through which it drops to the next deck. Retention period in the composter varies from two to four days. Based on a 3-1/2 day detention period, the digester's capacity is 4500 lb per day. (Editor's Note: The plant never functioned satisfactorily and later was closed.)

Anon.
"Digester Converts Sawdust into Humus"
Civil Engineering, 22:(No. 3), April 1956

The Ocean Pacific Company of Oregon has established the fact that certain selected bacteria can convert sawdust into a fine granular humus. Nutrients are added to enrich the humus. The key to the process is a continuous-flow eight-deck digester. The digester can also produce an odorless granular humus by adding sewage sludge to garbage. The complete organic fertilizer will be uniform in quality regardless of the basic organic waste used. The uniformity is due to the production of growth factors by the bacteria used, such as actumus, auxin, and kinin. (Editor's Note: This plant long ago ceased operation.)

Maier, P. P., E. R. Williams, and G. F. Mallison
"Composting Studies I - Composting Municipal Refuse by the Aeration Bin Process"
Reprint No. 277 from Engineering Bulletin, Proceeding of the 12th Industrial Waste Conference, Series No. 94, 13-15 May 1957, Department of Health, Education, and Welfare

Composting studies were started by the Cummunicable Disease Center at the Phoenix Field Station in December 1953. The plan was to investigate the potentials of the windrow method of composting and to proceed with such modifications as were indicated by the studies.

Efforts to provide sufficient oxygen for bacteriological activity led to placement of ground refuse in windrows on elevated hardware cloth racks so that air could permeate from below the material and create a natural draft upward. Temperature and oxygen determinations proved that this method was completely successful and that thermophilic aerobic conditions were maintained in all parts of the composting mass except the outer 2 inches at the surface. The pilot plant needed much hand labor, and therefore no reliable cost data could be given.

Since the process needed further study, a demonstration plant (capacity: 70 tons per week) was designed for composting refuse from Chandler, Arizona, so that further refinements on the process could be made and reliable cost data be gathered. The plant was able to incorporate sewage sludge from the city into the refuse for composting, and in the first few weeks of operation results were satisfactory. Further tests and experiments are planned at the plant to study effects of different factors on final compost.

Wiley, John S.
"Composting Studies II — Progress Report on High-Rate Composting Studies"
Reprint No. 237 from Engineering Bulletin, Proceeding of the 12th Industrial Waste Conference, Series No. 94, 13-15 May 1957, Department of Health, Education, and Welfare

Results from runs made by cooling composting matter during the thermophilic portion of the decomposition cycle indicate that the best decomposition may occur at temperatures less than those attained in noncooled units. A temperature of about 145°F resulted in better decomposition than was attained in noncooled units in which the maximum temperature was 152° to 162°F.

Heat production in a laboratory batch of refuse composting for 8 to 10 days amounts to 3000 btu per lb of volatile solids.

It is undesirable to heat the material to be composted to the thermophilic level in order to speed up initial decomposition.

Scovil, R. E.
"The Dano Method of Refuse Disposal"
California Vector Views, 5:5, February 1958

The author tells of the problems encountered in the use of various methods of accomplishing solid waste disposal, and points out that the Dano method of composting is the best means of disposal. Since October 1956, a full-scale Dano biostabilizer composting plant has been in operation near Sacramento, California. (Editor Note: This plant has since closed operation, shutting down in 1963.)

No inoculation is used during the process, which involves the use of a rotating drum (12 ft in diameter, 150 ft in length) for aerating and mixing the refuse. Retention of the refuse for a period of 10 days results in a compost having a low C:N ratio.

At times, refuse is retained in the biostabilizer for only a day. This "green compost" is spread over low quality soil where the final stages of decomposition take place. The Dano owners have no plans to market the end product, but they do want to recondition land with the compost, and are able to dispose of it for any city using the Dano system.

Hurter, H.
"A New Swiss Refuse Disposal Procedure"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 4, p. 1, March 1958

A new composting plant in Uzwil (Switzerland) using the Buehler system is described.

Mechanical: The plant has a bin with a storage capacity of 23 m^3. Refuse is not presorted. First mill: All material is broken up into pieces about 3 inches in cross section in the first grinding mill. Ferrous metals are extracted at this stage. A vibrating screen then separates the refuse into two fractions. The screened material consists of heavy materials which are pulverized in a rolling mill. The sieve residues pass a fine grinder. The milled and ground materials are brought together on the last chain-conveyor and are discharged into a storage bin outside the plant.

Composting: The ground refuse is stacked in piles 4 to 7 ft high. The composting refuse is turned two or three times in a period of three to four months.

Results: In the first year, 2845 m^3 of refuse from a population of 8760 were treated. Volume reduction was on the order of 4:1. Approximately 9.3 tons of iron were salvaged. Power requirements were 7.4 kw-hr per m^3 of raw refuse.

Teensma, B.
"Refuse Compost in Poultry Husbandry"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 4, p. 8, March 1958

Until the present, the bedding layer in poultry buildings (sand or peat bedding) had to be changed every 7 to 14 days. With the new thick litter method, hens and chicks are kept in pens on a 30 to 50 cm layer of organic matter such as straw, corncobs, wood shavings, horse manure, peat bedding, or composted refuse. Advantages provided by this method are labor saving, the bedding is always warm, lower mortality, cannibalism subsides, better growth of fowls, better results in brooders with eggs from fouls raised on deep litters, and space saving. (Editor's Note: Some experts hold that the advantages are exaggerated. For example, cannibalism is dependent upon a special vitaminosis.)

Wilson, N. G.
"The Refuse Composting Plant in Edinburgh, England"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 5, p. 1, August 1958

The Dano biostabilizer system is used. The plant was opened in July 1955. It can handle from 70 to 75 tons of raw refuse per week. From this amount, 35 tons of compost are produced each week. The plant operates 8 hours per day, 5-1/2 days per week. From 270 to 360 liters of sewage sludge are added for each ton of refuse introduced into the biostabilizer. The composting mass reaches a maximum temperature of 60°C. The selling price of the compost is $4.9 per ton.

The analysis of the product is as follows: moisture content, 44.9 percent; organic matter, 48.8 percent; ash, 51.2 percent; nitrogen, 1.1 percent; nitrogen in the organic matter, 2.3 percent; pH level, 7.0; C:N ratio, 25:1. The last six items (exclusive of pH) are on a dry weight basis.

Jeffreys, G. A.
"Simultaneous Aerobic and Anaerobic Composting Process"
United States Patent Office #2,867,521, 6 January 1959

This paper describes a supposedly new and improved (fungal, bacterial) process for producing humus from industrial and other wastes. The process involves subjecting raw wastes to at least three and generally four stages of bacterial and fungal activity. In the first stage, activity is predominantly that of fungi. From this stage the wastes progress through a period of predominantly bacterial activity at mesophilic temperatures. The third stage is one of maximum bacterial activity in the thermophilic range (50°C or higher). The final stage is one in which actinomycetes are the important organisms. After this stage, the thoroughly composted, stabilized material is dried and is ready for use.

Design characteristics and operational information of the unit are discussed in detail, e.g., moisture control, pH, aeration, types of wastes to be treated, types of specific organisms used, etc.

Wylie, J. C.
"Composting"
Preprint of Paper to be presented at the Symposium on Treatment of Waste Waters to be held at University of Durham, Kings College, United Kingdom, 14-19 December 1959 (Pergamon Press)

A description is given of all phases of the composting process, with each step being thoroughly discussed. Fermentation, mass composting, segregation and preparation of compostable materials, and the use of sewage sludge are all treated. The author pays particular attention to the use of sewage sludge in lowering the C:N ratio. Examples are given of the use of multistage silos in composting. Rather than making use of rotational movement or of turning of windrowed compost after a number of weeks, in some plants the mixed wastes are hoisted to the top of a silo and dumped into the first of a vertical series of fermentation cells. After a fixed interval, usually twenty-four hours, the wastes are dropped mechanically to the next lower platform. The number of platforms usually varies from four to eight. The wastes are supposedly stabilized by the time they reach the bottom of the silo. The "stabilized" wastes are transferred to open sheds, in which the compost is "matured" within six to eight weeks. Dropping the material from level to level is supposed to provide sufficient aeration.

Gotaas, H. B.
"Materials Handling Methods for City Composting"
Compost Science, 1:5, Spring 1960

Since the composting process is not as yet fully mechanized, and since the content of refuse varies from city to city, any area adopting composting as a method of refuse disposal must design equipment for the specific operations to be performed. The wastes and conditions of the area must be considered, and the design tailor-made for the particular situation.

The article covers in detail the several steps in the complete composting process: refuse reception, separation, preparation of salvable scrap, shredding and pulverizing, decomposition and stabilization, and market preparation. The receiving pits must be able to handle peak loads efficiently, while segregation may be mechanical or by hand-sorting. The article spends a great deal of time describing the various methods of grinding, both before and after decomposition. The final product should pass through a 0.5 inch screen. If sewage sludge is to be composted, it should be added after the refuse has been sorted and shredded, and the moisture content should remain between 40 percent and 70 percent.

A summary of 12 major points for checking the design of any composting plant ends the article, and emphasis is put on design for a specific area, with possible adaptability to changes in refuse content kept in mind.

Davies, A. G.
"Composting Sewage Sludge with Municipal Refuse"
Compost Science, 1:9, Autumn 1960

The addition of sewage sludge can be of help in the composting of municipal wastes. However, little has been done along these lines except on the island of Jersey. The addition of sewage sludge to municipal refuse increases the nutrient value of the composted product. Pathogens in the sludge are killed by the heat produced in a properly conducted aerobic, thermophilic composting process. To keep the moisture content at the proper level, the sludge should be partially dewatered before being added to the refuse. In the operation at Leicester, England, a vacuum filter is lined with wood flour prior to the addition of digested sludge. The sludge cake and thin layer of the flour are cut off by a knife at each revolution of the filter. Experiments are being conducted with the aim of improving the process.

The use of sludge-refuse mixtures in composting adds little to the cost of refuse composting. It does, however, provide good savings in sewage disposal.

Golueke, C. G.
"Composting Refuse at Sacramento, California"
Compost Science, 1:12, Autumn 1960

The Dano process of composting has a long history of success in Europe and Asia, with 52 plants treating about 200 tons per day of refuse. At the time the article was written, a Dano plant had been operating near Sacramento, California since 1956. The steps in the process are: conveying, hand and magnetic salvage and sorting; grinding; composting in a biostabilizer; screening; secondary magnetic separation and grinding; air jet separation of inorganics; and maturation in windrows. The two grinders are of the hammer mill type. The biostabilizer is a slowly rotating drum, 10.5 ft in diameter and 76 ft long, and is equipped with air and water valves. It holds from 90 to 120 tons of ground refuse. A temperature of 140°F is reached. Final maturation is in the windrows. It involves two to three turnings.

Inoculums are unnecessary in the process. The final compost contains 1.25 percent N, 0.4 percent P_2O_5, 0.3 percent K_2O, and many trace elements. It has a high moisture-holding capacity. Costs are less than $3.25 per ton of raw refuse. This compares favorably with incinerators that have adequate air pollution control devices. The latter cost from $3.25 to $8.00 per ton to operate. (Editor's Note: The plant has been closed since 1963.)

McGauhey, P. H.
"Refuse Composting Plant At Norman, Oklahoma"
Compost Science, 1:5, Autumn 1960

One of the major drawbacks to the composting process in the U. S. is the fact that there has not been adequate equipment to make a mechanical process technically or economically feasible. The Naturizer Company, Norman, Oklahoma, has developed good equipment. It has a demonstration plant in operation (at time of article).

The body of the article is concerned with a description of the Naturizer plant. As in any composting plant, the major steps of the operation include receiving, sorting and salvage, grinding and mixing, decomposition, screening, baggage, and storage. The refuse is ground and pulverized after the salvage operations, and is conveyed to a tri-level digester for partial decomposition. The refuse is reground and sent to another digester, reground and then either is stored or is bagged for sale. The plant is capable of composting 35 tons of refuse per day. (Editor's Note: The plant has been closed for several years.)

Dobrouchkess, M. G.
"Composting Refuse by the 'Biotank' System"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 8, p. 14, March 1960

The plant has two parts: The refuse processing (screening, milling, separation) is done in a single building. The fermentation chamber (biotank) in which decomposition occurs is a windrow device which is movable along the windrow axis. The windrow is formed in a long circle through the discharge of processed refuse from a pivoting conveyor. The biotank is not a tank, but is a movable windrow shelter. The biotank system is more aptly described as a sheltered, forced-air windrow composting.

Anon.
"A New Composting Process for Refuse and Sludge - The Tollemache System"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 10, p. 22, December 1960

The Tollemache System, as developed at the refuse composting plant at Mabelreijn (Southern Rhodesia), is as follows:

Refuse Preparation: Refuse passes on a conveyor from the bunker to a screen for ash removal, then on another conveyor where the first magnetic separation and hand sorting to remove salvage and discard items are accomplished. A ballistic separator removes glass fragments and rocks. After the addition of water or sludge, the compostable material is discharged into composting chambers.

Composting: The fermentation "silos" or chambers have masonry walls open at the top and a perforated concrete floor which permits forced aeration. From time to time the compost is mixed and simultaneously pulverized by a traveling turner-mixer (similar to a rotary cultivator). This procedure is repeated until the compost leaves the chambers. After two weeks in a chamber, refuse compost has the following typical analysis:

ANALYSIS OF COMPOST

Organic Matter	58%	C:N Ratio		20
Moisture	50%	Phosphorus	P_2O_5	0.7%
Nitrogen	1.4%	Potassium	K_2O	1.1%

The capacity of the plant is 40 tons of compost per day.

The manufacturer is the Composting Company of Rhodesia, Ltd. (member of the John Laing and Son Group of Companies), Salisbury, Southern Rhodesia.

Wiley, J. S. and J. T. Spillans
"Refuse-Sludge Composting in Windrows and Bins"
<u>Journal, Sanitary Engineering Division, American Society of Civil Engineers, 87</u>:(SA3) 33, 1961

Successful composting was achieved in two runs at Chandler, Arizona. Ground refuse and refuse-sludge mixtures were used. The operation consisted of four windrows and 25 aeration bins. Run one was comprised of three groups, each including a 4- to 6-ton windrow and seven aeration bins containing a total of 4 to 6 tons. In run two, a single 2.7-ton windrow and four bins containing 2.8 tons were involved. The raw sewage sludge was quite weak, containing almost 99 percent moisture. Because of the small amounts of sludge solids added to the refuse, the composting essentially was that of refuse alone.

The refuse was only grossly sorted, and therefore had large amounts of ash and paper. Even so, good decomposition was attained both in windrows and aeration bins. Little difference was observed between the decomposition rates in windrows and bins. However, the use of the former appears to be more practical for a plant operation. The decomposing materials are turned by regrinding through the plant. The refuse was reground an average of five times. The time of composting, or of composting plus curing, varied from 29 to 43 days.

In comparison with laboratory mechanical composting, the two outdoor methods appeared to accomplish about the same decomposition in 30 to 40 days as was accomplished in mechanical units with continuous aeration and mixing in about nine days. Good quality refuse or refuse-sludge mixtures could be decomposed in windrows in about three weeks with five vigorous turnings plus about three additional weeks of curing in sheltered piles or windrows. In mechanical units, similar results might be obtained by composting for about a week, followed by three weeks of curing.

Much data are presented including temperature tables, oxygen and weight changes, and comparison of analyses of outdoor and indoor methods of composting. The raw refuse used for composting at Chandler was compared to the raw refuse used at Savannah, Georgia, in respect to amounts of volatile solids, C:N ratio, etc.

Eriksson, A.
"Waste Treatment at Hawaii's Oahu Prison"
Compost Science, 1:44, Winter 1961

A composting project has been in operation for eight years at Oahu Prison. Agricultural and processing wastes from the prison and from many companies on Oahu are composted. The materials are ground in a hammer mill and composted in windrows 10 to 12 ft wide by 5-1/2 to 6 ft high. A heavy duty hammer mill with an elevator is used to turn the piles weekly. Compost time is from 3 to 6 weeks, depending upon the raw material.

Compost is sold in four grades: a fine lawn dressing, a coarse tree-planting compost, a garden potting compost, and a loosely shredded mixture for use as mulch. The compost is packaged in four-ply, used paper bags obtained from a sugar company. It is sold in one- and two-cubic foot bags.

Dunn, S. and J. D. Emery
"Wood Wastes in Composts"
Compost Science, 1:26, Winter 1961

Four methods of outdoor composting of wood wastes were tested in bins, piles, and pits. The best method was found to be one involving the use of composting mixtures in 1- cu yd wooden bins. Second in line was the method involving the use of pits to which no water was added but which were occasionally flooded at certain times of the year.

Various manures and other materials were tested as aids in composting sawdust. The composting process generally required 1 to 2 years to complete the breakdown of the wood. The composted wood-waste mixture was analyzed. Nutrient deficiencies were compensated for through the addition of fertilizers to the end product. The tests were made by growing various types of plants in succession in the compost or compost-soil mixtures contained in wooden boxes or in greenhouse pots. Yields were determined and compared to each other and to a control (soil only) for each crop and for the accumulation of all crops.

Best yields were obtained from sawdust-hen manure contained in wooden boxes. The silage-sawdust mixture was second in amount of yield. Poorest results were obtained with the use of sewage-sawdust combinations. Hen manure or chopped green vegetation added to sawdust resulted in satisfactory yields.

Stahel, R.
"Report on Recent Results at the Refuse Composting Plant at Kuesnacht-Zuerich"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 11, p. 17, June 1961

The plant has two hammer mills and one Dano mixing drum (without a bio-stabilizer). Sludge is added to the refuse. The plant serves a population of 35,000. After 200 hours of operation, one-third of the hammers in the course mill were in need of replacement. Two men are sufficient for all operations, including windrowing and loading the compost trucks. The equipment cost was $84,000; operating costs, $8,380 per year. Plant hazards were a massive damage to the hammers by large pieces of metal in the refuse, and clogging of the mill by rags. Bridging-over at the throat must be prevented by smooth feeding.

Zambetti, T.
"The Refuse Treatment Plant of the Baden-Brugg Region (Switzerland)"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 11, p. 21, June 1961

The city decided to build a composting plant incorporating the SMG/Multibacto process. The plant consists of a bunker, a conveyor (iron removed by a magnetic pulley), multirotor grinder, first sieve, digester, and a second sieve. The fines are discharged beneath the sieve to a bunker. As the fine refuse leaves the bunker it is inoculated with a suspension of bacteria in water, or with sludge. The digester has the appearance of a *Nichols furnace*. After 24 hours the refuse is supposedly ready for use as compost. Chemical fertilizers (N, P, K) may be added by a battery of mixers to enrich the compost.

The plant serves a population of 100,000. The operation began in 1961 to 1962. The plant cost about $500,000. Operating costs are $3.50 per ton. (Editor's Note: According to Mr. Hans Wasmer (September 1966) who has first-hand information concerning the plant, the costs for construction and for operation were much higher than expected. The plant did not work satisfactory and was closed for about two years. The City of Baden was considering an incineration plant in 1966.)

Teensma, B.
"Studies of the Effect of Windrow Height on Composting Rate"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 11, p. 13, June 1961

Two windrows of well-mixed, homogeneous refuse were formed, one was 1.5 m high, the other, 3.0 m. The analyses revealed a few interesting points: Insulation is better in the large windrow and therefore the heat loss is less. Less organic matter was decomposed prior to turning in the larger windrow, and thus a greater supply of nutrients was available to the bacteria. An increase in activity resulted. Anaerobiosis was less intensive in the interior of the smaller windrow. Maximum CO_2 content of gases was 38.3 percent. The reason for the CO_2 concentration was that a greater portion of the organic matter had been decomposed before turning. Increasing the height of piles did not result in any difficulties. A high pile may be desirable provided good drainage is done and the compost is not too wet at the bottom. Strong anaerobic action is to be avoided.

Schulze, K. L.
"Continuous Thermophilic Composting"
Applied Microbiology, 10:108, February 1962

Results of an experiment conducted on the campus of Michigan State University showed that with the use of a 55-gal rotating drum pilot plant, it is possible under complete mixing conditions to provide aerobic decomposition of mixed organic waste materials in the thermophilic phase. The process is maintained by continuously adding raw material and removing composted material. A continuous air supply of 5 to 12 ft per day per lb of volatile matter contained in the unit is needed.

Raw material can be added every day or every other day in amounts up to 18 lb per 100 lb of decomposing material. Under equilibrium conditions the weight of the material removed should range from 65 percent to 80 percent of the weight of the raw material added. The average detention time ranged from 7 to 18 days, depending on the feed rate. Under these conditions, most of the pathogenic organisms in the material are destroyed with a controlled heat of 54° to 70°C. The compost was stored in open bins for 2 to 3 weeks, after which time the decomposed material did not reheat, had a pleasant odor, and did not attract flies.

The author recommends that a larger pilot plant consisting of two rotating drums (8 ft in diameter and 20 ft in length) be constructed and supplied with the necessary equipment for grinding, mixing, and conveying. Such a plant could handle a maximum of 5 tons of refuse per day. A more complete study could then be made which would include the value of the finished compost.

Teensma, B.
"New Guidelines for the Composting of Raw Ground Refuse in the Netherlands"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 16, p. 5, December 1962

Negative results were obtained after the application of compost to the soil. The causes of the damage were due to the change in the characteristics of the product.

Old Composting Guidelines, 1955: The height of the windrows should not be more than 2 meters. Moisture content of the materials during stacking should not be more than 50 percent. Duration of decomposition for winter refuse should be at least 8 weeks, and for summer refuse, at least 12 weeks. During decomposition the windrow should be turned once, preferably after about 4 weeks.

New Composting Guidelines, 1961: Compost windrows should not be higher than 2 meters. The top of the windrows should be rounded or roof-shaped to permit the runoff of rain. The windrows must be separate. The windrow area must be well drained. Puddle formation after rains must be avoided. The moisture content of the raw refuse at the time of stacking must be between 50 percent and 55 percent. The interior of all windrows must be checked every week. When zones have been formed, the windrows must be turned — as a rule about 2 to 3 weeks for the first time. Checks must be continued after turning. As soon as new zones form, turning must be continued until they disappear. When this stage is achieved, the compost is finished and may be piled in large stacks. A belt conveyor and a nail-covered concussion mill as a turning machine are recommended. The addition of 10 percent to 20 percent volume of ripe compost or peat to the raw refuse is advisable.

Giger, R.
"The Refuse Utilization Plant of the Werdenberg-Liechtenstein Region (Switzerland)" International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 16, p. 15, December 1962

The compost system in use is the Buehler method. The plant includes a grinder, sludge mixer, and an incinerator for burning screen rejects and animal carcasses. The plant serves a population of 40,000. Sludge is added to the refuse as a part of the composting process. Composting began in February of 1962.

Schulze, K. L.
"Home Composting Units"
Compost Science, 3:5, Winter 1963

The home composting unit could handle garbage and organic waste such as paper. Cans, china, and objects too large for the home grinder would have to be removed from the refuse. Consequently, a trash collection and disposal system for handling such materials would have to be operated by the community. To insure a high-temperature phase, the pile of material to be composted must be sufficiently large. A pile 8 to 12 ft by 4 to 6 ft should be sufficiently large. Inasmuch as only from 4 to 22 lb of refuse are produced per household per day, not enough refuse would be available to keep the pile at its minimum required volume.

If the traditional method of composting is varied so as to add raw material directly to the decomposing hot mass in the rotating drum, it would be possible to operate continuously at temperatures of 127° to 158°F. The smallest size unit on the market is the Sculin unit. It can handle from 15 to 30 lb of mixed raw material per day.

Jacobson, A. R.
"Specialized Equipment Used in European Compost System"
Public Works, 94:158, October 1963

Several types of refuse disposal equipment have been designed for use in European composting systems, but as yet none have appeared in the U. S. The processes involve from none to one or more of the following: screening, hand sorting, magnetic separation, and inertial separation. Whether or not these operations take place before or after the refuse is composted, depends upon which process is being used.

Wicker, W. J.
"A New Look at Composting"
Public Works, 95:131, October 1964

In 1964, M. W. Kellogg Company agreed with National Organic Corporation to design, engineer, and construct NORCO plants throughout the world. Westinghouse signed an agreement with the Naturizer Corporation. The author inspected the Kingston (Jamaica) operation (NORCO). (Editor's Note: It closed down in 1966.) The NORCO flow pattern is as follows: Truck → hopper → conveyor belt → hopper → grinder I (particle-size about 7 in.) → grinder II (particle-size, 3 in.) → hopper → dump truck → inoculation → composting area → stack in windrows 5 ft high, 10 ft wide, and 50 ft in length.

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The composting period lasts 3 weeks. The moisture content is 55 percent. The windrows are "turned" approximately 10 times during the 3-week period. The final moisture content is 5 percent. After 3 weeks, the compost is transferred to the processing yard for storage and distribution.

Reimer, L. G.
"Refuse Reclamation — A Solution to a Growing Urban Problem"
Reprint No. 6422, Westinghouse Engineer, November 1966

A description is given of the compost plant opened recently in St. Petersburg, Florida. (The Naturizer process is used.) The plant is owned and operated by the International Disposal Corporation, Shawnee, Oaklahoma, and was designed, engineered, and built by Westinghouse.

The plant has a capacity of 105 tons per day. It serves 55,000 people out of a total of 210,000. The contract with the city calls for: the handling of 100 tons of refuse per day during a 6-day work week in a nuisance-free manner. The city pays $3.24 per delivered ton with allowance made for variations in future labor and material cost. The flow pattern of the process is as follows: receiving area → segregation → pulverizer → grinder → cell 1 of digester (24 hr) → cell 2 (24 hr) → grinder → cell 3 (24 hr) → cell 4 (24 hr) → cell 5 (24 hr) → screen → yard. Arrangements are provided for recycling oversized particles. (Editor's Note: The plant was closed in 1968.)

Furness, J. F.
"Disposal of Household Refuse in Wet Gravel Pits"
Public Cleansing, 57:255, May 1967

The author describes tipping into water as a new but not yet fully accepted method of disposal. Wet pits are a serious problem in some districts, and at the same time, dry sites are becoming very scarce.

Experiments are described in which crude refuse (100,000 tons per year) was tipped in a 36-acre pit from 12 to 15 ft deep. A rapid increase of sulfide concentration up to 30 mg/ℓ was observed, and the development of very bad odors become noticeable.

The writer claims that the odor nuisance can be eliminated through inoculation with sulfur bacteria, providing aeration, chlorination, and the addition of sodium dichromate. The inoculation proved unsuccessful. Aeration was successful only at temperatures below 10°C. Chlorination was successful but expensive. The dosage was 9,000 lb for 3 acres in which 2,000 tons per week were dumped. The addition of sodium dichromate was successful, but it gave rise to leaching problems.

Bacteria and organic matter did not persist in the underflow ground water for more than 50 yards. No significant increase of sulfates or hardness was noticed. An appreciable increase was noted in the amount of free ammonia.

The author recommends that a pit be filled to water level within a seven-month period.

Anon.
"Pulverization Facility Has Capacity of 15 Tons an Hour"
Refuse Removal Journal, Solid Wastes Management, 10:33, July 1967

Tollemache Composting Systems, Ltd. manufactures the pulverizer. The cost is \$51,800 for the plant and \$0.14 per ton for operation. It is used in preparing refuse for landfill.

Gotaas, H. B.
"Compost-Plant Design and Operation"
The American City, 82, July 1967

A general description of a plant operation is given. A typical plant operation involves receipt of the refuse; segregation and separation of salvable rags, paper, scrap iron, nonferrous metals, and glass; removal of noncompostable material; preparation of the remainder by screening and grinding or shredding to the desired particle size; and the biological decomposition and stabilization by composting.

Material in windrows or bins is turned every few days to maintain aerobic conditions. Aeration can also be supplied by the use of mechanized horizontal or vertical silo-type digesters in which the material is moved mechanically more or less continuously. The compost is prepared for marketing by screening and milling, by fortifying with additional nutrients when desired, and by bagging.

Refuse and Sewage Sludge

Burke, C. E.
"The Utilization of Organic Domestic Wastes"
Joint Conference: The Institute of Public Cleansing and the Institute of Sewage Purification, Manchester, 14 October 1949. Journal and Proceedings, Institute of Sewage Purification, Part 4, 1949

The paper is concerned with a proposed scheme for composting the refuse and sewage sludge from a town having a population of about 500,000. It was not the intention to discuss the manurial or fertilizing value of the organic wastes in sewage or household refuse or of composts prepared from such waste materials, but to accept the fact that they have a definite value when added to the soil. The paper draws attention to the fact that the last word on the use of organic fertilizers rests with the farmer, and that if he were satisfied, he would create the market. All three products, viz., refuse, dried sludge, and a compost of both would sell as a fertilizer. Therefore it depends on circumstances and site conditions as to the right decision regarding the timeliness of the initiation of a composting operation. The article also detail plant operations, machinery, labor costs, profits, and difficulties.

Anon.
"Economics of Composting Sewage Sludge and Household Refuse"
Commonwealth Engineer, 2 April 1951

Two types of wastes were considered, one of which was a combination of digested sludge and household refuse. Using this type would result in 1,000,000 tons of compost a year. The second type was one of sludge screenings and household refuse. This type would result in 5,000 tons of compost a year. The composting process was conducted in circular cells ventilated from below, in which alternate layers of crushed refuse and sludge or screenings were deposited. Steps in composting are:

1. the absorption of the liquid or semiliquid sludge by the refuse;

2. fermentation, which may be aerobic or anaerobic, takes place at 170°F, and evaporation of water from the sludge;

3. retention of the mixture in cells for about a week;

4. removal of the composting refuse from the cells followed by stacking for a period not less than 3 months to mature the compost.

In preparing sludge compost, it was not possible to find means by which the refuse could be induced to absorb more than its own weight of wet sludge.

Crops benefit from the constituent chemical elements of compost, viz., nitrogen, phosphorus, and potassium — modest though these components be in proportion to the total dry matter. The chief benefit in the use of compost is the resulting improvement in soil texture and moisture — holding capacity.

The final decision of the London County Council to abandon the production of sludge — refuse composting was arrived at with a considerable degree of regret — it having been made on a purely financial basis as affecting the County of London alone.

Gutteridge, H.
"Refuse - Sewage Composting - Engineering Aspects"
Transaction of Society Engineers, Inc., 17 Victoria Street, Westminster SW1, Great Britain, pp. 135-161, December 1952

The article proposes a method of refuse-sewage composting, and describes the development of a plant for a city of 500,000. Five pulverizing stations would be located in the city, giving a maximum haul of about three miles for the collecting vehicles. Each station could have a capacity of about 100 tons per day. The pulverized material could be transported to 3 or 4 composting stations at existing sewage plants. The best place for mixing the refuse and sewage sludge is in aeration cells, because the pulverized refuse readily absorbs liquid when lightly stacked, the material acts as a filter to retain the solids in the sludge, and the condition within the cell remains aerobic because of adequate draining.

The author gives a thorough description of each of the following aspects of operation: receiving refuse, separating of salvable materials, pulverizing, aerating cells, mixing of refuse and sewage sludge, and using maturative beds. He delineates physical and financial considerations to be considered.

A discussion follows, in which the opinions of attending experts are given. The general conclusion was that engineers, biologists, and chemists must work together in solving problems of refuse disposal. Little is known, and the field is wide open for much research.

Wiley, J. S.
"Refuse and Refuse-Sludge Composting"
Reprint No. 347, Journal, Boston Society of Civil Engineers, January 1962

Results of basic and applied research studies by various institutions in the U. S. show that composting of organic wastes is technically feasible either in mechanical units or in windrows. The highly satisfactory results of research on the composting process in the U. S. indicates the need for the construction and proving of full-scale composting plants.

Dozens of active plants compost refuse and refuse-sludge in Europe. The Dano biostabilizer system provides refuse sorting, composting with continuous tumbling and aeration for about 3-5 days, and refinement and curing of the compost. Drying and bagging are not usually provided, since the compost generally is sold in bulk at a price of only $1.45 to $2.40 per ton. The rasping system is named for the grinder developed by the Dutch V.A.M. (Refuse Disposal Company) and made by Dorr-Oliver, N.V., Amsterdam. The main steps in the "rasping" process are refuse sorting, grinding, and refining, followed by windrow composting for 3 to 5 months. Demand for compost usually exceeds the supply in Europe.

When sewage sludge is added to the mixed refuse, the final compost is improved in both structure and nutrient content.

A discussion is given by two Boston engineers in which one states that composting in the area seems practical, while the other takes a more skeptical line. The latter's skepticism is based on the fact composting hasn't succeeded to any great extent in the U. S.

Schroder, W.
"Dewatering and Drying as a Prerequisite to Composting of Sewage Sludge"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 14, p. 23, April 1962

The following dewatering processes for attaining the recommended final moisture content of 70 percent are discussed: sludge sieves, sludge centrifuges, sludge filters, vacuum filters, and pressure filters.

The conclusion is that the only dewatering procedure to be recommended for dewatering normal sewage sludge is vacuum filtration. In subsequent treatment, the moisture content of the dewatered sludge may be reduced to a final moisture content of 30 percent to 40 percent. This step can be accomplished with the use of a rotary drum dryer, a honeycombed band dryer, a selective dryer, or a belt dryer. Costs are given for the dryers.

Straub, H.
"Processing Technique — Practical Conclusions from Scientific Research"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 14, p. 1, April 1962

Certain advantages result from the joint processing of refuse and sludge. Combined refuse-sludge processing should be contemplated only when equivalent amounts of each per capita can be treated. The techniques for dewatering should be developed with the aim of eliminating the attendant high costs. Both incineration and composting are discussed.

Fundamentals (Environmental Factors, etc.)

Golueke, C. G., B. J. Card, and P. H. McGauhey
"A Critical Evaluation of Inoculums in Composting"
Applied Microbiology, 2:45, January 1954

Garden soil, horse manure, partially decomposed organic material, and a commercial preparation of special bacterial cultures were tested to study the effects of adding these inoculums to composting material. The inoculums failed to benefit the composting process because of the adequacy of the microbial population indigenous to the material, and because of the nature of the process itself. The composting process proceeded with equal rapidity on inoculated or uninoculated material – adding bacteria to the inoculums did nothing to hasten the onset of decomposition.

The article discusses the types of bacteria present. Acid-producing bacteria were the first to appear. Thermophilic bacteria and fungi were second in the succession. In the final stages, as the temperature began to drop, actinomycetes became the dominant organisms.

Wiley, J. S.
"Progress Report on High-Rate Composting Studies"
Engineering Bulletin, Proceedings of the 12th Industrial Wastes Conference, Series No. 94, pp. 590-595, 13-15 May 1957

Mr. Wiley reported in 1955 that better decomposition might be attained by preventing the maximum temperature from reaching the high values (150° to 168°F) which normally occur in insulated units. A few runs were made in which a water jacket was used to cool compost during the thermophilic portion of the composting process. Results indicate that best decomposition may occur at temperatures somewhat less than those usually attained in uncooled units. It appears that a much better decomposition results if the temperature is kept at a maximum of about 130° to 140°F. Results obtained with the maximum temperature kept at 145°F were somewhat better than those based on a decomposition attained in noncooled units at maximum temperatures of about 153° to 162°F. Cooling below 120°F does not appear to be desirable.

The article deals with heat production from composting and its possible use, and gives tables and figures for information. Heat production in a laboratory batch composting of refuse for eight days amounted to roughly 3000 btu per lb of volatile solids lost or decomposed.

A study was made to determine the effect of preheating on the composting process. Two units were filled with refuse; one was heated to 128° to 132°F throughout an eight-day run. Decomposition in the heated drum was only 1/9 that in the control drum as judged by CO_2 production, and only 1/4 that of the control drum as judged by destruction of volatile solids. These results indicate that material to be composted should not be preheated to the thermophilic level in order to speed up decomposition.

Nesbitt, J. B.
"Composting Municipal Refuse"
Public Works, 90:166, February 1959

The article is a shortened form of a report made by Mr. Nesbitt. The several factors fundamental to the success of the composting process, namely, segregation, shredding, C:N relationships, aeration, use of inocula, and time required for composting are described briefly. Investigations included first-hand visits to European installations at which the composting process is used as a method of municipal refuse disposal.

Cost data are listed in a chart, but no allowance is made for costs of collection or sale and disposal of the end product.

Glathe, H.
"Biological Processes in the Composting of Refuse"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 7, p. 8, July 1959

A research group was established at the Gieseen University to study the scientific and practical fundamentals of the composting of refuse and sludge from the point of view of agriculture, microbiology, and human and veterinary hygiene. Research has revealed that the inoculation of raw garbage with microorganisms adds nothing to speed up the composting process. Raw refuse-sludge mixtures contain an enormous primary flora, and any attempt to enrich the material with bacteria would be a superfluous gesture. Heavy inoculations with azotobacter, or nitrogen-fixing bacteria, were tried at Baden-Baden. The organisms did not survive.

The theory that inocula help prevent the formation of anaerobic zones in the piles is erroneous. The black areas are due to oxygen deficiency and not to a lack of certain organisms.

Schulze, K. L.
"Rate of Oxygen Consumption and Respiratory Quotients During the Aerobic Decompostion of a Synthetic Garbage"
Compost Science, 1:36, Spring 1960

Tests involving the use of a closed lucite cylinder, 10 inches in diameter, and 19 inches long and having a capacity of 0.75 cu ft were conducted at Michigan State University. Controlled, measured amounts of air were fed into the composting bin, and recordings were made of the amount of effluent air, temperature inside the cylinder, and of other important factors. Freshly ground garbage was used in all of the runs.

Oxygen consumption rates were computed by determining the difference in oxygen concentration between the incoming air and that of the exhaust air at known rates of air supply. The respiratory quotient – the amount of CO_2 produced divided by the amount of O_2 consumed – remained at one. Curves showing the temperature and oxygen consumption rates over the complete decomposition cycle show a definite relationship between temperature and oxygen uptake rates over the full range of temperatures reached in the experiments. The oxygen consumption rates varied directly with the temperature.

The average time needed for the active decomposition was 14 days, and an average of 40 percent of the volatile matter was oxidized during this time. To maintain aerobic conditions during peak oxygen demands, an air supply of 18,000 to 20,000 cu ft per ton initial volatile matter per day was found to be necessary.

Horstmann, O. and H. Sachsse
"Composting Urban Refuse with Various Additives"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 9, p. 12, September 1960

Experiments were begun in 1957 at the Heidelberg composting plant to determine if decomposition of urban refuse from the Dorr-Oliver rasping machine could be influenced by the admixture of partly ripe or mature summer or winter compost or stable manure.

Schulze, K. L.
"Relationship Between Moisture Content and Activity of Finished Compost"
Compost Science, 2:32, Summer 1961

The oxygen consumption rate, R, in mg of O_2 per mg of volatile matter per hr is an accurate indicator of the progress of the composting process. During the composting process, oxygen consumption increases directly with temperature, and ranges from 1 to 5 mg per gram of volatile matter per hr at temperatures ranging from 80°F to 145°F.

Oxygen consumption by finished compost was measured by means of the Warburg technique. It was found to increase with increase in moisture content until a level of 70 percent was reached, after which there was a slight decline. It ranged from no measurable rate at 11.2 percent moisture to 0.756 mg/gram of volatile matter per hr at a 60.4 percent moisture content, and then declined. The temperature was 20°C. The maximum rate of uptake of oxygen by finished compost was 1/7 that by decomposing material at the optimum moisture content. Therefore, finished compost can be safely shipped in paper bags, provided the moisture content of the material is below 20 percent.

Graphs and tables are given for components of garbage mixture, relationship between moisture and volume of finished compost, and the relationship between moisture and oxygen uptake rate of finished compost.

Snell, J. R.
"Proper Grinding — Key to Efficient Composting"
Compost Science, 1:9, Winter 1961

Grinding is essential to efficient composting, both in terms of space and of time. It results in the exposure of surfaces to decomposing organisms, in mixing, and in aeration. Proper particle size is important. Wet materials should receive a coarser grind than dry materials. Materials to be composted in a mechanical digester may be ground finer than those to be composted by the windrow method.

The author prefers wing hammer mills equipped with a large throat and constructed ruggedly. He advocates double grinding or two-state grinders. Wear is rapid and special alloy steels are advocated along with the rebuilding of hammers with special welding rods. The author believes that experience gained by grinder manufacturers will result in improved design, especially for handling U. S. refuse.

Horstmann, O. and E. Engelhorn
"Does Aeration Accelerate the Composting Process?"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 11, p. 1, June 1961

Experimental results with ground refuse from Heidelberg showed that supplemental aeration improved windrow composting. In the smaller (1.5-m high) windrows the material packed less; aeration in the pile interiors was greater; the temperature increased more slowly, stayed longer in the range below 55°C (supposedly a range favorable for decomposition), and did not rise as high as in the larger (3.0-m high) windrows. Particle size, pore volume, density, and Neubauer pot trials indicated that more intensive decomposition occurs in the smaller than in the larger windrows.

Because of area limitation, large cities with high refuse yield have to avoid small windrows in composting. The experiments showed the advantages of small windrows to be slight. While decomposition probably occurs somewhat faster in 1.5-meter than in 3.0-meter windrows, the increased space required is not offset by the decrease in time of composting. If a plant must use 3.0-m high windrows due to lack of space, provision must be made for supplementary aeration. Air channels cannot substitute for turning.

Pöpel, F.
"Effects of Moisture and Oxygen Contents on Refuse Composting"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 13, p. 19, December 1961

Subjects covered in this bulletin are the influence of wetting refuse on respiration and multiplication of microorganisms, the effects of different moisture contents, the comparative effects of water and sewage as refuse wetting agents, the effects of adding sewage sludge to refuse, the degree of rotting of previously composted refuse, the degree of rotting with and without self-heating of the refuse, the effect of variation in oxygen supply, a comparison of methods for measuring temperature in Dewar flasks for laboratory determination, the effects of quantity and ventilation in Dewar flasks, the effect of varying the proportions of refuse and sludge in mixtures, and a comparison of activated sludge, sewage, and water as means for wetting refuse.

The author gives some results and emphasizes that these laboratory results should be checked on a pilot plant.

Niese, G.
"Experiments to Determine the Degree of Decomposition of Refuse Compost by Its Self-Heating Capability"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 17, p. 1, May 1963

The following experiments were conducted: heat loss in self-heating, self-heating capability of various refuse and refuse compost samples, and microbial counts and self-heating capability.

The experiments demonstrated the self-heating capacity of organic matter with the use of an adiabatic apparatus (no heat exchange with the surroundings). The heat loss resulted in temperature differences as high as 35° to 40°C.

Public Health Aspects

Knoll, K. H.
"Composting from the Hygienic Viewpoint"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 7, p. 10, July 1959

The author concludes that hygienic requirements are largely fulfilled by the regulated composting of refuse and sludge. The biological self-purification processes are carried out by composting. They eliminate the hazardous characteristics of wastes. It may be possible to meet simultaneously the requirements of the hygienists, technicians, and farmers by regulating the temperature and moisture content of the wastes to be treated.

Farkasdi, G.
"Contribution on the Microbiology of Composting"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 13, p. 2, December 1961

The report gives a cross section of studies made on the microbiology of composting. Waksmann and Feher showed that molds play an important role in the decomposition of organic matter. Rhode demonstrated the intensive proliferation of fungi throughout piles of composting material set up as windrows. He showed the existence of a close relationship between the amount of oxygen available and the number of mold fungi; as well as the relation between the incidence of fungi and moisture content and temperature level. In his work with animal pathogens, Strauch demonstrated that paratyphoid, hog erysipelas, and psittacosis agents were completely killed off under practical composting conditions. Bornkessel in his parasitological studies showed that the use of raw sludge in vegetable gardens and orchards results in a direct health danger to man.

Wiley, J. S.
"Pathogen Survival in Composting Municipal Wastes"
Journal, Water Pollution Control Federation, 34:80, 1962

The author presents a well-referenced review article having a 23-item bibliography.

Pathogen destruction during the composting process occurs primarily as a result of thermal kill and kill by antibiotic action or by the decomposing organisms and their products. The following table gives a list of key pathogens and their thermal death points:

TIME-TEMPERATURES REQUIRED FOR ORGANISM DESTRUCTION

Organism	Destruction Temperature (°F)	Time at Temperature (Minutes)	Destruction Temperature (°F)	Time at Temperature (Minutes)
Salmonella typhosa	131-140	30	140	20
Salmonella sp.	131	60	140	15-20
Shigella sp.	131	60	-	-
Ent. Hystolica Cysts	113	Few	131	Few Seconds
Taenia saginata	131	Few	-	-
Trichinella spiralis Larvae	131	Quickly	140	Instantly
Brucella abortis, Br. suis	144-145	3	131	60
Micrococcus pyogenes var. aureus	122	10	-	-
Streptoccus pyogenes	129	10	-	-
Mycobacterium tuberculosis var. hominis	151	15-20	152.6	Momentarily
Corynebacterium diptheriae	131	45	-	-
Necator americanus	113	50	-	-
Ascoris lumbricoides Eggs	122	60	-	-
E. coli	131	60	140	15-20

The use of compost in the deep-litter method of chicken raising almost entirely eliminates cecumcoccidiosis or limits it to a benign form with practically no mortality. Antibiotic activity does occur in composting and is as important as the time-temperature relationship in eliminating pathogens. A description of experiments performed by Knoll (K. H. Knoll, "Compost Preparation from the Hygienic Viewpoint," Intern., Congr. on Disp. and Util. of Town Refuse, Schvenigan, mimeo. (Brit.) 12 pp. 27 April - 1 May 1959) is provided as evidence.

Parrakova, E.
"Hygienic Criteria of the Evaluation of Refuse Compost"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 16, p. 10, December 1962

Emphasis is placed on the coli titer. The destruction of coliform bacteria permit the assumption that the less resistant pathogenic bacteria are also destroyed. In addition to the coli titer, a titration for Clostridium perfringens, for mesophilic bacteria, for mold fungi, and for actinomycetes should be made.

An unobjectionable production should have an ammonia content less than 1 percent to 2 percent of the total content of nitrogen and a corresponding coli titer of less than 0.01.

Hartman, R. C.
"Composting Controls Flies"
Reprint from Pacific Poultryman, February 1963

The Prohoroff Ranch at San Marcos, California, is one of California's largest egg producing units. It has been situated in one location for some years. The operation has no fly problem due to a program of composting the droppings. From 70 percent to 75 percent of the composting takes place beneath the cages. The process begun under the cages is completed within four to five weeks after the manure is removed and stacked outside the bird shelters.

Removal of the manure from the egg rooms is a twice-a-year task. At these times the manure is carted to a selected area and there is stacked into a mound 3 to 4 ft high. Not all of the manure is removed from the shelters, however. The lowermost six-inch layer of manure is left in the shelter. It is loosened and leveled to form a pad about six inches high. Leaving this layer is considered to be the most important aspect of the program. The composted manure pad is fairly dry, and therefore can absorb excess moisture from the droppings. The pad is sufficiently broken up to permit aerobic conditions. The droppings are dumped in an area to form a mound about 3 to 4 ft high.

Prohoroff estimates that if he followed a weekly cleaning program, his costs would be from $60,000 to $70,000 a year. As a result of composting, he has an easy-to-handle organic fertilizer, the sale of which returns enough money to cover his costs, overhead, and maintenance of equipment to handle the manure. (Editor's Comment: The article glosses over many undesirable features.)

Analytical Procedures

de Groote, R.
"Analysis and Evaluation of the Quality of Refuse Compost"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 3, p. 3, October 1957

Analysis and evaluation of refuse compost is broken down into the following categories: sampling, chemical analysis, physical analysis, microbiological analysis, photophysiological tests, and interpretation of the results. Each item is described in detail.

Gerretsen, F. C.
"The Determination of Domestic Coal in Refuse Compost"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 5, p. 10, August 1958

The content of more or less burned household coal in refuse compost varies from about 6 percent to 30 percent, depending upon the time of the year in which the raw material was collected. Such coal residues should not be included with organic substances useful to agriculture.

Two methods are given for determining the coal content: In the first method the decomposable organic substances (protein, humus, lignin, hemicellulose) are separated by boiling the compost in dilute H_2SO_4 and H_2O_2. The residue is extracted with dilute NaOH or NH_4OH. The remaining cellulose is dissolved in Schweitzer's reagent (ammoniacal solution of cupric hydroxyde). Domestic coal and ashes are left as residue. The carbon content of this residue is determined by combustion.

In the second method, the decomposable organic substances are separated with the use of the Scharrer-Kuerschner reagent (a mixture of trichloracetic acid, acetic acid, and nitric acid). Protein, lignin, humus, and most of the hemicelluloses dissolve in this reagent. The residual cellulose can be separated either with Schweitzer's reagent or by hydrolysis with diluted H_2SO_4. The residues are ash and coal.

Both methods give good agreement, therefore the method that can be the more conveniently performed may be used.

The reagents used in the methods are described in detail. Fatty substances in the material should be removed by extraction prior to beginning the separation. The so-called useful organic matter may be readily calculated by subtracting the weight of domestic coal, ash, and CO_2 from that of the original weight.

Tietjen, C. and H. J. Banse
"Structural Analyses of Compost Piles"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 8, p. 1, March 1960

A structural analysis made of compost piles with the compressed air pycnometer (of von Nitsch) and with a special apparatus developed by W. Sauerlandt showed the existence of definite differences between samples of stable manure composted for two, four, and six months. Only slight differences could be detected in the structure of compost cured for six and that for nine months. However, significant structural differences were noted between materials taken from various strata within a given pile.

Tietjen, C. and H. J. Banse
"Strukturuntersuchungen an Kompostmieten" (Investigation on Change of Structure in Compost-Stacks)
Special Reprint from International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 8, p. 3, March 1960

I. R. Snell investigated the air demand of compost stacks. A description is given of the special apparatus used in measuring water volume, oxygen, and pore size in a compost heap.

Anon.
"Simple Control Test Which Can Be Made By Compost Plant Operations"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 9, p. 16, September 1960

The article lists several control tests. Among them are:

1. Determination of hard particles: The refuse is put through a sieve having round holes and mesh size of 6.8 mm. The maximum percent of particles larger than 6.8 mm which may be present in compost destined for gardening use is glass - 0.05 percent, ceramics - 0.10 percent, coal and slag - 0.30 percent, and iron - 0.05 percent.

2. Determination of moisture content: The material is dried at 105°C. Special attention should be given to the method of sampling.

(Editor's Note: The determination of moisture content is not according to the DIN Norm. At present the DIN Norm generally is used in all European Institutes.)

Keller, P.
"The Significance and Methods of Evaluation of the Maturity of Refuse and Refuse-Sludge Composts"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 10, p. 5, December 1960

Compost is considered to be mature when the available carbon has been largely consumed and the decomposition proceeds only very slowly. Better results are obtained in agricultural applications with the use of mature compost rather than with immature composts or raw wastes. The ultimate aim of compost application, viz., to increase the humus content of soil, can be attained only with the use of mature composts.

The degree of maturity can be determined by relying on the physical characteristics of the composting material, i.e., earthy odor, dark color, fluffy structure, low specific gravity. Conclusions dependent solely on these criteria can be quite erroneous.

Compost may be judged to be mature if after turning and moistening, it no longer spontaneously heats up. This method is simple, practical for compost plants, and is reliable. Degree of maturity may be based on chemical analysis. The use of the C:N ratio has its limitations in operations involving urban wastes, but it can be used to evaluate composting of homogeneous materials. Relying upon NO_2-N and NO_3-N tests can lead to unreliable conclusions. Cellulose content is a good index and is the best suited of the chemical tests. Humus chemistry is not sufficiently advanced to permit its use in the determination of degree of maturity of compost.

Biological tests based upon the presence of earthworms may be very misleading. Microorganism counts, CO_2 production, and O_2 consumption may give comprehensive indications — the latter two being of greatest importance. Plant growth tests are subject to appreciable errors, and should be used only in conjunction with other techniques.

Anon.
"Tentative Methods of Analysis of Refuse and Compost"
Municipal Refuse Disposal Public Administration Service, 1313 E. 60th Street, Chicago, Illinois, 1961

The publication covers the following: Initial sampling, and tests for: moisture (oven drying, infrared, and toluene distillation methods), volatile solids and ash, lipids (ether extracts), liquids, crude fiber, sugars, starch (anthrone-sulfuric acid and direct acid hydrolysis methods), carbon, nitrogen (organic, ammonical, and Kjeldahl-Wilfarth-Gunning methods), protein, carbon-nitrogen ratio, phosphorus (phosphate), potassium (flame photometric and sodium tetraphenyl borate methods), hydrogen-ion concentration (pH), gross calorific value, net calorific value, sulfur, and hydrogen and carbon.

A compilation of proposed methods for the examination of solid and semisolid wastes, particularly of domestic refuse, is found in the Appendix. The tests described were selected because of practical experience with them in several comprehensive municipal studies. Several of the methods of testing were developed or adapted for use by the Technical Development Laboratory Communicable Disease Center of the United States Public Health Service in Savannah, Georgia.

Horstmann, O.
"Determination of Maturity of Compost"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 13, p. 7, December 1961

Determinations of the degree of maturity of a compost may be based on the external characteristics of the compost (color, odor, and structure), the decomposition status, physical analysis, chemical analysis, biological analysis, and crop tests.

Factors of importance in the chemical analysis are weight, volume, pore volume, and particle size. In the chemical analysis they are C:N ratio, nitrogen fractions, cellulose content, readily decomposable organic substances, and humus materials. In the biological analysis they are ratio of consumption of O_2 to the production of CO_2, self-heating capacity, number of themophilic and mesophilic bacteria, shifting of pH, inhibitory action on Azotobacter, and count of microorganisms.

Use of Compost and Sewage Sludge on Land

Clark, H. W.
"The Fertilizing Value of Sewage and Sewage Sludge--A Sanitary and Economic Problem"
Reprint from the Monthly Bulletin of the State Board of Health of Massachusetts for December 1913, Wright and Polter Printing Company, Boston, 1914

The total amount of fertilizing and fatty matter in each 1,000 gallons of American sewage is not worth more than 6 or 8 cents. About half of the fertilizer content is in the NH_3 in solution. There is no way this can be used except by application of the sewage to land. All experience with sewage farms show that only under the most favorable conditions can they manage to pay operating expenses.

To reclaim the 2,400 lb of sedimentable matter in a million gallons of sewage, which is worth from $15 to $18, the sludge must be dried, pressed, and subjected to a process for the separation of grease from the fertilizing constituents. The grease can become an article of commerce and the sludge of real agricultural value. However, this is a costly procedure. The nitrogen, phosphoric acid, and other plant nutrients generally are in a less favorable form than are the same materials in commercial fertilizers. However, it seems inevitable that sewage sludge will become of greater agricultural value than it is at present, especially as a base for the production of a fertilizer enriched by the addition of potash, phosphate, etc.

Interim Report by Inter-Departmental Committee to Study Utilization of Organic Wastes
"The Utilization of Organic Wastes in New Zealand"
New Zealand Engineering, 3, June 1948

Farmers and gardeners will buy compost only if it can be shown that it will pay them to do so. Municipalities will make compost only if they are assured a market for the product, and if they are shown how to make it at no added cost. The gradual loss of soil humus leads to inferior quality in plants. This in turn leads to deficiency diseases in livestock from the consumption of deficient food grown in unfertile soil. An efficient method of composting produces sufficient heat to destroy most weed seeds and pathogenic bacteria. Therefore, there would be no danger to plant, animal, or human health if compost made from sewage and/or garbage was used as a fertilizer. The manurial value of compost rests on its water-holding power, its effect on soil structure, its supplying of nutrients, its supplying of energy for nitrifying bacteria, and its serving as a suitable medium for mycorrhizal association where these are necessary.

Anon.
"Soil, Sewage Sludge, and Plant Growth"
The Water and Sanitary Engineer, p. 375, March 1951

Sewage sludge can be substituted for farmyard manures or green-manuring, and is perhaps the cheapest form of organic material that can be applied to the land. Improvement of the mechanical properties of the soil can be gained through the application of dried sewage sludge over a period of years. To provide for aeration of the soil, dried sewage sludge should be used in adequate applications with a view to introducing porosity and a granular structure to the soil. Light, loose, and impoverished sandy soils can be made fertile by applying sewage sludge as a humus.

Using sewage sludge as a base for producing a compost with other refuse has proved to be economically unfeasible. Composting involves aeration that does not easily lend itself to mechanization. The cost of the labor which would be required makes the price of the product too high.

Givens, H. D.
"Report of Experimental Usage of Compost Material"
Private Communication to O. Dwyer, Director of Services, City of Berkeley, California, December 1952

The Parks Department of Berkeley received approximately 45 cu yd of garbage compost from the city's compost plant. Of this amount, 10 to 12 cu yd were applied to soils in several grass and flower areas in the parks and was used in special experiments.

On 8 August 1952, the compost was applied to two areas approximately 75 ft x 30 ft each. The soil was of a very poor grade and was very heavy in structure, consisting principally of adobe and clay. Grass was planted and the areas were watered when necessary. The compost assisted materially in the mechanical improvement of the soil and in increasing the soil's moisture-retaining qualities. However, the grass grew and developed slowly and retained a yellowish-green color. The compost had improved the moisture-retention ability of the soil, but there was a considerable lack of available nitrogen and phosphoric acid. The compost was added to two large flower bays in front of the city hall, and pigmy marigolds were planted in the soil about two weeks later. At the normal flowering time, the plants showed practically no bud development, but with the addition of nitrogen and phosphorous, both plants and flowers quickly developed. The soil became very spongy and the moisture-holding ability improved greatly, but there was again a lack of available nitrogen and phosphorous for the soil.

In all experiments, the compost materially increased the moisture-retention ability of the soil, and the soil body showed improvement. Nitrogen and phosphoric acid were lacking in all samples of the compost.

Preshuda, H. J.
"Returning Wastes to the Soil"
Reprint from Chemurgic Digest, April 1953

A summary is given of the problem of soil depletion and the part the humus from the composting process in the rebuilding of soils is given. Various composting methods are described. It is noted that these methods, while successful in Europe for years, are still in the developmental stage in the U. S. and that many problems have to be worked out.

Wood wastes and stubble mulching for use in developing the soil are discussed. The article points out, however, that the effects of organic residues on the soil are not completely understood, and that much more research is needed.

Kendall, R. W.
"Special Report on Organic Materials, Composts, and Agricultural Minerals as Used as Soil Amendments and Fertilizers"
Special Report to P. R. Gadd, J. G. Boswell Company, Corcoran, 1955

The report is a compilation on the subject of the use of organic materials as soil fertilizers. Such topics as soil, soil composition, humus, soil microorganisms, C:N ratio, composting, organic economics, and composting practice are covered.

Heukelekian, H.
"Report to the Government of Israel on the Agricultural Utilization of Sewage"
Expanded Technical Assistance Program, FAO Report No. 559, Rome, October 1956

The report encompasses the following topics: problems recommended for study, recommendation for a program of agricultural utilization of sewage, regulation on the utilization of sewage for farming, general survey of the problem, sewage treatment and utilization, disposal and utilization of industrial wastes, stream pollution, and garbage and sludge composting.

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Westrate, W. A. G.
"What is a Good Refuse Compost?"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 1, p. 11, November 1956

A good compost should directly increase the productivity of the soil during the first two years, maintain the soil in a good condition, and increase the fertility of the soil over a long period. The beneficial effect depends upon the nature of the soil, of the climate, and of the methods of cultivation. The compost should be free of impurities. While the impurities do not have a direct influence on the compost as a fertilizer, they do make the product less attractive and sometimes unusable.

A ton of compost intended for horticultural use should not contain more than 0.5 kg of glass fragments, not more than 0.5 kg of ceramic (pottery) fragments, and not more than 5 kg of coal and slag, and no iron. If used for agriculture compost, the amounts of these materials can be 10 times as high without rendering the product unusable.

Springer, U.
"The Evaluation of the Organic Matter in Humus Fertilizers"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 1, p. 16, November 1956

A commercial humus fertilizer should be required to have at least 25 percent active organic substance. (Active organic substance is the difference between the total organic substance and the inactive substance, i.e., the humus carbon.) Total organic substance is based on loss on combustion. Salts which volatilize during combustion should be eliminated first. The concentration of pure organic substance is defined as the difference between the total loss from combustion and the calculated amount of salts.

A detailed description is given of a method for the determination of the percentage of inactive material.

Klerk, E.
"The Use of Refuse Compost in Viniculture"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 2, p. 3, April 1957

Compost is an economical source of humus. Of the costs involved in composting, 8 percent is for transportation, 44 percent for the composting process, 32 percent for screening, 5 percent for removal of debris, 7 percent for machinery, and 3 percent for interest.

The use of compost in viniculture results in an optimum regulation of the water content of the soil, in an increase in amount of water absorption, and in affecting the soil such that steep slopes (50 percent inclination) can be cultivated mechanically. It reduces the danger of extensive erosion even at rains as heavy as 70 mm in 20 minutes. The quantity and the quality of the vines are enhanced.

Anon.
"Composting and the Use of Refuse Compost in the Netherlands"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 2, p. 8, April 1957

The article consists of a brief summary of a brochure published in the Dutch language. In 1957 more than 25 percent of all urban refuse was subjected to composting.

Cosack, J.
"The Reforestation Experiment at the Zonser Heath"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 3, p. 8, October 1957

The fallow soil (sand dunes) was treated with compost, the amount of compost ranging from 0 (control) to 75 tons per hectare (one hectare is 2.47 acres). The following table lists test results:

RESULTS OF 13 TESTS DURING 1953-1954

tons per hectare	Height of Pines (cm)		
	1954	1955	1956
30			
45	8.6	18.8	49.6
60	9.6	28.3	58.2
75	10.6	33.5	75.0

Springer, U.
"The Effect of Refuse and Refuse Sludge Compost on Plants and Soils"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 4, p. 4, March 1958

The advantageous effects of compost on soil are described. These are primarily physical in nature, viz., improvement of texture, increasing of moisture-holding capacity, and increasing of pore volume. Negative effects may be a dangerous raising of the pH level in a neutral soil, crop damage if the compost is rich in trace elements, and release of toxic materials.

Gerretsen, F. C.
"On the Content and Value of Trace Elements in Urban Refuse Compost"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 6, p. 1, January 1959

Some trace elements are indispensable for plant growth. Examples are manganese, boron, copper, molybdenum, and zinc. The content of trace elements and magnesium in a Dutch compost was in terms of percent dry weight: Cu, 0.01 to 0.06 percent; Mn, 0.002 to 0.03 percent; Zn, 0.007 to 0.023 percent, B, 0.005 to 0.007 percent; Mo, ± 0.001; and Mg (as MgO), 0.11 to 0.34 percent.

Chandra, P. and W. B. Bollen
"Effect of Nitrogen Sources, Wheat Straw, and Sawdust on Nitrogen Transformations in Sub-humid Soil under Greenhouse Conditions"
Technical Paper No. 1228, Oregon Agriculture Experiment Station, Corvallis, (Reprinted from Journal, Indian Society of Soil Science, 7:115, March 1959

In the region around Oregon, soil nitrogen and moisture are the two main limiting factors in crop production. Many studies have been made on the effect of organic residues such as straw and sawdust on nitrogen transformations and on the extent of nitrogen losses. Results of such studies may be equally applicable in India where deficiency of nitrogen in soil is a well-recognized problem.

Although sawdust and straw have little fertilizer value as such, they may contribute to nitrogen conservation as well as improve the physical properties of soil. When mixed with the soil, they improve aeration and increase the soil's water-holding capacity. The incorporation of straw and sawdust in a silt-loam soil conserves added nitrogen. Since straw and sawdust can contribute to the formation of humus, improve aeration, increase the water-holding capacity of soil, and aid in the conservation of nitrogen, they may be used for the improvement of sandy as well as heavier soils.

Sauerlandt, W.
"The Influence of Organic Fertilizers on the Uptake of Mineral Nutrients by Plants"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 7, p. 12, July 1959

It should be possible to determine the quality of different types of refuse by long-term field experiments. However, it appears necessary to determine not only the yields, but also the nutrient uptake and the organic substances contained in the crops. Therefore, a comprehensive soil analysis is imperative. Sometimes, differences in the first year are scarcely noticeable, while in the second year, the onset of a brisk mineralization brings on favorable results. Composted refuse produces positive results during the third year as opposed to raw refuse.

Kortleven, J.
"Long-Term Effects of Urban Refuse Compost"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 7, p. 16, July 1959

The short-term effects of the use of compost on soil are similar to those of mineral fertilizers. The long-term effects are based on an increase in the humus content of the soil. The article contains some confusing calculations.

Tietjen, Cord
"Zur Unterbringung Von Abwasserschlamm in Der Landwirtschaft" (Sludge Disposal by Use in Agriculture)
Landbauforschung Volkenrode, Mitteilungsblatt der Forschungsanstalt fur Landwirtschaft Braunschweig-Volkenrode, Vol. 10, No. 2, p. 43, 1960

The problem of sludge disposal is becoming more important with the increase in number of sewage treatment plants. One of the cheapest solutions in disposal on agricultural land. This may cause severe damage if the sludge originates from a plant where domestic and industrial wastes are treated together. The "soil nutrients" in sewage, and in raw and digested sludge, are discussed and compared with those in stable manure. Concentrations of trace elements (B, Cu, Mn, Mo, Zn) are mentioned. A summary is given of methods for disposing of sludge at different levels of moisture content.

Tietjen, Cord and H. J. Banse
"Soil Improvement Society Organized to Produce and Utilize Compost of Refuse"
Compost Science, 1:35, Summer 1960

Composting interests two types of people: those who want to get rid of the wastes, and those who regularly or periodically buy the compost. At Bad Kreuznach, Germany, the financial problems involved in composting were solved by forming a soil improvement society or union which guarantees a market for the compost and apportions the processing and administrative costs between its shareholders. The members of the society share the compost according to the amount of acreage they own. If a person does not use his share of the compost, or if he uses only a part of it, the remainder is left to the disposal of the society as it sees fit.

The composting plant at Bad Kreunzbach is similar to the Dano plant at Sacramento, California. This German town is surrounded by mountains with very steep slopes, good only for vineyards. It is difficult to apply compost to the soil due to these terrain conditions. The usual manure spreader is not feasible. The most common method of application is the use of wooden sledges. A winch placed at the upper end of a row pulls the sledge with its load of manure, and a man does the spreading. A new method of spreading developed by the society is the use of a blower truck. The compost is placed on the contour path in a regularly shaped pile. The blower truck flings the compost down the hill much like a snow plow cleans roads of drifts. The compost is applied as needed.

Tietjen, Cord and H. J. Banse
"Soil Improvement Society Organized to Produce and to Utilize Compost of Refuse"
California Vector Views, 7:1, January 1960

A brief article demonstrating, by example, how cooperation between people who produce wastes and those who can use the wastes leads to increased efficiency in waste disposal. By forming a union, the German town of Bad Kreuznach is able to use its municipal waste to manufacture a compost which the local farmers can use. In this way, a market is guaranteed for all the compost that is produced. They go so far as to modify the composting process through the years to meet the changing needs of the crops. The costs of the composting process are shared by the members of the union. Waste disposal has become an asset rather than a liability.

Adritti, E.
"Urban Refuse for Soil Improvement in Israel"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 8, p. 12, March 1960

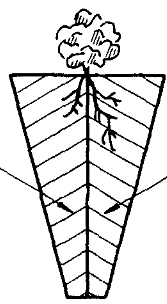
Israel has no available land for sanitary landfills in the vicinity of its cities. Incineration is too costly. On the other hand, the agricultural need for fertilizers made from community wastes is urgent because stable manure provides only 60 percent of the required amount. Only a few compost plants are in Israel. They are in Tel Aviv, Haifa, and Jerusalem (1960). The demand for compost is great and new plants are planned. The need for cooperation and coordination by various governmental agencies is apparent. The "Interdepartmental Committee on Refuse Problems" has such duties as examination, testing new systems, and the provision of information.

Keller, P. and R. Halter
"The Boron and Manganese Content of Refuse and Refuse-Sludge Compost"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 8, p. 7, March 1960

Plant damage after use of refuse or refuse-sludge due to a deficiency or excess of boron or manganese is not likely. Caution is only needful when large yearly compost applications are made, such as is done in tree nurseries or in certain gardening operations. The assimilable boron content of compost is considered to be a positive factor since it can contribute to the elimination of a boron deficiency in soils which may be boron-poor. Composting sludge with refuse, particularly winter refuse, acts not only to balance the contents of the usual nutrients and of humus, but favorably influences the content of trace elements by leveling-out the extremes. Glass pulverization by processing refuse in hammer mills has practically no effect on the boron content of a compost.

Teensma, B.
"The Effect of Urban Refuse on Root Growth"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 9, p. 7, September 1960

The author describes experiments with rooting boxes. A root box consists of a small box, about 30 cm by 20 cm by 50 cm. The walls are sloped toward each other such that they are only one cm apart at the bottom. The box may be divided into two equal parts by a "longitudinal wall" not reaching the top of the box. The two sloping sidewalls are made of glass. The box is covered with a removable wooden lid, since the roots must sprout in darkness.



Wurfbain, H.
"City Refuse Disposal by Composting"
Paper - 7th International Sanitary Engineering Congress, Montevideo, Uruguay, October 1960

The composting of city refuse, either as a means of waste disposal or to produce an organic manure for the upkeep of farmland dates back to the middle ages. At that time, garbage, which accumulated in the streets, was removed occasionally by farmers when they needed it for their fields. Agricultural producers continued to use city wastes for this purpose until around 1900, when chemical fertilizers were introduced. The farmers lost their interest in the garbage, and consequently another means had to be sought for the disposal of city wastes. These means proved to be dumping and incineration. The generally accepted opinion at that time, based on the chemical theories of the German chemist von Liebig, was that plant life needed only the water soluble minerals present in the soil and the carbonic acid present in the atmosphere, and that the humus content of the soil did not play an important part in plant nutrition. Although the use of organic wastes as fertilizer maintained the productivity of the soil, it was not possible to increase its fertility until the advent of chemical fertilizers. During the 20 to 30 years after the introduction of inorganic fertilizer, crop yields increased considerably. However, it became progressively more difficult to maintain this high production level, and increasing amounts of fertilizer were necessary to maintain the same high production level.

In 1925 Hoagland discovered that plant roots need oxygen in addition to dissolved nutrients. An adequate air supply to the roots is maintained by keeping the soil porous. The addition of sufficient plant nutrients and water bring about optimum soil conditions. These optimum soil conditions are maintained by biological activity. Subsequently, the interest in organic manure was revived.

The application of compost made from city refuse rapidly brings about a remarkable improvement in the soil structure. The benefits derived from the regular use of refuse compost are as follows: The soil structure is improved as a result of microbial activity. (This results in improved permeability, greater water retention, and better oxygenation.) A direct fertilizing effect comes about. Indirect fertilizing is accomplished by the better retention of chemical fertilizers in the soil. The soil is enriched in trace elements and the antibiotic action of stimulated bacterial life is enhanced, especially in soils which show symptoms of exhaustion brought about by bacterial parasites.

To arrive at maximum soil fertility it is necessary to use both organic and chemical fertilizers. At present in Holland, about 25 percent of city wastes are composted for agricultural use. The percentage is increasing. (Editor's Note: The percentage has been decreasing since the mid-1960's.)

Bollen, W. B. and K. C. Lee
"Cellulosic Wastes as Fertilizers"
Agriculture and Food Chemistry, 9:9, January 1961

An economical method has been developed for the conversion of fine sawmill and other cellulosic wastes into a useful agricultural product. The process consists of treatment with mineral acids, addition of plant nutrients, heating, and conditioning. Very thorough and complete studies of raw and reacted sawdust, raw and reacted bagasse, and spent and reacted spent coffee grounds were made to evaluate these materials on the basis of their reactions under controlled conditions in the laboratory.

The bulk of the paper is concerned with explanations of tests run on the raw and reacted samples. Tables are given of the pertinent information. Samples (100 lb each) of raw and reacted sawdust, bagasse, and coffee grounds were individually well mixed. One-pound samples of each were ground through a No. 800 screen. The fine materials were required to ensure adequate mixing with small quantities of soil.

Conclusions reached in the paper are as follows: Reacted sawdust, bagasse, and coffee grounds are more resistant to general decomposition in the soil than are the raw materials. This increased resistance is desirable; not only does it result in a decrease in nitrogen demand during decomposition, but it also enhances its soil conditioning effects. Nitrogen in the reacted products was more than sufficient to provide an excess over that required for decomposition, and the excess should become rapidly available for plant growth.

Trinel, M.
"Ten Years of Soil Improvement with Peat, Refuse, and Sludge"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 12, p. 1, September 1961

The ten year field test showed that:

1. Soil physical properties (humus content, hygroscopic moisture, water-retention capacity, absorption capacity) were particularly improved by the peat. Chemical properties, on the other hand, were improved over long periods particularly by the refuse and sludge.

2. Peat, mature refuse, and sludge when applied to poor soil appreciably increased the yields of winter and summer rye, oats, and potatoes, and improved the certainty of yields in dry years.

3. Since these results were obtained by the application of large amounts of compost, and consequently at a high cost in terms of distribution, the use

of refuse compost and sludge should be geared mostly to specialty crops, such as those raised in gardening and in viniculture. The high boron and copper contents of refuse must always be kept in mind when considering the use of compost on soils in which boron-sensitive plants may be cultivated.

4. The known unfavorable action of the amendments on lupine and serradella cannot be explained. It may be a function of the high boron content.

5. The experiments confirmed the well known fact that organic matter is rapidly decomposed in light soils.

The article has an excellent set of references (77 in number).

Banse, H. J.
"Influencing Physical Fertility of Soil by Application of Compost"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 13, p. 34, December 1961

Experiments in vineyards have shown that with compost applications of 50, 100, 200, and 400 tons per hectare a considerable improvement of soil characteristics occurred. In light soils the maintenance of soil moisture during drought is of great importance. The increase in moisture holding capacity imparted by the compost is of great importance in this respect. In heavy soils which cake during dry periods, the pore volume is increased through the application of compost, thus improving the structure and the tilth of the soil. In times of heavy rainfall silting is prevented and good aeration of the root areas is provided through the application of compost.

Sauerlandt, W.
"Evaluation of Refuse Compost in Field Trials"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 13, p. 22, December 1961

Results of field trials with agricultural crop plants are reported. Although many results are given, the data cannot be of much practical value, because a uniform material was not used in the tests.

Peyer, E.
"Erosion Damage in Viniculture and Preventive Measures"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 15, p. 21, August 1962

Erosion in vineyards due to precipitation is discussed and its effect demonstrated by actual measurements. Winegrowers have a great interest in eliminating or reducing soil erosion. Control possibilities include the construction of artificial erosion stops, the practicing of green manuring, the use of sodding or sod strips, the terracing of steep slopes, or the application of coarse material to the soil. Several ways of increasing the soil humus content are mentioned.

Nakamura, N.
"Plant Growing Experiments with Refuse Compost in Japan"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 17, p. 14, May 1963

The plant-growing experiments were conducted at the Hyogo Agricultural University under the direction of Professor N. Nakamura. The following results were obtained:

1. The refuse compost proved to be equal or superior to stable manure.

2. The addition of 7.5 tons of compost per hectare resulted in a higher yield than that of 15 tons per hectare. The optimum amount is probably about 10 tons per hectare.

3. Compost not only increased the yield and sugar content of sugar beets but also reduced the content of nitrogen. The reduction is desirable in sugar processing.

4. In experiments with onions, it was found that a concentrated application of compost (directly in the rows) results easily in an overdose.

5. During the experiments with celery, it was noted that the pH value of the soil was not increased, but that the acid effect of the necessarily high mineral salt additions was neutralized.

Economics

Anon.
"Pilot Composting Plant"
State of California Department of Public Health, Bureau of Vector Control, April 1957

The article deals with the basic principles for accelerating the composting process, e.g., control of moisture content, particle size, and aeration. Mechanized composting, even in the U. S., has a potential for development as an economically competitive, sanitary refuse disposal method, even if the end product is not a source of income. The remainder of the article includes design considerations in sufficient detail to visualize the operation of a mechanized pilot composting plant. Approximate first costs and annual expenses are also included.

Anon.
"Composting: Is it Economically Sound"
Refuse Removal Journal, Solid Wastes Management, 9:10, July 1966

Despite considerable investment and technical know-how, not one large-scale composting plant has operated economically long enough in the United States to indicate that the process is feasible. As of July, 1966, three limited installations are in operation in the U. S., viz., Altoona, Pennsylvania; Largo, Florida; and Boulder, Colorado. Although the process has a poor record in this country, composting plants on a large scale are under construction or are in the planning stage in a number of cities.

Composting has failed in the U. S. for four main reasons:

1. No steady market for the end product has as yet been found.

2. Initial investment and operating costs are generally high compared to other disposal methods.

3. A high quality end product usually cannot be derived from refuse in the U. S.

4. The separation of noncompostables requires either a sanitary landfill site or an incinerator to dispose of them.

Many composting plants have been operated by private contractors; the city is charged an amount that will defray operating costs. Profits for the contractor are hoped to be realized from the sale of the end product. Operators usually charge the city from $1.00 to $5.00 per ton, while the costs for composting refuse usually range from $5 to $10 per ton. The operators must make up the balance of the costs and any profits from the sale of the compost, and so far it just hasn't been possible to do so.

The history of composting in the past 15 years in the U. S. is one of failure. There are, however, three notable exceptions, as mentioned above. Altoona, Pennsylvania, collects only table garbage, composts it, and uses it as a soil conditioner fertilizer. All other refuse is collected by a private contractor and taken to a privately-owned landfill site for disposal. Boulder, Colorado, opened its compost plant late in 1965, and bags its product for a limited regional sale. (Editor's Note: The plant was closed recently.) The plant at Largo, Florida, composts materials from agriculture, stockyards, canneries, and sewage. A small market for the product includes golf courses and agriculture. The selling price is $16 per ton. There is little objection to odors produced at these plants, which was a very definite problem at some of the plants that were shutdown. Mobile, Alabama, built its own composting plant at a cost of $1.5 million; the builders of the plant have setup a corporation to buy all the city's compost at $3 per ton. (Editor's Note: The plant was shutdown for a month or so because of difficulty in the disposal of the product.)

Kupchick, G. (Kynruk)
"The Economics of Composting Municipal Refuse"
Public Works, 97:127, September 1966

Cost and income data were collected from 14 composting plants in Europe and Israel. These plants employed either the Dano Biostabilizer, the Dorr-Oliver Rasp, the ventilated cell, the Bühler-Dano combination, or the van Maanen process. The average cost to process one ton of raw refuse was $4.55, of which capital cost (amortization, interest, and rent) amounted to $1.76 and operating expenses $2.79. Based on comparative cost indices, it is evident that construction and operating cost in the U. S. would be considerably higher.

The weight of compost produced was 46 percent of that of the processed raw refuse, and the average income from sales amounted to $2.73 per ton of compost, or $0.90 per ton of raw refuse. Additional income from salvage materials averaged about $0.20 per ton of raw refuse. However, only in Great Britain was salvage income substantial.

Not one of the plants are able to cover its capital service costs and operating expenses through income obtained from salvage and sale of compost. Deficits ranged from $0.32 to $5.32 with an average net cost of $3.38 per ton of refuse processed. The only substantial prices for compost were obtained in Israel. On the basis of the experiences encountered, it is most important that a continuing demand for compost should be established before a compost plant is constructed.

Pulverization appears to hold promise as a pretreatment to reduce substantially the volume and alter the character of refuse prior to landfill, incineration, or composting operations.

Kolb, L. P.
"Municipal Composting: Some Economic Consideration"
Compost Science, 8(No. 2):9, Autumn 1967-Winter 1968

"A brief examination of a few specifics and many generalities of composting economics has led to one conclusion: the deeper one looks into the subject, the more dismal seem the prospects for economical composting. What can be done? Since virtually all studies on the subject seem to be concluded with calls for more of the same, the writer would suggest two promising objectives for future research efforts:

1. The development of a rational method of market prediction for compost in a given geographical area.

2. The development of techniques for tailoring the product to fit local needs. For example, can compost be efficiently pelletized for easier handling or can spreading costs be reduced by combining the compost with chemical fertilizers?

Composting is still seen by some backers as a 'wave of the future' in solid waste disposal. But until some fundamental economic problems are solved, the 'wave' is likely to remain a ripple."

Status – United States

McGauhey, P. H.
"New Methods of Refuse Disposal"
The Sanitarian, 15:59, February 1952

There are two main reasons why new methods of refuse disposal are needed. First, the present methods of disposal are rapidly becoming inadequate, and second, there is a need to reuse the organic wastes to fulfill our needs, and this need will grow in the future. The two main means of disposal in the U. S. today are sanitary landfill and incineration. The land needed for disposal at landfill sites is rapidly running out, and the air pollution problems of incineration are growing as the amount of garbage to be disposed of increases.

Composting has succeeded in Europe for a number of years, but the content of the refuse in Europe is different from that in the U. S. Also, Europe has a more pressing need for the humus end production than has the U. S. at the present time. The cost of labor is less in Europe. A number of composting processes were established in Europe and succeeded fairly well. In the U. S., due to a lack of accurate knowledge, more "processes" were developed, trying to sell a scheme for composting, and these secret rituals have retarded the development of a simple, efficient process.

Other factors hampering the development of composting in the U. S. have been the lack of economical equipment especially suited to handling refuse; overenthusiasm for the process – blindly believing that there will be an ample market for the end product when there probably will not be; and the lack of planning for the disposition of large amounts of compost if and when composting becomes a widespread practice.

Stovoroff, R. P.
"Capitalizing on Municipal Wastes by Composting"
Paper Presented at the Annual Meeting of the American Society of Civil Engineers, New York, 20 October 1953

In Oakland, California, an experimental composting plant was constructed in which the open windrow composting method was used. The values that follow are for Oakland only, they are not an average. A plant with a capacity of handling 265 tons of refuse 8 hours per day, 5 days per week will produce 125 tons of compost and 80 tons of marketable scrap materials per day. The capital investment would be $715,000. The forecasted yearly profit, $235,000. Labor costs per ton would be $2.45. Other costs per ton would be $0.45.

Composting has not worked before in the United States because of the lack of scientific know-how and poor timing.

McCauley, Robert F.
"Recent Developments in the Composting of Organic Wastes
<u>Water and Sewage Works</u>, <u>103</u>:522, November 1956

Based on Michigan State pilot studies with a compost plant having a capacity of 2 tons per day, it appears that composting could be an economically feasible method for disposing of garbage, refuse, and sewage sludge. However, to date, a process of composting has not been developed which is economic and completely free of odors. No breeding of flies can take place in properly turned windrow piles or in properly aerated digesters because of high temperatures generated in the material. All of the necessary organisms required for composting are indigenous to both soil and garbage, and it is necessary to provide only the proper environmental conditions for these organisms to grow and multiply. Composting will be more and more widely used as a process for treating solid organic wastes in the future. Because of the absence of adequate machinery and technical know-how, composting will not be used on a widespread commercial basis at once.

Reidel, E. O.
"The Refuse Typhoon, a Mobile Processing Plant"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 6, p. 8, January 1959

The mobile unit provides for a magnetic separation, sieving to remove ashes and powdery wastes and for grinding. No plant building is needed for the Refuse Typhoon. The capacity is 12 to 15 tons (metric) per hour. The author makes some calculations concerning economics. He says that the plant would cover all the operation costs and 8.75 percent of the capital costs per year. (Editor's Note: In another article in IRGR Information Bulletin 6, the Typhoon is discussed. It shows that the Typhoon is not suitable for most conditions.)

Rees, D. F.
"What is Necessary for Composting Success?"
Compost Science, 2, Autumn 1961

Composting of municipal wastes can be both a means of waste disposal and a means of producing useful organic manure. In many cases, however, there has been no coordination between the disposal and the agricultural requirements. Cities cannot afford to consider the national aspects of composting, but must look only at the economics and convenience of municipal composting.

The author thinks that the value of the compost has been overstated in the U. S. and that plants which have shutdown have done so because of inability to sell an overpriced material. Compost is similar to good farmyard manure and should be sold at or below prices for such. As garbage disposal is a municipal service and responsibility, economics should be based on a reasonably low selling price to insure sales of all compost, not selling part at a high price. Until the market is established, total output may not be sold for a year or two. Flexible operation of the plant is very important, and it must have good management.

Sullivan, R. H.
"Phoenix Will Compost All Municipal Refuse"
Public Works, 94:82, March 1963

Three composting plants will be installed, each with a 300-ton per day capacity. The city will pay the operator $1.25 per ton in the first year and $1.10 per ton thereafter. Dano-type plants will be constructed by the Arizona Biochemical Company. The company agrees to pay the city a certain percentage of the profits from sale of the compost product. Operation of the plant is typical of composting setups. (Editor's Note: The plant was closed in 1964-65 because of financial difficulties.)

Behe, R. A.
"Disposal of Municipal Garbage by Altoona FAM and the Hardy Digester"
Paper Presented at the Meeting of Division of Sanitation, Pennsylvania State Department of Health at Pennsylvania State University, August 1964

Composting has been practiced most extensively for many years. Twenty Dano Engestor plants were built in Europe during the years 1932 to 1955, and 24 Dano Biostabilizer plants since 1953. An optimum C:N ratio of 30 percent to 35 percent is recommended. Initial bacterial activity is carried out by mesophilic bacteria until a temperature of 100°F is reached. As the temperature rises above 110°F and progresses to 130°F, themophilic bacteria take over. All activity ceases at 170°F.

Turning at 2-day intervals is necessary for compost having a moisture content from 50 percent to 60 percent. If the moisture content is between 40 percent and 60 percent, turning should be done at 3-day intervals. Water should be added when the moisture content drops below 30 percent.

Temperatures range from 59°F to 135°F during a 16-day cycle. The Altoona FAM disposes of Altoona's garbage for $2,700 per month. The yearly average is 26.25 tons per day, ranging from 44.3 tons per day in August to 23.2 tons per day in February. Incoming material is 60 percent garbage and 40 percent refuse. The garbage is ground, discharged to a collector tank, and digested in a Hardy Digester. The finished compost is sold in large shipments to fertilizer companies, truck farms, and local farmers, although some is bagged at the plant for commercial sale. The digester is clean and sanitary and fully automatic, and can be used for both garbage and sewage sludge.

Anon.
"Composting Gets a Tryout"
The American City, 80:99, April 1965

A pilot plant was built in San Fernando, California, to compost domestic refuse. The rated capacity of the plant is 70 tons per day. Operating costs are placed at $3.50 to $4.50 per ton of refuse received.

The plant layout is described, as are the operations. The finished compost presently is sold at $10 per ton. The plant is operated by SACS, Inc. Six days are required to complete the transformation from a raw material to a composted soil conditioner. (Editor's Note: The plant no longer is in operation.)

Sanford, C. F.
"Elmira To Try Composting"
The American City, 80:93, July 1965

Elmira, New York, faced with a waste disposal problem that could not be handled by any other means, turned to composting in July 1964. NORCO of Atlanta, Georgia, contracted to build, finance, and operate the plant. Under a 20-year agreement, the city will pay $4.35 per ton of refuse. The cost of the plant will be $650,000. From 20,000 to 40,000 tons of refuse will be composted each year.

Anon.
"A Thorough Look at Composting"
The American City, 81:30, May 1966

Three public agencies recently signed an agreement to conduct full-scale studies of composting: The Office of Solid Wastes, U. S. Public Health Service; Tennessee Valley Authority; and Johnson City, Tennessee. TVA will design, construct, and operate a composting plant which will process Johnson City's daily production of refuse and untreated sewage sludge. The plant will cost $750,000 to construct and $100,000 per year to operate. The end product will be tested as a soil conditioner, and public health aspects will be studied.

The program will be carried out under the new Solid Wastes Program of the U. S. Public Health Service.

Anon.
"The Composting Game--Mobile Loses--Houston Takes Chance"
Refuse Removal Journal, Solid Wastes Management, 9:36, August 1966

Despite the hitherto poor record for composting in the United States, the city of Houston, Texas, has contracted to have three 300-ton per day capacity composting plants built and operated by three different companies. The setup is not financially perfect. The estimates of cost per ton to the city to have its refuse disposed of have been raised from $2.75 to $3.51. The city had to purchase the plant sites for the companies, whereas the fringe benefits promised to the city are not forthcoming.

Whether or not the finished product will have much of a market value is an unanswered question. The cost to process refuse has been estimated at $6.80 per ton, with $3.51 to be paid by the city. That leaves $3.29 per ton that must be made on compost sales and salvage of tin cans, glass, etc., merely for the companies to break even. With a projected production of 100,000 tons of material per year, a large market must be secured for the year-round.

After eight months of operation, Mobile, Alabama's, $1.4-million composting plant has shutdown. Very little of the end product was sold, much of the machinery failed to stand the rigors of the process, and labor costs were double the original estimates. The plant, after only eight months of operation, has suffered from failure of overworked motors, the necessity of rebuilding crushing mechanisms, and the assembly line of the facility needs to be redesigned. The estimated building costs of $980,000 turned out to exceed $1,400,000, and the only profits from sale of the end product were $1,000. An annual payroll of $90,000 was estimated for a crew of 20 men, where in actuality the workers numbered 53, with a sum of $182,000 annually for salary costs. (Editor's Note: One of the Houston plants was closed by order of the city's health department.)

Anon.
"Problems Beset Composting"
Refuse Removal Journal, Solid Wastes Management, 10:12, July 1967

The Mobile, Alabama, plant was closed but has reopened after a 5-month shutdown. The consulting engineer was released from his contract, and is now being sued by the city. No market has been found for the product. An experimental pilot plant was built at Largo, Florida; a major plant is in operation at St. Petersburg, Florida. One is in construction at Gainesville, Florida. One is under consideration for Jacksonville and another for Miami. (Editor's Note: The plants in Largo and St. Petersburg have been closed down, the plant in St. Petersburg because of complaints about odors by the citizenry.)

Composting is beset by four major problems, which are: 1. the rapidly changing composition of unburn refuse; 2. a mistaken belief that salvage will recoup income; 3. the need of a great deal of labor and many handling steps (need for parallel and additional steps to handle noncompostable refuse); and 4. the fact that success or failure depends upon the development of an expanding market for a hard-to-sell product.

Anon.
"Houston Forces Compost Plant Shutdown"
Refuse Removal Journal, Solid Wastes Management, 10:6, July 1967

One of the city's two large composting plants (United Compost Services, Inc.) was closed because of a consistent discharge of bad odors. The Metropolitan Waste Conversion Corporation plant (300 tons per day) operated as Lone Star Organics, Inc. continues to operate, although complaints about odors from it are fairly numerous. A third projected plant by NORCO will not be built, probably because of lack of financing.

The idled composting plant was constructed on city-owned land in a residential neighborhood despite vigorous protests by the inhabitants. The company had invested from $1.5 to $2 million dollars in the plant. The original agreement provided for the city to pay $3.47 per ton refuse up to 300 tons per day. The contract stipulated that the city accept the plant if it satisfactorily completed a 6-day trial period. The city states that no trial period has been completed. One-half the total investment can be recovered if the plant is shutdown permanently. Phoenix Mutual of Hartford, Conneticut, holds a $1.2 million dollar mortgage. (Allstate owns 1/3 of International Disposal Corporation which formerly operated the 150-ton plant at St. Petersburg, Florida.)

A $4.5 million incinerator begins operation this summer.

The Lone Star Organics compost operation finished its trial runs in January, and so far is meeting the city's requirements. Houston must deliver 300 tons per day at $3.50 per ton. However, the company need accept only 150 tons. The Metropolitan Wastes Conversion subsidiary also is selling compost in bulk and in small quantities to the Texas Valley fruit growers, to the Brozos River bottom planters, and to homeowners.

Spitzer, E. F.
"Composting Works in Houston"
The American City, 82:97, October 1967

A very optimistic account is presented of composting in Houston to counteract the unfavorable accounts given in another journal. The article deals mainly with the Metro-Waste process (Waste Conversion Corporation of Wheaton, Illinois.)

Interesting statements are as follows:

1. Since November of 1966, Metro-Wastes Corporation has composted over 65,000 tons of wastes.

2. Only 2 percent to 3 percent by weight of the raw material had to be disposed of by landfill. Another company in Houston, which had composted over 8000 tons during the first four months of this year, was closed because extreme pressure by irate citizens forced the city to stop delivering refuse to the plant.

3. The market for compost is seasonal, and prospects for its disposal are not very bright at present.

Ideas of the company directors as to ways of developing a market are presented. For potential markets, the compost should be blended with fertilizers to form an enriched organic product. The product could serve as a replacement for wood fibers in hydromulching. It could be sold to paper companies for use in reforestation programs. It can be used in reclamation and conservation projects.

The Metro plant in Houston has a capacity of 360 ton per day. It cost $2,000,000 exclusive of land. The company pays rent on the land, and taxes on the buildings and machinery. It has a workforce of 29.

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Anon.
"Arizona Biochemical Co."
Stock Market Magazine, p. 6, December 1967-January 1968

The Arizona Biochemical Company offers a complete service including pickup from the point of origin as well as disposal. The company was formed in 1962. Capital of $800,000 was raised through the sale of 200,000 shares. The company received and processed in excess of 75,000 tons. The contract with Phoenix was terminated within a year of the start of operations. The plant was then dismantled.

After the Phoenix difficulty, the company entered an agreement with the Parish of Jefferson, Louisiana, to handle that city's entire collection and disposal operation, but with a combined incinerator-composting disposal system. According to the article, the project has been successful, especially since the collection phase of the operation was successful.

The company has diversified to real estate in Florida.

The Jefferson Dispoal Company — a subsidiary of Arizona Biochemical Company — operating for only 7 months at full capacity earned $91,849 before depreciation and net profits of $22,397 for the fiscal year ending 31 August 1967.

Anon.
"St. Petersburg Shuts Down 'Model' Compost Plant as Malodorous 'Public Nuisance'"
Air/Water Pollution Report, 6(8):59, 19 February 1968

The $2-million St. Petersburg compost plant, opened in 1966 as a model pollution-free reclamation facility, has been shutdown by the City Council as a "public nuisance." The reason: uncontrolled odors. The plant, located in a resort and retirement community, was built as a pilot project for others around the country by International Disposal Corporation. The latter is one-third owned by Westinghouse Electric Corporation, one-third by Allstate Insurance Corporation, and one-third by Salvage and Conversion Systems, Inc.

The facility took 600 tons of garbage weekly and produced "cura" soil conditioner, and recently added a $60,000 blender to make "cura-soil" fertilizer. In unanimous action, the City Council terminated IDC's 20-year contract, as recommended by City Attorney Frank McDevitt. An arbitration smell-committee, named to investigate the persistent malodorous aromas, told the Council that "this plant in its present state of design and operation has considerable potential for odor generation and is in fact generating odors to the point of being a public nuisance." The scents from the facility were described by citizenry as varying from rotten apples to stale beer to musk.

An IDC spokesman explained the stench as arising when bacterial action is interrupted by change in temperature, or in amount of oxygen or carbon dioxide, or when there is a mechanical breakdown.

Paul Willis, President of IDC, called the Council action a "bombshell" but indicated that further efforts would be made to solve the odor problem and get the contract reinstated. The things that went awry were described as "bugs" that plague many new productions, and it is believed that correction will involve some revamping and refining rather than major redesign. The Council did not rule out the possibility of future renegotiations with IDC.

Meanwhile, the city is sending its weekly 600 tons of formerly composted refuse to an incinerator which already burns about 2,000 tons of city refuse weekly. The city had been paying IDC $3.24 per ton and the incinerator operator $3.40 per ton. The incinerator is now owned by the First National Bank of St. Petersburg, after foreclosing against original owners, U. S. Incinerator Corporation, and taking title. (Editor's Note: Westinghouse plans to give up its part of the combine.)

Anon.
"$1-1/2 Million Composting Plant Closes"
Refuse Removal Journal, Solid Wastes Management, 11:23, May 1968

St. Petersburg's composting plant was closed down after a 3-man fact-finding committee for the Florida city declared the operation a public nuisance. The group found that there was:

1. A lack of preventative maintenance causing frequent breakdowns of essential equipment.

2. The building was poorly designed, since incoming trucks had to be unloaded in the open.

3. Winds carried odors to a nearby residential area and a golf course.

4. The dryer which was installed to alleviate odor has repeatedly malfunctioned.

The 150-ton per day plant was operated by the International Disposal Corporation, a company jointly owned by Westinghouse Electric Corporation, Allstate Insurance, and the shareholds of IDC's predecessor, Salvage and Conversion Systems, Inc. (SACS). It cost $1.5 million to erect. A 20-year contract has been negotiated with St. Petersburg's City Manager. IDC was to dispose of 31,200 tons of refuse per year (100 per day, 6 days per week) in a "nuisance-free" manner. The city was to pay $3.24 per delivered ton with allowances for some fluctuation in future years. IDC attempted to sell the compost for $9.00 per ton to commercial agriculture and for $1.98 per bag to homeowners. The plant employed 26 people. Nearly $500,000 was spent by the firm to operate on a nuisance free basis. Of this $110,000 was spent on a dryer.

Outside the U. S. the average gross cost for composting one ton of raw refuse is about $4.45. Amortization, interest, and rent account for an average of $1.76, and operation accounts for $2.79. These costs would be much higher in the U. S.

> "Experts now agree with Victor Brown, President of Metropolitan Waste Conversion Corporation that 'Unless the city is willing to pay for the service on a substantial basis, I do not believe at this stage that a composting plant is going to be able to go into that city.'"

Other facilities which have closed in past years are the plants in Scarsdale (New York), McKeesport (Pennyslvania), Oakland, Sacramento, and San Fernando (California), (Editor's Note: These three plants were pilot plants – not full-scale enterprises), Mobile (Alabama), Springfiled (Massachusetts), Norman (Oklahoma), Williamston (Michigan), Phoenix (Arizona), and one in Houston (Texas).

Status - Foreign

Stone, Ralph
"Experimental Project Offers Solution to China's Sanitary Needs"
Civil Engineering, p. 166, March 1948

The project was intended to serve as a demonstration night-soil fertilizer plant. The aim was to economically convert night soil into a sanitary organic fertilizer. Night soil was digested with garbage and bone meal aerobically and anaerobically. The aerobic process proved to be the more satisfactory of the two processes.

Truman, H. A.
"Disposal of Wastes--Composting"
The New Zealand Institution of Engineers, Ferguson and Osborn, Printers, Lambton Quay, 1949

Municipal composting provides a sound and hygienic method for the disposal of difficult organic wastes. The general policy of burying and burning huge quantities of economically and agriculturally useful materials is not sound. A source of moisture is necessary for a composting scheme. Composting refuse with sewage sludge assists in the disposal of the sludge and at the same time provides the necessary moisture. Municipal composting makes it possible to return to the land converted town refuse and town sewage as an organic manure. Municipal composting can earn a return for the rate-payers both in cash and soil fertility. If temperatures of 150°F to 160°F are maintained in the compost for 2 to 3 weeks there is no likelihood of matured compost to act as a medium for the dissemination of infective material.

Anon.
"Report on the Conservation of City Waste"
The Journal of the Australian Institute of Agricultural Science, 21, No. 3, September 1955

Garbage can be composted successfully with or without the addition of sewage sludge. Plants equipped to dispose of garbage by composting it are in operation in many parts of the world. However, many plants have been closed down because of mechanical difficultures and high costs. The Committee cannot recommend composting as an economical method of garbage disposal in Victoria for the following reasons:

1. The composting plants which have been developed thus far require a large labor force for hand sorting, and generally give rise to a dust and odor nuisance in closely settled areas. Moreover the capital cost of installation is very high.

2. Composting would be an additional charge upon the cost of garbage disposal; while farmers are not prepared to pay a sufficiently high price for compost to cover this extra charge.

3. Moreover the method used at present for tipping and covering garbage is satisfactory, and there are sufficient tipping sites within the Melbourne Metropolitan area to satisfy the demands of most of the municipalities for years to come.

Sewage sludge contains much useful organic matter and fertilizer material. However, the present methods of disposal of sewage are economical, and health regulations prevent the sale of all forms of sludge produced in Victoria at the present time. The Commission of Public Health would not agree to the sale of compost resulting in the combined composting of refuse and sludge. The reason for the restriction is the difficulty of providing the strict supervision of the process needed to ensure the exposure of all of the treated materials to temperatures lethal for pathogenic organisms and parasitic ova.

Krige, R. P.
"A Study of Modern Methods of Municipal Waste Utilization and Conversion to Compost"
Water Research Division, National Chemical Research Laboratory, South African Council for Scientific and Industrial Research
(Reprinted from Municipal Affairs, September to December 1955)

The study is concerned with the technicalities involved in the economic processing of organic wastes into compost for rehabilitation of impoverished soils in South Africa. Part I of the report deals briefly with the general attitude of the public toward refuse and other organic wastes, with impressions regarding soil fertility and farming practices in general, and with the demand for compost.

Of the countries visited only those which had developed a reason for soil consciousness were interested in organic wastes as soil conditioners. The Dutch and Danes were the only ones to utilize compost for soil improvement to any extent. In the U. S. the hygienic-disposal aspect is first and foremost of concern. The compost product receives little attention, and its benefit to the soil is a secondary consideration. An explanation and detailed description of installations visited constitute Part II of the report. Part III is concerned with modern trends in composting techniques.

From the commercial angle, refuse and most organic wastes have a negative value.

The advantages of composting are as follows:

1. It is the hygienic method of dealing with waste materials.

2. The end product takes on a positive monetary value in areas where soil fertility is at a low level.

3. In countries where the need for organic matter in the soil is an accepted fact, attention has been directed towards the composting of municipal refuse as a means of providing humus, and the general trend is toward a more complete mechanization of the composting process.

Anon
"The New Compost Plant at Duisburg-Huckingen in Operation"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education and Welfare. IRGR Information Bulletin 4, p. 10, March 1958

The plant was officially opened on 16 December 1957. Refuse trucks dump their loads into receiving bunkers. The refuse is transported to the compost plant on apron and belt conveyors. Scrap iron is sorted out by magnetic pulleys and baled. In the winter, screens are used to separate out ashes and clinker. On the final sorting conveyor, valuable materials are picked out by hand. The refuse is then conveyed to rotating drums, and there is mixed with sludge. The compost leaves the drums after four days retention and is screened again.

The plant serves a population of 140,000 (one-third the total population of the city). It has the capacity to process 200 m^3 of refuse per day (i.e., 80 tons per day), 10 to 20 m^3 of sludge per day, and 2 tons of iron per day. From this would be produced 50 to 60 tons of compost per day. The plant has two biostabilizers, each 25 m long and 3.5 m diameter. They have a capacity of 250 m^3. The installed power is 200 kw. The plant cost about 1,500,000 German marks to build. (Editor's Note: In 1965 the city of Duisburg ordered an incineration plant because the capacity of the compost plant was not large enough to handle the city's output of refuse.)

Westrate, W. A. G.
"Inauguration of the Composting Plant at Dantumadeel, Netherlands"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education and Welfare. IRGR Information Bulletin 5, p. 8, August 1958

The plant was designed to serve a population of 10,000. No information is given on the system of composting in use in the plant. Sorting is done by hand, and milling is done with the use of a hammer mill. The pulverized refuse is mixed with sludge in a mixing trough. The time required for a given batch of material to compost is from 3 to 4 months. Operation of the plant was inaugurated during December of 1957.

Anon.
"Composting Municipal Garbage in Israel"
Tavruah, No. 5, pp. 26-39, July - December 1958

Nonmechanized windrow composting has proved unsuitable for two reasons:

1. Anaerobic windrows are attended by odor nuisances and fly breeding.

2. Operations based on manual labor are marginal since the cost of labor is high.

Processing old stabilized garbage from open dumps into compost is being used as a means for filling Israel's demand for fertilizer. The long uncontrolled period of anaerobic composting results in tons of organic and nitrogenous material. A mechanized high-rate aerobic composting plant designed to turn garbage into compost in 3 to 4 weeks is being tested at Tel Aviv. The finished compost is a black odorless humus and is in high demand as an agricultural material. Haifa is in the process of constructing a Dano Biostabilizer garbage composting plant having a capacity of 50 tons of garbage per day.

Garbage composting in Israel is economically profitable because of the high organic content of Israel's raw garbage and the critical shortage of organic fertilizers and soil conditioners. Moreover, scrap metal and rags have a high salvage value.

van de Passche, A. W.
"Development and Significance of Compost Preparation in the Netherlands"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 7, p. 2, July 1959

Agricultural research was heavily emphasized by the authorities after World War II. In 1950 the government appropriated 10 million guilders ($2.67 million) for the construction of two composting plants, and for making 20-year interest-free loans to municipalities for the construction and operation of composting plants. In 1959, about 350,000 metric tons or 25 percent of the total urban refuse was processed into compost.

Gothard, S. A.
"Special Technical Problems in the Processing of Urban Refuse"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 7, p. 5, July 1959

The Jersey (Great Britain) plant must comply with the following requirements: It must produce good quality, sanitary compost for equivalent amounts of refuse and sludge. The operation must be carried on as efficiently as is possible on a small site. The operation must be done with a minimum of labor and a maximum degree of mechanization and automation wherever possible. All odors must be avoided.

The plant is designed to serve a population of 100,000. It has the capacity to process 100 tons of refuse per day. The system used is the Dorr-Oliver (tower with six chambers). The composting period is 6 days in the tower and 8 to 12 months out-of-doors for curing. The capital cost was $597,000. The operating costs were $504 per ton per year.

Livshutz, A.
"Production and Utilization of Compost in Subtropical Countries"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 7, p. 1 , July 1959

The application of compost to a soil brings about a reduction in irrigation requirements by increasing the moisture-holding capacity of the soil. With the use of compost, the need for irrigation water can be reduced by 10 percent, thus permitting a 10 percent expansion in extent of areas under irrigation.

Much compost has been used in Israel in citrus groves, vineyeards, and in growing bananas, potatoes, and strawberries. In 1958 a total of 12,000 m^3 were used in citrus groves alone.

Two plants were in operation in Israel in 1958. In one of the plants refuse accumulated for many years is stacked in heaps about 4 m high. Compost from this plant contains some glass and china, nails and other metal pieces. It therefore cannot be used in gardens. However, it is good for use in vineyards and orchards. Refuse is presorted in the second plant. The presorted refuse is passed through a Dorr-Oliver rasping machine and is composted in windrows. The windrows are turned 4 to 6 times during the compost period. Sludge is added to the incoming refuse to give a moisture content of 50 percent to 60 percent. Ballistic and magnetic separators refine the completed compost.

Joint Commission on Rural Reconstruction
"Compost Studies at the Pingtung Experimental Plant"
Report - Organic Wastes Section, Taiwan Institute Environmental Sanitation
Provincial Health Administration Tapei, Taiwan, China, December 1959

A remedy to the shortage of green manure acreage in Taiwan was urgently needed. To solve this rather serious problem, a pilot compost plant was set up in Pingtung City. Following these experimental studies, a full-scale forced-air bin-compost plant of 25 tons capacity per day was constructed. The plant was constructed as an experimental plant with a number of objectives in mind. Among these are the following:

1. to obtain reliable data on refuse collected and on the finished compost;

2. to make a comparison between the operational problems and suitability of bin composting with forced-air supply with those to be met in the windrow method of piling and hand turning;

3. to study operational control practices and their practicality, e.g., length of aeration period and rate of aeration in the forced-air bin method and the frequency and timing of turning in the windrow method;

4. to make a comparison between the two processes in terms of sanitation and operating costs;

5. to assess the acceptance and marketability of the compost in the Pingtung area.

The 38-page booklet goes into great detail in the presentation of data on the biological aspects of the composting process. Graphs and charts are presented. A comparison is made of data concerning three different methods of composting, namely forced-air aeration, turning of windrowed piles, and a control compost that was stacked, but not turned. A detailed discussion is included on the economic considerations of the operation. Proceeds from the sale of the compost almost equalled the total annual costs of operation. The description of plant setup is explained. A comparison of the cost of hand turning with that of forced-air aeration shows that the forced-air method is more economical in that it costs only about 60 percent that of turning.

Shuval, Hillel
"Composting Municipal Garbage in Israel"
Compost Science, 1:21, Spring 1960

Interest in composting municipal garbage has grown in Israel during the past five years for a number of reasons. The compostable fraction of Israeli refuse is about 84 percent of the total, as compared to that of countries such as England where the refuse is only about 30 percent compostable. Israel needs the end product as fertilizer for its growing agricultural economy. Consequently, the government has started to subsidize to some extent companies which will build composting plants.

The present, dominant method of wastes disposal is the unsanitary open dump. Tremendous fly problems have been encountered. In some cities, an unmechanized windrow method of composting has been used. These operations are characterized by the anaerobic decompostion of the refuse. They generally have failed because they did not alleviate the fly problem, and because of the high labor costs. Refuse which had been partially stabilized in open dumps, is being composted. The end product of such operations is of a fairly good quality.

The city of Tel Aviv contracted to have a 500-ton capacity compost plant built. A pilot plant was set up to find the most efficient type of operation for the city. The pilot plant is fully mechanized, and has a daily capacity of 80-100 m^3. Salvageable materials are segregated. The compostable materials are ground and pulverized before being stacked in windrows for decompostion. The composting refuse is turned by tractors and is left in the piles for from 3 to 4 weeks. The final 500-ton plant will cost about $1,100,000. The city will pay the operators $0.75 per ton for each ton of raw garbage handled. Haifa has a 60-ton pilot plant — a model for a larger setup to serve the city's 150,000 population.

Anon.
"New Composting Plants"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 8, p. 16, March 1960

In the following table are listed new compost plants, along with their capacities and the cities served by them.

City	Country	Method	Capacity (tons/day)	Population Served
Himeji	Japan	Dano	30	-
Deventer	Holland	Dorr-Oliver		55,000
Maastricht	Holland	-	-	90,000
Mierio	Holland	Van Maanen	(53,000 tons/yr)	-
Udine	Italy	Dano		80,000
Verona	Italy	Earp-Thomas	50	-
Mexico City	Mexico	Earp-Thomas	25	-
Baden-Turgi	Switzerland	*Multibacto*	50	-

(Editor's Note: The Multibacto system did not function satisfactorily. The plant was closed for two years. The city of Baden-Turgi ordered an incineration plant in 1966. Recent (1967) attempts to obtain information on the Italian and Mexican plants have been unsuccessful.)

Deszö, N. and T. Jenö
"The Reclamation of Refuse at Budapest"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 9, p. 1, September 1960

The city of Budapest decided against incineration because of the low calorific value (600 k-cal/kg) of its refuse, high ash content in winter, and the high capital cost. It selected composting as the alternative method of disposal. The author describes experiments with composting, such as decompostion factors, the required minimum organic content in the raw materials, the effect of microbiological inoculation, the course of temperature in the piles, the influence of pH, and the degree of aeration needed.

Anaerobic digestion with gas production was also considered. Pilot plant experiments were conducted with the use of sealed iron tanks (900-liter capacity) placed in a Beccari chamber filled with decomposting refuse. A mixture of garbage

(300 kg) and sludge (100 kg) maintained at 25°C to 30°C produced 17 m^3 cf gas per month with a methane content of 45 percent to 50 percent. The times required for complete fermentation were 4 to 5 days at 42°C to 50°C, 30 to 40 days at 20°C to 30°C and 70 to 80 days at 10°C to 15°C.

Teensma, B.
"Use of Compost in the Netherlands in 1959"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 10, p. 20, December 1960

The twelve municipal compost plants in the Netherlands (Wijster, Mierlo, Delft, Schiedam, Enschede, Almelo, Hengelo, Venlo, Sneek, Vlissingen, Soest-Barn, and Dantumadeel) disposed of 194,331 metric tons of refuse compost in 1959. The following table indicates the use of compost in the year 1959:

Grassland pasture	4%	Chicken litter	1.9%
Field cropland	35.3%	Forest culture	3.1%
Mixed with manure	9.1%	Parks, gardens	22.3%
Horticulture	2.6%	Hotbeds	5.0%
Market	12.9%	Flower bulb-raising	3.8%

Teensma, B.
"Composting City Refuse in the Netherlands"
Compost Science, 1:11, Winter 1961

The article describes the need for refuse composting in the Netherlands, and explains how the process progressed in that country. Composting on a large scale began with the operation of the Van Maanen plant at Wijster in 1929, a time when compost was needed to restore the physical fertility of the soil depleted after 30 years of solely chemical fertilization. At the end of 1960, 15 composting plants were in operation in the Netherlands — two Van Maanen plants, eight rasping plants, four Dano plants, and one hammer mill plant. The large Wijster plant was modernized in 1962. These composting systems processed nearly 30 percent of the total municipal refuse output in the Netherlands. The systems are briefly described in the report. The part played by the Dutch government in making possible the development and installation of the systems also is told.

The author predicts the construction of more composting plants, because he forecasts a demand for additional compost.

Glockner
"The Refuse Composting Plant at Stuttgart-Mohringen"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 15, p. 15, August 1962

The compost plant serves a population of 100,000. The cost of construction was 1,434,000 DM (about $335,000). The Dorr-Oliver system is used. A flow diagram of the process is as follows: bunker → magnetic separator → hand separation → rasping machine → ballistic separator → windrow.

The plant has an incinerator for burning industrial and noncompostable wastes.

(Editor's Note: The City of Stuttgart ordered an incineration plant (system Duesseldorf) with a designed capacity of 480 tons of refuse per day. The operation began in 1966.)

Krige, R. P.
"The Utilization of Municipal Wastes"
Report on the Processing of Urban Wastes in a Mechanized Composting Plant.
Pretoria, South Africa, CSIR Research Report No. 211, 1964

Disposal of municipal wastes by dumping creates problems and results in a total loss of valuable organic material. Systems hitherto adopted in the Republic for the conversion of wastes into compost have fallen into disfavor mainly on account of prohibitive labor requirements and odor nuisances.

The report describes the development of a mechanized compost research plant in which the primary biological breakdown of crude wastes is expedited under optimum conditions.

The research plant and the research program are described in detail and data are given with reference to the physical and chemical factors during stabilization and during the secondary maturation process. Very little was known previously about these two phases of composting. The investigation covered all the aspects of waste utilization. An assessment of the costs of composting versus conventional dumping is reported and established that composting has economic advantages in the case of large-scale installations located nearer to town than dumping sites.

Among the various aspects reported upon, the bacteriological and helminthological studies are of particular importance to medical officers and health officials. In this connection specific recommendations are made.

Anon.
"Dutch Compost Pile Shrinks"
Refuse Removal Journal, Solid Wastes Management, 9:20, November 1966

Glasgow, Scotland, has abandoned composting plans because of failure to find market for compost. It is building an incinerator instead. The subsidy for the 500 ton per day plant at Tel Aviv had to be increased. Japan has closed all seven of its plants. Plans to reopen the compost plant in Kingston, Jamaica, have been abandoned.

Fifteen compost plants are in operation in Holland, three are run by V.A.M. and the remainder by the municipalities in which they are located. Total production until 1966 was 190,000 tons per year, of which 100,000 tons were produced by V.A.M. Most of the latter is dependent on refuse from The Hague. With The Hague switching to incineration, this production will be reduced drastically. Haarlem has abandoned composting. Rotterdam and Amsterdam (total population 1.6 million) are building incinerators. Costs of composting The Hague are as follows: rail transport, $1.12 per ton to load, and $1.12 to $1.26 to transport; $1.76 to V.A.M. for processing. The total cost per ton, therefore, is $5.12. At Rotterdam it costs $2.80 per ton to incinerate refuse. The moisture content of the compost is 40 percent; the organic matter, 15 percent; and other matter, 45 percent. High-grade compost sells for $4.90 per ton; and the lowest grade, for $1.96. Market farmers buy about 22.8 percent of the total compost; vegetable, fruit, and bulb growers, 46.6 percent; and 35.6 percent is used for lawns, and recreational areas.

Dr. Stolp, Director of V.A.M., states that composting is too expensive for cities having a population greater than 300,000, i.e., too expensive to transport away from the city.

The V.A.M. now is trying to interest smaller communities in composting to compensate for the loss of The Hague.

The Dutch are losing their interest in composting because it is too expensive, too slow, and often a source of nuisance.

Hart, S. A.
"Solid Wastes Management--Composting: European Activity and American Potential" Final Report, United States Public Health Service, Contract PH86-67-13, University of California, Davis, December 1967

Reports from Europe have suggested that composting and compost utilization have been more successful there than in the United States. A study was therefore made of the status of composting and compost utilization in Germany, Holland, and Switzerland, and the findings were related to the solid wastes problem in America.

Nine compost plants are in operation in Germany, one-sixth of Holland's domestic refuse is made into compost, and Switzerland has an active composting program. Yet, in all countries, composting is a very minor pathway for the disposal of solid wastes, and there are serious production costs and marketing problems. All of the countries make only as much compost as can be sold; excess refuse from the communities is burned or buried. Generally, compost can be sold only if it is well screened and of good appearance. The compost is used almost exclusively in luxury agriculture, bulb and flower growing, grapes for fine wine production, and gardens and parks. There is simply no market for the compost in basic agriculture.

This same approach to composting has also been attempted in the past in the United States. The results have been similar, though even less successful. The market (in luxury agriculture) has been smaller, and the cost of producing the compost has been greater than in Europe. This approach to compost utilization in the United States seems fated to continue to be unsatisfactory.

There are possibilities, however, for a more satisfactory program of composting for solid wastes disposal. "Rough"-quality compost, cheaply produced without grinding or fine screening, has real potential for the reclamation of spoiled lands (as from mining), for the prevention of erosion, for reduction of the volume of material going into a landfill, and as a cover material for above-grade landfills. A further and even more favorable avenue of composting practice will be to consider land as an acceptor of compost rather than compost as a benefit to the land. Rough-quality compost might be applied at the maximum assimilable rate (perhaps 100 tons per acre per year) to a piece of land. The land would not be used for crop production, but neither would the land be irreparably changed, as with a landfill or dump. If or when the land becomes needed for subdivisions or agriculture, the compost application could be stopped and the land would recover.

The report contains a survey of 14 European plants:

1. Germany: Bad Kreuznach, Blauberins Duisberg-Huckingen, Heidelberg, Schwainfurt, St. Georgein, Stuttgart.

2. France: Versailles.

3. Switzerland: Buchs, Hinwill, La Chaux-de-Fonds, Turgi.

4. Holland: Arnheim, Wijster.

Miscellaneous

Gotaas, H. B.
"Bibliography on Disposal of Organic Refuse by Composting"
Technical Bulletin No. 2, Institute of Engineering Research Series No. 37, Sanitary Engineering Research Laboratory, University of California, Berkeley, August 1950

The bibliography is an exhaustive list of 610 articles on composting. It was compiled after a critical review of the literature. The main source of references from which the bibliography was compiled was Chemical Abstracts. In those cases where the original articles were not available or could not be readily translated, the articles either were condensed from Chemical Abstracts or reproduced verbatim.

Anon.
"A Bulletin on Garbage and Refuse Disposal"
Papers Presented at the 1952 Disposal Seminar, Tomah, Wisconsin
League of Wisconsin Municipalities, 30 E Johnson Street, Madison, Wisconsin, 1953

More and more attention is being given to solid waste disposal problems in Wisconsin, and the bulletin was published as a general review of the several disposal methods which municipal officials may wish to consider. Included in the report are several papers presented at the garbage and refuse disposal seminar held at Tomah, Wisconsin, on 13-14 November 1952.

The bulletin is a summary of methods used in the state; methods used include hog feeding, incineration, sanitary landfill, open dumps, open burning, and various combinations of the last three mentioned. Public reaction to the efficiency of the operation was sampled, and 48 percent of the people interviewed felt the service was good, 32 percent considered it poor or unsatisfactory, and only 20 percent felt that service was excellent.

Various reports were reprinted in the bulletin, reporting on the sanitary landfills, incinerators, and hog-feeding methods used throughout the state and the public health considerations to be kept in mind when concerned with solid waste disposal.

Gotaas, H. B., P. H. McGauhey, and C. G. Golueke
"Reclamation of Organic Wastes by Composting"
Paper - No Information on the Occasion, 1953

The article begins with a brief history of the composting process. Fundamental concepts of composting are explained, as are the various methods used throughout the world. The partially aerobic process of composting requires little machinery and has been widely used in China, India, and South Africa. Many European countries have used a partially mechanized process. A fully aerobic process involving a great amount of equipment has been tried in the United States, Holland, and Central America.

The value of the fully composted end product varies, depending on the type of agricultural situation in which the plant is located. If the use of compost is the basis of survival for the farmer, then the compost will have a good market. If it is just one of many available fertilizers in an area of fertile land, the value will go down, making the economic feasibility of the composting process questionable in that area.

The article goes into detail on public health aspects of composting. If a normal temperature range (70° to 75°C) is maintained, and the plant is kept clean and free of litter, then no problems will arise from rodents, flies, or bacteria.

McGauhey, P. H. and C. G. Golueke
"Possibilities of Composting Municipal Refuse"
Reprint - Public Works, October 1953

The paper discusses the problems encountered in solid waste disposal. A full report is given of the composting process. The Berkley pilot plant was used for the study.

McGauhey, P. H. and H. B. Gotaas
"Stabilization of Municipal Refuse by Composting"
Paper - Presented at New York City Convention, 19-22 October 1953

The paper deals with the basic operations of decomposition of municipal refuse. Important aspects of composting are segregation, grinding, stocking, turning, and remilling. The problems of composting on a municipal scale are reviewed. The process is found to be economically feasible and of great value to agriculture.

Golueke, C. G.
"Composting Farm and Garden Wastes"
California Vector Views, 2:58, December 1955

Various aspects of composting are treated, both aerobic and anaerobic. Four main types of procedures are described, viz., the Indore method; a method developed by the University of California; mechanized digestion; and anaerobic composting or digestion.

It describes the use of anaerobic manure digestion in the treatment of animal wastes on farms in Europe. Gas production per ton of manure ranged from 5.3 cu ft at a digester temperature of 60°F to 7.6 cu ft at 93°F. The gas can be burned for heating the digester and for household use. This procedure is not followed to any extent today.

Wiley, J. S.
"Composting of Organic Wastes - An Annotated Bibliography, Supplement 2"
U. S. Department of Health, Education, and Welfare. Public Health Service, Bureau of State Services, Communicable Disease Center, Savannah, Georgia, April 1960

This is the third in a series of bibliographies. The initial one was published in February 1958 (Abstract 1-145); and the first supplement, in June 1959 (Abstract 146-287).

McGauhey, P. H.
"Composting of Solid Cannery Wastes"
Research Proposal, 28 March 1961

This proposal outlines the problem of composting cannery wastes, and describes a project that involves a study of the feasibility of composting such wastes. The Sanitary Engineering Research Laboratory of the University of California was to provide a suitable site for the operation at the Richmond Field Station. Staff from the laboratory would provide guidance and supervision.

The development of a plan completely independent of other agricultural and municipal waste disposal problems was the objective. The paper was written as an introduction to the project, outlining objectives and procedures to be followed. No data are given concerning the actual operation or the feasibility of composting solid cannery wastes.

Horstmann, O.
"Technical and Practical Results and Developments in Refuse Processing and Composting"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 14, p. 15, April 1962

Some of the subjects of the article are quantities of different types of refuse, effects of distribution and selling prices, and financial problems. Great surprises can be expected when a plant is designed on the basis of average figures. The sale of compost rarely develops according to plan. It is desirable to have alternate outlets for compost sales. Manual labor should be replaced by machines. Of course this increases the capital costs, interest, and amortization.

Andres, O.
"Agriculture and Compost"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 15, p. 6, August 1962

The author discusses the term composting from the viewpoint of an agriculture engineer.

Anon.
"Cooperation for Composting"
Newsletter, Sanitary Engineering Division, American Society of Civil Engineers, p. 6, July 1966

The Tennessee Valley Authority, Johnson City, Tennessee, and the Public Health Service will undertake a full-scale composting study of municipal refuse and raw sewage sludge. The TVA will design, construct, and operate a composting plant at Johnson City, disposing of that city's wastes of about 60 tons daily. One of the aims of the project is to find an economic use for the finished product, in the form of soil conditioners and fertilizers, to offset disposal costs. The investigators also wish to determine whether or not composting is a safe means of disposing of refuse and raw sewage sludge without creating health hazards.

The plant will cost $750,000 to construct and about $100,000 annually to operate. As a part of the process, metals and glass will be removed, and the remaining refuse will be ground with sewage sludge. The wastes will be stacked in long rows to facilitate decomposition. Tests will be made on the use of compost on "poor soil," and studies will be made to determine its agricultural value.

Wiley, J. S.
"Refuse and Refuse-Sludge Composting"
Journal of the Boston Society of Civil Engineers, January 1967

In the article are discussed some of the results obtained in composting studies in the U. S., and descriptions are given of two processes of composting widely used in Europe. Results obtained in the U. S. studies showed that composting of organic wastes is technically feasible either in mechanical units or in windrows. The organic wastes have moisture contents ranging from 40 percent to 70 percent. In the processes, decomposition generally takes place in the thermophilic range, i.e., 113° to 140°F. End products are humus, or humus forming substances, CO_2, and H_2O.

The author notes that 30 percent to 40 percent of the decompostion of volatile solids occurred within 6 to 11 days in the laboratory, and within 29 to 43 days in outdoor windrows and bins. At the end of the composting process, fibers constituted about 50 percent of the composted material. A good correlation existed between temperature and CO_2 production, water produced and evaporated, and O_2 consumed. Correlation coefficients averaged from 0.75 and 0.85. The respiratory quotient was on the order of 0.9.

Health and nuisance hazards are minimal. Pathogens are killed. Weed seeds, fly eggs, and larvae are destroyed.

Of the European composting systems, the Dano method provides refuse sorting, composting with continuous tumbling and aeration for three to five days (biostabilizer), refinement, and curing of the compost. The rasping system process includes refuse sorting, grinding, and refining, followed by windrow composting for 3 to 5 months.

In combined refuse-sludge composting, raw sludge is added to sorted refuse. The sludge raises the nitrogen content of the material to be composted, and speeds decomposition. The final compost is improved in structure and nutrient content.

SPECIAL METHODS

Rendering

Bloodgood, D. E.
"Annual Report of Sewage Disposal and Garbage Reduction"
Board of Public Works and Sanitation, City of Indianapolis, Indiana, 1937

An interesting quotation reflecting the importance of hog feeding in the disposal of garbage at the time of this report is as follows: "It is interesting to note that the quantity of garbage for the year increased to approximately the same as in 1933 and 1934, indicating that there must be considerably less garbage being fed to hogs by private individuals."

The receipts for by-products are listed as follows:

Grease	$80,328.79
Fertilizer	$13,483.63
Feed	$15,198.40

This amounted to a revenue of $4.45 per ton of green garbage.

> "Because the prices of grains did not follow the price of grease and because the price of grease governs the sale price of feed, it made the price of garbage tankage high as compared with other feeds."

Approximately 37,278 barrels of night soil were removed from a total of 2397 vaults at a total cost of $1,355.21.

The percentage composition of the feeds (garbage by products) is shown in the following table:

Item	Moisture	Protein	Ether Soluble	Fiber	Ash	N.F.N.	Glass
Mixed Feed	8.02	16.79	21.90	17.39	10.77	25.13	-
"Beef Builder"	8.93	17.68	12.07	17.95	11.63	31.29	-
Table Scrap No. 1	6.12	20.23	3.84	22.28	12.55	34.93	0.067

The percentage composition of the fertilizer tankage was as follows: moisture, 5.76 percent; ammonia as NH_3, 3.08; and ether soluble substances, 2.70 percent.

Bloodgood, D. E.
"Annual Report of Sewage Disposal and Garbage Reduction"
Board of Public Works and Sanitation, City of Indianapolis, Indiana, 1938

The quantity of garbage disposed of in 1938 was 12 percent higher than that in 1937. A reduction in the amount of garbage fed to hogs is blamed for the increase. The market price for the garbage by products was lower than that in the previous year. Sales of by products amounted to $11,484 for fertilizer tankage, $22,545 for feed; and $51,950 for grease. This amounted to a revenue of $3.13 per ton of green garbage.

Approximately 36,927 barrels of night soil were removed from 2327 vaults at a total cost of $1,300.

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The chemical compostion of the by products was fairly close to that reported in 1937. (See the previous abstract.) The composition of the garbage grease was as follows: moisture, 0.92 percent; insoluble material, 0.27 percent; unsaponifiable, 3.38 percent; and F.F.A. (oleic), 31.40 percent.

Bloodgood, D. E.
"Annual Report of Sewage Disposal and Garbage Reduction"
Board of Public Works and Sanitation, City of Indianapolis, Indiana, 1939

The garbage tonnage for 1939 was 7 percent higher than that in 1938. Revenue from by products was as follows: grease, $56,570.60; fertilizer, $20,193.56; feed, $19,274.70. The revenue from by products amounted to $3.13 per ton of green garbage. The cost of operating the garbage plant was $0.19 less per ton of green garbage than was the case in 1938. From the 29,348 tons of green garbage received, 832 tons of grease, 2,657 tons of fertilizer, 1,027 tons of feed were produced and sold. To produce this material, slightly over 102 million pounds of steam and 679,500 kw-hr of electricity were needed. The operating costs were $3.55 per ton.

Approximately 38,188 barrels of night soil were removed from 2340 vaults at an average cost of $0.035 per barrel.

Dual Disposal of Garbage and Sewage

Fair, G. M.
"Digestion of Garbage"
Sewage Works Journal, 6:259, 1934

The article refers to a study in which the proportion of sewage sludge to garbage was inadequate. The result was an absence of gas production. The author believes that normally the quantity of sewage sludge would not be sufficient to satisfy the demands for ready digestion of all of the municipal garbage. He advocates recirculating a digested mixture of garbage and sludge.

Keefer, C. E. and H. Kratz
"The Quantity of Garbage That Can Be Digested With Sewage Sludge"
Sewage Works Journal, 6:250, 1934

The article contains a good discussion of the technique used in the study. According to the authors' results, a mixture of equal quantities of garbage and raw sludge digests rapidly in terms of volatile solids reduction, when seeded with the proper amount of digested sewage sludge. A maximum daily addition equal to 5 percent of the initial volatile solids, consisting of equal percentages of garbage and raw sludge can be satisfactorily digested.

Babbit, H. E.
"Disposal of Garbage with Sewage Sludge"
Sewage Works Journal, 6:1103, 1934

According to the article, mixed digestion was practiced in Southampton, England as long ago as 1885. A long list of factors to be studied in research on digesting sewage with garbage is given. Equipment used in the research at the University of Illinois included one-gallon bottles, 50-gallon casks, two Imhoff tanks capable of holding 80,000 gallons, and a separate tank holding 25,000 gallons of sewage.

Babbit, H. E.
"The Dosing of Sewage Tanks with Ground Garbage"
Sewage Works Journal, 7:16, 1935

Imhoff tanks were used in the study. It was found that one of the digesters could handle the equivalent of one ton of garbage per million gallons of sewage.

Carpenter, L., A. C. Rogel, and B. Grabois
"The Disposal of Garbage in the Sewerage System"
Sewage Works Journal, 7:728, 1936

Garbage ground by the kitchen wastes disposal units can be digested satisfactorily in separate sludge digestion tanks. The gas production per gram of fresh volatile solids was essentially the same with the addition of ground garbage. No marked difference was noted between the composition of the gases evolved by the seeded sludge alone and that by the mixture of garbage and sewage. Garbage mixed with sewage settles readily but the concentration of total solids in the supernatant will be that of settled sewage. The increase in BOD of the supernatant is proportional to the increased volatile solids added.

Bloodgood, D. E.
"Digestion of Garbage with Sewage Sludge"
Sewage Works Journal, 8:3, 1936

The work was done with the use of five-gallon cream cans. Daily charges of primary sludge, activated sludge, and garbage (of which the volatile content of garbage solids was 33 percent of the total volatile solids) were added to the digesters. The material was digested for nine days at 85°F. For each gram of volatile solids added to the digesters, an average of 562 cc of gas (CO_2, 32.7 percent) was produced. Reduction in volatile solids amounted to 59.9 percent. Digestion took place more rapidly when garbage was present in the sludge mixture than when sludge alone was used.

Hazeltine, T. R.
"Addition of Garbage to Sewage"
Water and Sewage Works, 84:4, 1937

Digestion of garbage alone produced acid conditions and resulted in a pH level too low to permit digestion. The nitrogen content of garbage (1.5 percent volatile matter as compared with 4 percent in sewage) likewise is too low for good digestion. Digestion with sewage sludge is permissible in ratios of 1.5 to 3 garbage to 1 sludge

Wylie, G. F.
"A Year's Experience in Digestion of Sewage and Garbage Solids"
Sewage Works Journal, 12:760, 1940

In the experiments garbage was ground with a Jeffrey Manufacturing Company hammer mill. After the removal of bones and egg shells, the ground garbage was placed in digesters. The addition of the garbage resulted in an increase in gas production over that coming from the digestion of sludge alone.

The proportion of CO_2 to CH_4 also was higher. Stage digestion was indicated as being necessary for obtaining a supernatant low enough in solids to permit its return to the treatment plant.

Taylor, H.
"Garbage Grinding at Goshen"
Engineering News Record, 127:441, 1941

All of the garbage is ground and digested along with sewage. The plant has been in operation for not quite one year. Performance is satisfactory. Enough gas is produced to supply electrical needs of the village with the exception of street lights.

Cohn, Morris M.
"Effect of Food Wastes on Sewers and Sewage Treatment"
Sewage Works Journal, 18:477, 1946

The per capita production of garbage is approximately 1/2 pound garbage per day. The garbage is about 70 percent moisture; and therefore amounts to about 0.15 lbs of solids per capita per day. The author estimates that the total sewage flow would be increased by 1 percent to 2 percent, suspended solids approximately doubled, and BOD increased by 15 percent to 30 percent.

Simpson, R. W.
"Effects of Ground Garbage on Sewers and Sewage Treatment"
Wastes Engineering, 23:33, 1952

The author discusses the effect of ground garbage on conventional digester performance. An addition of approximately 0.5 lb of solids and an increase in flow of 3 gal per capita per day would be a consequence of universal home garbage grinding. A 56.5 percent increase in raw sludge necessitates a 50 percent greater digester capacity. Garbage decomposes more rapidly than sewage and is accompanied by an increase in gas production and in strength of the supernatant. It also brings about a magnification of the problems of scum and grease. Frequent pumping of raw sludge and two-stage digestion are recommended.

Erganian, G. K., W. G. Belter, and R. C. Graber
"Effects of Community-Wide Installation of Household Garbage Grinders on Environmental Sanitation"
Pamphlet — U. S. Department of Health, Education, and Welfare, Public Health Service, Division of Sanitation, Bureau of State Services, 1952

At the time the Town of Jasper, Indiana, was planning a new sewage disposal system, an outbreak of hog-cholera occurred among garbage-fed hogs near the city and it was unable to find a contractor to handle its garbage. It was decided to use household garbage grinders, but first it was necessary for the State Legislature to enact a bill giving the city legal authority to purchase and install the units on a city-wide basis. Over 900 grinders were in operation at the end of 1950, serving 75 percent of the population of Jasper. No noticeable increase in residential water consumption, no increase in BOD loading, volatile solids, and suspended solids quantities were noted. Seasonal fly populations and rodent proliferation were reduced. Ground garbage constituted 65 percent to 100 percent of the sewage load in terms of lb BOD per capita, 0 percent to 100 percent in terms of suspended solids, and 20 percent to 90 percent of suspended volatile solids.

Plans for the sewage disposal plant prepared prior to the decision to use household garbage grinders were revised by increasing aeration facilities by 50 percent and the volumes of the digestion tanks and sludge drying beds by 60 percent.

Erganian, G. K., W. G. Belter, and R. C. Graber
"Community-Wide Installation of Household Garbage Grinders"
U. S. Department of Health, Education, and Welfare. Public Health Service Publication No. 224, Washington, D. C., 1952

The installation of 900 household grinders serving 75 percent of the population in the city of Jasper, Indiana, increased the BOD of the sewage and resulted in some variations in the quality of the sewage. The improved garbage handling practices reduced the fly problems. The rubbish, free of garbage, is collected once every three weeks and disposed of at the city-owned open dump.

Ross, W. E. and S. F. Tolman
"Garbage Grinding Pays Its Way"
Public Works, 84:70, May 1953

In Richmond, Indiana, garbage is ground at the sewage treatment plant and is added to the digesters along with sewage sludge. The results have been good. The plant was built in 1948 and was in operation in 1951. Prior to the undertaking of the garbage grinding operation, separate collection had been the practice.

The garbage is reduced to a slurry by means of a Jeffrey grinder. Approximately 207 tons of garbage are digested each month (0.35 lb per capita per day). Very little seasonal variation is noted in the amount of garbage production. In September it was 0.42 lb per capita per day, and in February, 0.26 lb. About 95 percent of the garbage solids are volatile.

A financial balance of the operation is given in the following table:

FINANCIAL BALANCE

Operating costs	$4,286.00
Garbage gas at $0.65/1000	5,250.00
495 loads of liquid sludge to farmers at $1.50 per load	743.00
Total Income	$5,993.00

Net profit per ton of garbage:

(5993-4826) ÷ 2474 tons = $0.69

Ross, W. E.
"Dual Disposal of Garbage and Sewage at Richmond, Indiana"
Sewage and Industrial Wastes, 26:140, February 1954

Excellent results were obtained with the use of a sewage disposal system adapted to the increased load. An excellent table of volatile and total solids content as well as digester performance is given in the article.

Allenspach, H.
"Investigation of the Common Treatment of Digested Sludge and Rubbish"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 1, November 1956

A brief abstract is given. It was reprinted from the Publication of the Swiss Association for the Protection of Water, Plan No. 3, 1956.

Tietjen, Cord
"Methane Fermentation with Coffee Shells"
Special Print: Landbauforschung Bolkenrode Mitteilungsblatt der Forschungsanstalt fur Landwirtschaft Braunschweig-Volkenrode, No. 1, Vol. 8, 1958

The article deals with the disposal of coffee shells by means of combined digestion with domestic sludge. The yield of gas at 35°C after 21 days was 313 liters per kg of organic matter fed to the digester.

Watson, K. S. and C. M. Clark
"How Food Waste Disposers Affect Plant Design Criteria"
Public Works, 93:105, June 1962

The community under study was Aurora, Colorado. Sixty-five percent of its population is served by garbage disposal units. The population of the town is 53,000. It is a "bedroom" community and has no industries. The average per capita discharge is 50 gal per day. The disposal units contribute 0.052 lb BOD and 0.064 lb suspended solids per capita per day. The ground garbage constitutes a 30 percent increase in loading to the digesters. The following table is a summary of the sewage plant operation data.

SUMMARY OF PLANT OPERATION DATA
(from 234 to 937 new disposers added each year during the period)

	BOD		Suspended Solids		Costs: Treatment	Costs: Maintenance
	mg/ℓ	lb/capita/day	mg/ℓ	lb/capita/day	$/mg	$/foot of line
1956	271	0.106	277	0.107	127	0.031
1957	323	0.142	321	0.141	96	0.037
1958	318	0.147	332	0.156	82	0.029
1959	290	0.130	348	0.156	98	0.047
1960	316	0.136	365	0.157	80	0.042

Davis, P. L. and R. J. Black
"Effects of Garbage Grinding on Sewage Systems and Environmental Sanitation"
American Public Works Association Reporter, p. 26, December 1962

Although a small portion of total refuse can be disposed of by garbage grinders, 26 percent of total refuse by weight, 7 percent by volume (Don E. Bloodgood, "Digestion of Garbage with Sewage Sludge," Sewage Works Journal, 8:3, January 1936), this portion is the most troublesome part. The garbage-can fly problem is reduced through the use of garbage grinders. By reducing the quantity of food that is available to rats, the use of garbage grinders helps to curb an urban community's rat problem. Although garbage grinding increases the sewage flow by only 1 or 2 gal per capita per day, i.e., by 1 percent to 2 percent, BOD suspended solids, and grease will increase markedly. In Aurora, the BOD was increased by 18 percent, and the suspended solids by 25 percent. (K. S. Watson and Curtis Clark, "How Food Waste Disposers Affect Plant Design Criteria," Public Works, 93:105, June 1962.) Ground garbage has essentially the same specific gravity as the constituents in ordinary sewage, and few new materials are introduced by grinding food wastes.

Little or no increase in capacity is required in primary sewage treatment devices, since they are designed on the basis of sewage flow, which is increased only slightly. However, grit may increase by as much as 40 percent, and the amount of scum formed on the top of primary settling tanks is magnified. An increased secondary treatment capacity is needed to handle the additional BOD and primary effluent.

A greater digester capacity is needed to handle the additional solids (70 percent to 100 percent increase in sludge). The quantity of gas produced when all of a community's garbage is ground is likely to be amplified by 100 percent. Septic tanks must be expanded up to 50 percent in size.

Watson, K. S., R. P. Farrell, and J. S. Anderson
"The Contribution from the Individual Home to the Sewer System"
Journal, Water Pollution Control Federation, 39:2039, December 1967

In an evaluation of the load contributed to the sewer system by three homes using disposers in which the homes were maintained at least one month with and another without the disposers in use, the following results were obtained: 1. No significant increase in use of water took place because of the use of a disposer. 2. The average per capita load increase was 26 percent for suspended solids, 17 percent for BOD, and 35 percent for grease. Data in the following table indicate the effect of garbage disposal by sewer on sewage.

PER CAPITA CONTRIBUTION TO THE SEWER SYSTEM
DUE TO THE USE OF DISPOSER

Parameters	Home	Without Disposer	With Disposer
Water Consumption (gpd/cap)	1	78	71
	2	66	51
	1	24	29
Suspended Solids (gpd/cap)	1	106	134
	2	73	70
	3	44	67
COD (grams/day/cap)	1	205	269
	2	135	125
	3	82	127
BOD (grams/day/cap)	1	158	145
	2	135	69
	3	82	67
Grease (grams/day/cap)	1	28	38
	2	8.3	7.9
	3	6.1	10.3

Digestion

Straub, C. P.
"Digestion Studies of Pure Vegetables"
Sewage Works Journal, 15:658, 1943

Potato skins do not digest as readily as potato pulp. Digestion of cabbage was accompanied by the production of strong odors. These were controlled by the addition of activated carbon or ortho-dichlorobenzene. (No information is given on time, or on other factors.)

Straub, C. P.
"Effect of Addition of Nitrogen on Digestion of Paper Pulp"
Sewage Works Journal, 16:30, 1944

The authors studied the effect of adding salts containing nitrogen on gas production. He noted that the pH dropped with the use of $(NH_4)_2SO_4$. The addition of ammonium sulfate resulted in the production of H_2S. H_2S was not present when $NaNO_3$ was used. Adding nitrate to digesting paper pulp caused an increase in the nitrogen content of the gas, a decrease in methane content, and a more complete destruction of volatile solids.

Babbit, H. E.
"Garbage Disposal as a Sewage Problem"
Sewage Works Journal, 16:861, 1944

Digestion of garbage with sewage has outstanding advantages, even though it involves more work. Information is given on various factors to be considered.

Schlenz, H. E.
"Controlled Garbage Digestion"
Journal, Western Society of Engineers, 49:273, March 1944

A description is given of a system for providing the controlled digestion of garbage solids in a special garbage digestion tank. Garbage is ground in digester supernatant and is placed in perforated containers which remain submerged in the garbage digester for 10 days. The tank is seeded by supernatant from sewage sludge digestion tanks, which also receive the liquid from the garbage digester.

Hungate, R. C.
"The Anaerobic Mesophyllic Cellulolytic Bacteria"
Bacterial Review, 14:1, 1950

An extensive study was made of the isolation of pure cultures of anaerobic, mesophyllic, cellulolytic bacteria from sewage sludge. No cellulose-digesting organisms were isolated from the raw sludge. However, bacterial counts of 880 per ml and 2600 ml were obtained from the first- and second-stage digesters at the Moscow, Idaho, sewage treatment plant. There appears to be a marked prevalence of nonspore forming, obligately anaerobic bacteria among the cellulolytic strains isolated from digesting sludge.

Fester, J. W.
"Disposal of Biodegradable Solid Wastes by High-Rate Thermophilic Digestion"
Public Health 257, University of California, Berkeley, March 1967

The biodegradable and oxidizable fraction of wastes may represent over 60 percent of the wastes generated in a metropolitan area. Optimizing the disposal of this fraction will have a profound effect on the overall situation. The system proposed in the paper is designed to optimize the disposal of garbage, rubbish, and that of waste water. Through rubbish incineration, heat is generated to supply energy for use within the system (digester heating, sludge drying, electricity generation, excess water evaporation) in conjunction with high-energy containing digester gases. An estimated 35 percent overall savings can be gained by using the proposed system exclusive of the savings through electricity generation and lowered handling costs.

MISCELLANEOUS

Pan American Resources, Inc., Lantz Converter Division
"Destructive Distillation: Lantz Converters--Basic Conservation Machinery"
Brochure issued by the Company

The Lantz Converter originally was developed for use in the disposal of wastes from ranch operations. From one pound of a typical combustible waste can be obtained 1/3 pound of carbonaceous fuel which may be compressed for industrial charcoal fuel or briquetted for commercial charcoal; 1/2 pound of cresotar (a variable of liquid creosote and tar); and 4 cu ft of combustible gas.

The three types of Lantz Converter units are the batch type, the interval-feed ram type, and the continuous flow multiple screw type, of which there are the dual cylinder utility types and the completely automatic types. The latter do not require a full-time operation. A description of the converter and illustrations are presented.

Sullivan, W., E. Maharg, and E. H. Hughes
"The Garbage Hog Feeding Business in California"
California Agriculture Extension Service, The College of Agriculture, University of California, Berkeley, Circular 166, April 1950

Points covered in the circular are as follows:

1. Laying out the feeding lot so that a minimum of time and motion is used in performing the necessary chores;

2. The elements of good breeding management — keeping the breeding and feeding herds in balance with the amount of feed available;

3. Keeping costs in line by balancing labor and feed with the size of the herd;

4. Maintaining accurate records that will point out management errors and show where the money is going.

The following are some of the facts given in the circular: One ton of garbage will produce approximately 50 lb of pork. The number of garbage feeding operations from 355 to 417 during the year 1947-1948. Most of the feeding lots were located in the vicinities of Los Angeles and San Francisco. In southern California, 5.5 million lb of pork were produced in the period 1945-1948. A 100-sow unit requires 9.5 tons garbage per day and a minimum of 2 acres of land.

Data listed in the following table give some idea of the value of garbage as a feedstuff.

ANALYSIS OF GARBAGE AS A FEED

Kind	Dry Matter	Crude Protein	Fat	Fiber	NFE	Ash
Fresh Garbage						
Municipal	31.50	4.98	4.82	2.15	16.06	3.50
Hotel, Restaurant, Hospital, etc.	23.81	4.26	5.95	0.68	13.97	1.45
Military	30.13	6.47	8.98	0.61	12.41	1.65
Dried Garbage						
Municipal	89.4	16.90	19.70	11.54	38.23	10.88
Dried Refuse						
Municipal	91.7	17.17	18.49	16.60	34.89	12.79
Digestible Nutrients in Dried Garbage						
Municipal	53.66	8.64	17.10	5.68	24.24	

Anon.
"Raw Garbage Spreads Animal Disease--An Analysis Report"
Clayton Manufacturing Company, El Monte, California, 1953

This is a booklet which covers the swine disease problem in its totality. The discussion of the problem of heating raw garbage before feeding to hogs is based on articles written in newspapers, correspondence between men interested in the field, and on proposed legislation. The booklet provides an overall view on hog feeding, reprinting various related articles and papers dealing with the problem. The solution generally recognized as the most efficient means of ridding garbage of any disease producing organisms is heating. Many states either already have passed legislation requiring garbage to be heated before feeding to hogs, or such laws are pending in the legislature.

Anon.
"Raw Garbage Spreads Animal Diseases"
Bulletin - U. S. Department of Agriculture, Bureau of Animal Industries, Agricultural Research Administration, March 1953

Losses due to animal diseases can be cut simply by giving the proper heat treatment to the garbage which is fed livestock and poultry. The disease-producing organisms are killed by the heat. Garbage containing raw meat scraps, and trimmings can spread such damaging diseases as foot-and-mouth disease, vesicular exanthema, hog cholera, Newcastle disease in poultry, and many other infections.

All costs that can be attributed to communicable animal diseases probably exceed a billion dollars a year. Cooking garbage will not prevent all such losses, but cutting of these losses even by only a small percentage is a wise investment. Almost every case of vesicular exanthema in swine can be traced to hogs fed on raw garbage. Direct costs for eradicating the disease amounts to about $15,000 per day. The last two outbreaks of foot-and-mouth disease can be traced to swine fed on raw garbage. Direct losses from hog cholera are $64,000,000 per year. The disease is spread by feeding to swine, scraps of raw pork infested with the hog cholera virus. Approximately 11 percent of the hogs fed on raw garbage are infested with trichinae, while only a fraction of one percent of hogs fed on grain are so infested. When poultry are fed raw garbage, Newcastle disease is easily spread, affecting from 10 percent to 60 percent of the flock.

Although in the past, the cooperation of farmers was greatly instrumental in curtailing the spread of disease in livestock and poultry, further attacks on infection are needed. The state must pass legislation requiring that garbage be cooked before being fed to hogs. Cooking would greatly reduce the incidence of vesicular exanthema and other major diseases. Vesicular exanthema is the principal disease now, and most efforts have been aimed at eliminating this disease.

Kersetter, J. B. and R. D. Bugher
"Swine Feeding Method of Garbage Disposal"
Public Works Engineers' Special Report No. 15 (with American Municipal Association), May 1953

The publication is a survey report dealing with municipalities using garbage feeding as a method of disposal. After the outbreak of vesicular exanthema in 1952, many municipalities and states required that garbage be cooked before being fed to hogs. The first part of the report deals with cities, listing information in several tables. Cities which switched from raw garbage feeding to other means of disposal, reported their new method of disposal. Costs and revenues from garbage feeding are listed for those cities still using the method.

Since garbage cooking was a relatively new method of disposal in 1953, accurate data concerning the nutritive value of the cooked garbage was not available. It was reported that the method reduced the incidence of disease in hogs. Likewise, data related to costs and methods of cooking were incomplete. A temperature of 212°F was prescribed in most states. In an appendix is given an example of the economics of feeding cooked garbage. The example quotes a net profit of approximately $8,000, plus additional benefits that could not be given a monetary value.

Coogan, G. J.
"Aerobic Treatment of Household Wastes"
Report - The Commonwealth of Massachusetts, Department of Public Health, Experiment Station, Shattuck Street, Lawrence, Massachusetts, February 1962

The Cavitette system was installed and began operation in January 1961, with the following objectives to be pursued:

1. to determine the biochemical oxygen demand of the raw domestic wastes as it enters and leaves the system;

2. to determine the suspended solids under the same conditions as above;

3. to determine the extent of the reduction in the coliform count;

4. to make other chemical and biological observations deemed appropriate for the study.

The results were not good. A further study is being made to determine whether the deterioration in Cavitette performance resulted from excessive hydraulic loading, excessive organic loading, or from a combination of the two.

Black, R. J.
"Combined Disposal of Sewage Sludge and Refuse"
The American City, 77:139, August 1962

Combined disposal of sewage sludge and refuse by landfill, incineration, or composting can result in worthwhile savings to a community if these facilities are located so as to minimize hauling costs. The two types of wastes can be disposed of together in an efficient manner by any of the three methods listed, but the economics involved often make such a plan unfeasible.

A recent survey by the ASCE revealed that 81 percent of reporting sanitary landfills prohibited the disposal of septic tank sludge. This is because some disposal sites are located too near usable waters to allow the risk of contamination from seeping sewage. In other landfill operations, the sludge is spread on top of a layer of compacted refuse so that the refuse can absorb the drainings. The operator must be sure to promptly spread cover material over the sludge so as to reduce odor, rodent and insect problems.

In several cities, including Frederick, Maryland, Louisville, Kentucky, Merrill, Wisconsin, and Whitemarsh Township, Pennsylvania, both refuse and sewage sludge are disposed of in an incineration plant. The cost of hauling either refuse or dewatered sludge often precludes a combined disposal, however. These cities have various methods of combined disposal, yet the process used at Whitemarsh Township, Pennsylvania, is fairly typical. There, excess heat from refuse combustion is used in the incineration of the raw sludge. The water from sewage treatment is used to cool the incinerator furnace walls and scrub the incinerator stack gases. The main difficulty with the combined disposal again is the fact that sewage treatment plants are seldomly located conveniently to refuse collection areas. The added length of haul required to transport the refuse to a combined plant would reduce or even eliminate any anticipated savings.

Studies have shown that almost any amount of sludge can be added to refuse for composting provided the sludge is dewatered such that the moisture content of the mixture is not excessively high. Although the combined disposal of refuse and sewage sludge appears promising, the usual location of the sewage treatment plant would offset any savings because of the resulting increase in haul distance.

Wiley, J. S.
"Some Specialized Equipment Used in European Systems"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 18, p. 25, August 1963

Refuse processing requirements in Europe differ from those in the United States because of differences in the relative amounts of individual components. The author describes the following equipment: rotary screens, vibrating screens, hammer mills, rasping machines, pulverization machines, and inertial separation equipment.

Lucia, F. J.
"Disposal of Bulk Wastes"
Public Works, 95:100, October 1964

In New York City, over 600,000 tons demolition and construction wastes were produced in 1963. Of this debris, 40 percent was combustible. Burning-pits were used for incinerating the combustibles. The pits were constructed as follows: a berm of residue 10 to 15 ft high was setup to form a horseshoe-shaped enclosure 350 ft by 350 ft. A dividing berm erected in the center formed two separate pits with a common entrance. Waste lumber is dumped in one pit in a series of consecutive piles, 30 to 50 cu yd per pile. Ten piles were brought in per 8-hr shift. While one is burning, the other is formed. Fire is kept under control by bulldozer and flusher.

Data pertaining to the year 1964: The fees for using the disposal site were $2.00 per truckload of 10,000 lb or less gross weight; $5.00 per truckload over 10,000 lb gross weight; and $10.00 per tractor-trailer load. Over 25,000 abandoned vehicles were collected. The weight of the bulky refuse (furniture, baby carriages, stoves, etc.) was 110,000 tons. Over 500,000 Christmas trees were discarded. Pier and demolition debris are barged to sea and burned. Burning requires 36 hr. The cost per trip ranges from $1,300 to $1,800.

Martin. S. B. and R. W. Ramstad
"Stable Pyrolysis Products of Cellulose Exposed to Intense Thermal Radiation"
U. S. Naval Radiological Defense Laboratory, January 1965

The volatile products of pyrolysis generated from cellulose as a function of time before, during, and after ignition in air are estimated from gas chromatography analyses of vapors evolved during exposures of cellulose to intense radiant energy in a helium atmosphere. In all, 24 components were resolved, and 18 were identified. The chromatographically measured components comprise 20 percent to 50 percent of the exposure weight loss. The remainder is believed to be mostly levoglucosan. With regard to the phenomenon of spontaneous flaming ignition, the most interesting of the products are H_2, CH_4, C_2H, and C_2H_3. These substances either appear for the first time in the chromatograms or show a large increase in amount at an exposure duration corresponding to ignition in air. Arguments are presented for concluding that these products do not derive from cellulose per se, but are rather products of secondary reaction in the surface char layer.

Cooper, R. C., W. J. Oswald, and J. C. Bronson
"Treatment of Organic Industrial Wastes by Lagooning"
Proceedings of the Twentieth Industrial Waste Conference, Engineering Bulletin of Purdue University, Purdue University, Lafayette, Indiana, May 1965

A brief description is given of aerobic, faculative, and anaerobic ponds. The oxidation pond is recommended for industrial waste treatment. Some industrial installations have been studied. These include the lagooning of wastes from an animal-rendering plant, from a hide-curing plant, from a petroleum plant, and from a chicken-raising operation.

"The Porteus Process"
Brochure by the BSP Corporation, San Francisco, California, Bulletin No. S 114, 1967

Raw sludge (primary or secondary) is pumped from sedimentation tank or digester to storage tank. From the tank, the sludge is pumped through a heat exchanger to the reaction vessel. Within the reaction vessel, temperatures are maintained at 350° to 390°F, pressures at 180 to 210 psi, and the use of a specially designed steam-jet circulator assure an intimate mixture of sludge and steam. After a cycle of approximately thirty minutes, the conditioned sludge is passed back through the heat exchanger, gives up its heat to incoming raw sludge, and enters the decanting vessel. When the treated sludge leaves the heat exchanger, the temperature has been reduced to about 90°F.

The decanting vessel acts as a sedimentation tank. The solid material settles rapidly while supernatant water rises to the top where it is drawn off. At this point, the treated sludge has been reduced to about one-third its original volume. This dense product is passed for final dewatering to vacuum-filters, filter-presses, or other mechanical dewatering equipment. Selection of this final dewatering step depends upon individual plant requirements. Vacuum-filtered cakes with 55 percent moisture have been produced in one Swiss installation. Filter-pressed cakes are more commonly used in Great Britain. These cakes contain as little as 35 percent moisture. With either technique, the final product is an easily handled sterile cake. Dewatered cakes are ideally suited for fuel-free autogenous combustion in a BSP multiple-hearth furnace. Where local codes permit, the cake can be used for compost or landfill.

Creisler, J.
"Today's Pride and Joy, Tomorrow's Refuse Problem"
Public Works, 98:65, January 1967

In the article are discussed the legal problems which beset the handling of junked abandoned autos. Del Norte County, California, has established a public disposal site at which private and commercial owners can dispose of junked cars. The bodies are piled and then burned to hasten the oxidation of the metal. Then a bulldozer is used to crush the cars to an unrecognizable mass and to a fraction of their original volume. The mess is buried.

Problems to be solved are untangling the legal web; and hauling the cars to the disposal site.

Hoffman, D. A.
"'Burns' Refuse Without a Flame"
The American City, 82:102, February 1967

A short report is given of experiments on pyrolysis being done by researchers in San Diego.

The portion of the original retort charge accounted for (percent by weight) at 900°F was 98.7 percent; and at 1200°F was 100.4 percent. A list of the temperatures at which individual gases appeared is given in Table I. Charging a loaded cold rotort into the furnace resulted in the yields presented in Table II. The higher the furnace temperature the higher the yield of gases and the lower the yield of pyroligneous acids. The investigators isolated 23 compounds, and tentatively identified 9. The number includes methanol, ethanol, isobutanol, n-pentanol, tertiary pentanol, and acetic acid.

TABLE I - GAS DETECTION TEMPERATURES

Constituent	(°F) Furnace Temperature at First Detection
CO	500
CO_2	600
CH_4	750
H_2	1000

TABLE II - GAS DETECTION TEMPERATURES

Materials	Furnace at 900°F	Furnace at 1200°F
Condensables	60.3%	54.5%
Char	21.8%	21.8%
Gas	16.6%	24.2%

Borggreen, Georg (Plant Supervisor)
"Refuse-Gasification-Plant"
Newspaper - Die Weltwoche, No. 1739, 10 March 1967

Heizgas aus Kunststoffabfallen: Allenthalben findet man an Schuttabladeplatzen, an den Ufern von Flussen, Seen und an der meereskuste Kunststoffabfalle in Form von leeren Verpackungen, Flaschen and Dosen, die praktisch unzerstörbar sind. Sie häufen sich immer mehr an, so dass schon die Befürchtung geaussetzt worden ist, unsere Nachkommen werden einmal vor hoffnungslosen Bergen unvergänglicher Kunststoffverpackungen stehen; denn bis jetzt konnte man das Material nur verbrennen. Dazu musste man es aber erst sammeln, transportieren und verheizen, was bei den heute anfallenden Mengen erhebliche Kosten verursachen würde.

Daher interessiert hier eine dänishe Erfindung, mit der es möglich ist, Kunststoffe praktisch ohne Rückstände in Heizgas zu verwandeln. Das erste Müllgaswerk der Welt wurde vor kurzem in der jutländischen Stadt Kolding dem Betrieb übergeben. Während man bei Müllverbrennungsanlagen üblicher Art gebrauchte Kunststoffverpackungen ungern sieht, sind sie dort ausgesprochen erwünscht. Der Gedanke, sie zu vergasen, beruht auf der Erfindung des Betriebsleiters Georg Borggreen.

Er ging davon aus, dass Kunststoffe ausnahmslos auf Erdolabkömmlingen beruhen, die daher auch vergast werden konnen. Bei den vorbereitenden Versuchen ürber den Wert der verschiedenen Müllformen zur Produktion von Heizgas hat es sich gezeigt, dass gerade Kunststoffabfälle einen hohen Nutzwert besitzen. Während beispielsweise der gewöhnliche täglich angelieferte Müll je Kilogramm 0,4 m^3 Gas von 3600 Wärmeeinheiten liefert, ergibt die gleiche Menge Abfall mit einem Gehalt von 40 Prozent Kunststoff bis zu 6000 Wärmeeinheiten.

SPUR (San Francisco Planning and Urban Renewal Association)
"San Francisco Solid Waste Disposal Problem"
A SPUR Report and Recommendations, 4 pages, September 1967

A summary report is given on three proposals for the disposal of San Francisco's refuse. It includes a list of advantages and disadvantages and a discussion of proposed unit-train, incineration, and ocean disposal methods of waste treatment.

Editorial
Solid Wastes Management, Refuse Removal Journal, 11:14, March 1968

A portion of the Editorial is devoted to comments about Tezuka Kosan refuse baling process. A "working" model, six stories high, costing the equivalent of 1.5 million dollars has been erected in Tokyo to demonstrate the procedure. The manufacturers claim that the press can reduce a ton of refuse into a "hard" bale, one cu yd in size. The blocks can be transported by rail or road to a landfill or tipped into the sea. The manufacturer claims that the bales can be coated with an inch of concrete or asphalt and used as building blocks. No methane would be formed because the bacteria would be killed by the pressure! One machine can bale 750 tons of refuse a day and provide a like number of compressed blocks every 24 hours.

> "The Japanese baling process has never been put into use. In fact, the present demonstrations show it to be far from living up to the claims of its backers. Many failings must be eliminated, before a full-scale experimental trial can ever be made."

GRINDERS AND PULVERIZERS

Anon.
"Wood Chipper Pays Its Way"
The American City, 72:25, December 1957

When three severe windstorms hit Springfield, Illinois, they blew down hundreds of trees and thousands of branches and limbs, cluttering the streets with debris. During a 12-week cleanup period, the wood chipper disposed of six times as much debris in truckloads. The chipped brush also is much easier to dispose of and can be used as mulch. The blades must be kept sharpened. This has been the only maintenance expense encountered thus far.

Pfeiffer, E. F.
"Comments on the Construction of Grinders for Urban Refuse"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 6, p. 4, January 1959

Hammer mills for grinding urban refuse are severely tested by two factors, viz., the irregular sizes and shapes of raw refuse materials and the irregularity of feeding rate. The mixing of organic and inorganic components results in a sticky, yet abrasive, mass which wears down the hammers. The wear is increased by the buildup of the abrasive mass in the grinder.

The author gives some tips on how to overcome these difficulties.

Anon.
"The Salvage Potential of Domestic Refuse"
Public Cleansing, 51:81, February 1961

The article is an analysis of the refuse situation in England with regard to salvage and its potential. It contains an extensive consideration of the salvage potential of domestic refuse and on the sorting, handling, marketing, and utilization of salvage material. It contains a thorough analysis of refuse and of the factors which would have an effect on future changes in the composition of refuse. English refuse is changing continually in composition in that it has less weight and more bulk. Waste paper increases by 4 percent per year. In 20 years, paper will constitute 25 percent by weight and 75 percent by volume of the total refuse. Factors having a bearing on the change are the increasing use of paper and packaging material, change in dwelling heating methods, and the extensive use of metal containers.

Anon.
"Waste or Wealth?"
Public Cleansing, 51:182, April 1961

In the article is discussed the possible utilization of discarded waste materials such as plants, grass cuttings, waste paper, bottles, and cans. "Pernicious" and "contraries" are terms used to describe substances which cannot readily be detected and which interfere with the reuse of waste products. Any foreign element is a "contrary," e.g., glass and metal scraps in the garbage to be fed hogs. In paper reuse, the most "pernicious" of the "contraries" are the resins added to give paper "cut strength." Other "contraries" are waxed laminates, plastics, polyethylene, and other films. They interfere with repulping.

Andreas, E.
"Grinding Harbor and Bulky Refuse in Amsterdam"
International Research Group on Refuse Disposal, English Translation by U. S. Department of Health, Education, and Welfare. IRGR Information Bulletin 18, p. 48, August 1963

The Hazemag Impact Crusher is described. The model SAP 5/M has a capacity of 120 to 160 m^3 per hr. Energy consumed amounts to 70 kw-hr per m^3. It can crush refuse containing large crates, furniture, mattresses, barrels, refrigerators, carpets, and pieces of stone and concrete.

Anon.
"Clippers Counter Cleo Debris"
The American City, 80:36, February 1965

In Miami Shores, Florida, hurricane Cleo uprooted trees and shrubs and whipped them into the streets. Two new brush clippers were added to reduce the volume of material to be disposed of. Each machine can reduce a truckload of tree branches into a small pile of chips in a fraction of the time otherwise needed to haul and load the branches away. They can shoot the chips directly into truck boxes.

Anon.
"Refuse Reduction Plant Saves Landfill Space"
The American City, 80:92, November 1965

Sanitary Refuse Collectors, Inc. (Montreal) placed into service a $650,000 refuse-reduction and transfer plant. Bulk is reduced by 65 percent (including salvage) and thereby a change is brought about in the nature of the refuse. The processed refuse can be used in the first stage of composting. The plant has a 500-ton per day capacity. The flow chart of the operation is as follows: hopper → pan converyor → conveyor belts → sorting room → salvage (metal, paper, rags, and glass) → crushers → transfer trucks. The hammer mill units consist of 4 rows of swing-hammers with 12 hammers per row in a unit. Each hammer weighs 15 lb and revolves at 1,200 rpm. The hammers are repositioned after each 500 tons of refuse and are replaced after each 1,000 tons. Maintenance of the hammer mill cost (Europe) 57 cents per ton of refuse. The expected operating costs are $1.50 to $2.00 per ton. The addition of capital costs brings the amount to $3.00 per ton.

Meyer, A. F.
"Grinding--An Aid in Refuse Disposal"
Public Works, 97:156, May 1966

The Heil-Gondard process automatically selects out nongrindable refuse and grinds the rest. It thus makes possible the combined collection of any refuse--combustible and noncombustible. By grinding and mixing the refuse to a uniform composition, it facilitates landfill, incineration, and composting operations. It also facilitates salvaging, and makes possible shorter haul distances through the use of milled material at small incinerators and landfills closer to population centers, than is feasible with the large operations needed for unground refuse.

Anon.
"Solid Waste Problems Solved"
Brochure of General Products of Ohio, Crestline, Ohio, 1967

The brochure contains pictures of the Cobey composting machine in action. The machine is a portable or motile combination shredder and windrow forming machine. In operation, collection trucks discharge the refuse in long windrows. The Cobey machines begins at one end of the windrow and proceeds to process it. Refuse enters at the front end of the machine and is discharged as a windrow out the rear end. The windrows are processed once every three days.

Anon.
"New Shredding Machine for Waste Processing"
Public Cleansing, 57:106, February 1967

A description is given of the new design of a shredding machine for the rapid reduction of nonsorted industrial or municipal waste to a predetermined size for continuous feeding to a process plant or disposal system. The machine is manufactured by the Centriblast Corporation, Pittsburgh, Pennsylvania. In the machine, rotary impact hammers are arranged in a spiral formation at intervals along a high-speed revolving shaft. This arrangement allows the full power of the drive unit to be applied to a single hammer at any one time. The hammers intersect a series of star wheels welded to another shaft which revolves slowly, providing the functions of impeller and anvil. Since it is not a fixed anvil, wet or gummy items will not choke the mechanism. If a specific size of particle is needed, a heavily perforated screen is fitted around the assembly.

(Also see: Anon., "The Joy Crusher Disintegrator.")

Anon.
"First Pulverization Plant for Scotland"
Refuse Removal Journal, Solid Wastes Management, 10:40, April 1967

A 96,000 ($268,000) pulverization plant, the first of its kind in Scotland, is expected to serve the new town of Glenrothes for the next 20 to 30 years. The plant will operate 8 hr per day for a population presently 40,000 and expected to increase to 75,000 to 80,000. The system consists of a hopper equipped with a mechanical feeder-conveyor, elevator with over-band magnetic separator, and pulverization equipment consisting of a Dano Egestor and a hammer mill.

Anon.
"The Joy Crusher Disintegrator"
Brochure - Centriblast Corporation, Subsidiary of Joy Manufacturing Company, Pittsburgh, Pennsylvania, 1968

The disintegrator is designed to grind municipal refuse to 4-in. by 4-in. particle size. The machine handles any material. Oversize material passes through the machine without affecting or being affected by the machine. The material is broken and torn by rapidly rotating impactors between slowly moving anvils. It consists of two sections: a crushing section and a disintegration section. The crushing section consists of two heavy duty converging steel tracks. At the crusher discharge opening, the material is gripped by a slowly revolving "star" shaft with equally spaced star shaped rings. Parallel to this shaft is a "high-speed disintegrator" shaft with spaced impactors. The shafts are so arranged that the impactors and star wheels comb through each other. Both impactor and star teeth make point penetration of the material. "Star" surfaces act as anvils for secondary penetration. The close clearance between impactors and star wheel shaft provides a third tearing action.

Anon.
"Pulverization at British Site Reduces Matter by 50 Per Cent."
Solid Wastes Management, Refuse Removal Journal, 11:16, February 1968

Some of the major advantages inherent in the pulverization of wastes are as follows: 1. It accelerates decomposition and fermentation. Hence the deposits are not infested by vermin or insects. Flies, larvae, and eggs are killed by the machinery. 2. Rapid consolidation of the material increases the exclusion of oxygen, thereby reducing the danger of spontaneous combustion. 3. Swift settling is another feature. 4. The appearance of the ground material is nonobjectionable.

The particle size of the material at the Worthing landfill is 2 to 3 inches. It is deposited in layers up to about 8 ft in depth. No covering material is said to be required. The bulk content of the refuse is reduced by about 50 percent.

The smallest economic plant should be related to an input of 10 tons per day. Preferably the input should be automatic since the capacity of one man to feed a pulverizer is only 3 tons per hour. (Editor's Note: A rather optimistic figure!)

The Worthing plant serves some 43,000 people and over 17,000 dwellings. Pulverization of refuse was begun there in 1947.

Anon.
"Two European Cites Use Crushers Operating on 10-Hour Schedule"
Solid Wastes Management, Refuse Removal Journal, 11:45, February 1968

The employment of an impact crusher to crush its refuse has saved Amsterdam from the need to install an additional incinerator. In 1961, Amsterdam incinerated 158,000 cu yd of bulk refuse in two furnaces. It was then decided to crush and incinerate any additional bulk refuse in domestic refuse furnaces. The next year it handled 162,000 cu yd of bulk refuse and 324,000 cu yd in 1963. If the crusher had not been used, the sole alternative would have been to erect an incinerator.

So far no serious breakdowns have occurred. The crusher is operated about 10 hr per day. Replacement of parts costs about 3 cents per cu yd of refuse processed.

Hagen (Germany) has been operating its crusher on a tipping site. A vibrating chute feeds in bulky items from the top level. A heavy-duty bulldozer pushes out the crushed material that is accumulated beneath the unit.

The equipment in both these cities is manufactured by Hazemag of Münster, Germany. The company reports capacities available ranging from 75 to 780 cu yd per hr, with feed openings ranging from 3 ft 7 in. by 4 ft 5 in. to 5 ft 10 in. by 13 ft. A horizontally mounted rotor is housed in a steel casing. The rotor throws refuse entering the crusher against two impact blades. Impacting the material against them reduces the bulk. If the material is not reduced by initial impact, heavy reinforced ribs on the rotor and a second impact plate, with teeth on its lower edge, reduce the refuse by shearing. The impact blades are designed to retract when uncrushable material enters the machine. The unit needs about 0.8 kw per cu yd of throughput.

Anon.
"Wallingford R.D.C. Installs Vickers Seerdrum Pulverizer"
Public Cleansing, 58:185, April 1968

Wallingford has installed a single unit Mark II Seerdrum at their existing landfill. The unit, located in a simple, prefabricated building, is loaded by a tractor shovel operating from the receiving slab.

The Mark II Seerdrum is a 29-ft cylindrical drum 8 ft in diameter, and is rotated by 13 rpm twin 35 hp electric motors. Water is added to the contents to establish a 40 percent to 50 percent moisture content. The drum has an input capacity of about 9 tons per hour.

Anon.
"West German Pulverization Developments"
Solid Wastes Management, Refuse Removal Journal, 11:10, June 1968

A pulverization plant in Wiesbaden, West Germany, is the largest installation of its kind in Europe. The cost of the pulverization plant was $720,000, with $150,000 being used to purchase four crushers inclusive of hoppers and all electrical work. Each unit can handle 11.5 tons per hour. Refuse is dropped from hoppers into the pulverizing mills by way of gravity chutes. The refuse is shredded and all unpulverizable material is rejected up the tower by ballistic separation. Each crusher is, in effect, a 30-ft tower of metal-plate construction set over a swinging-hammer pulverizer.

In each mill there are 48 hammers set in four rows of 12 each, swung from a rotor, which is built up with discs that are positioned with distance pieces both on the main shaft and on four subsidiary shafts. The whole unit is built together with end-plates threaded and locked on the main shaft. Motive drive is from a 140 hp electric unit.

The lower semicircle of the grinding chamber is formed by a three-section grill, the center section being hinged. A choice of grinding widths is available to accommodate varying requirements. The grinding chamber is divided laterally, the upper part consisting of two bolted sections. The sections can be unbolted and separated by undoing 24 bolts – a 20-minute operation. The tower is composed of five sections, with the head part containing a trap for collecting and retaining rejects. (Rejects – mainly rubber products, nylons, plastic containers, and bottle tops – constitute about 3 percent of the total refuse.)

Hammer replacement is necessary every 1400 to 1600 tons of refuse pulverized. Hammers cost about $175 per set, and two men a total of three man hours to complete. Disposal costs run about $1.44 per ton; of which labor costs $0.30 per ton; hammer replacements $0.25 per ton; electricity $0.05 per ton; normal maintenance $0.04 per ton; and loan charge and depreciation $0.80 per ton. Rüsselsheim (Germany) has an 80-ton per day plant; and Wetzlar (Germany), a 40-ton per day plant.

Randles, L. C., Jr.
"The Field of Refuse Salvage"
Compost Science, 4:5, Summer 1963

An evaluation is made of the salvage potential in the disposal of domestic refuse. A detailed discussion is given of the various salvable items of importance. The article contains a table listing the composition of Los Angeles refuse. The table probably is based on data collected by the company to which the author belongs, viz., Los Angeles By-Products Company.

Story, W. S.
"Problems of the Salvage Industry As They Relate To Solid Waste Disposal"
Paper Presented Before the National Conference on Solid Waste Research at Chicago, Illinois, December 1963

(Mr. Story is the Executive Vice President of the Institute of Scrap Iron and Steel, Incorporated.) The paper contains many interesting items of information, among which are the following: 1. In 1962, the ferrous scrap industry provided 25 million tons of processed iron and steel scrap for U. S. consumption and exported 5 million tons. (The nonferrous scrap was approximately 2.3 million tons, of which copper constituted more than a million tons.) 2. The origin of the scrap was along these lines: a. one million tons came from industrial plants; b. four million tons from autowreckers; c. three million tons from demolition; d. 500,000 tons from shipbreaking; e. one million tons from farmers; f. public utilities and government agencies contributed one million tons; g. detinning and tin shredding produced 850,000 tons; and h. individuals, nonmanufacturing, secondhand dealers, and others produced the remainder. 3. The junk dealer and junkshop operator are the mainstays in the collection of obsolescent material. Processing equipment may cost more than a million dollars. The least expensive guillotine shear costs $50,000. 4. A difficulty encountered by the scrap industry stems from the fact that in urban planning, too often no provision is made for the return of the salvage operator. The difficulty arises from the fact that cost of handling and transportation demand that the operator be in the light industry zone. 5. Salvage operations are necessary to the ferrous industry.

A method is described for processing ferrous and nonferrous scrap, including tin cans. The method is the Proler process.

Unfortunately, the demand for scrap is falling. The impact is felt first in the obsolescence scrap area, and consequently is reflected by an increase in amount of wastes to be disposed.

Dunkley, J.
"Waste Paper - Wasted Millions"
Progress — The Unilever Quarterly, Vol. 51, No. 286, 1965

The United Kingdom in its struggle to overcome its balance of payments deficit by cutting imports and producing more at home, is failing to make full use of a commodity it possesses in plenty. Every day, waste paper is thrown away which could save millions of pounds a year on wood pulp. In 1964, the United Kingdom, the largest importer of pulp in the world, spent £122,000,000 on raw materials for paper and board making and a further £133,000,000 on imports of finished paper and board. The recovery and reuse of waste paper saved a further £60,000,000 from being added to the bill. About 27 percent of the waste paper is recovered in the United Kingdom whereas this number is 46 percent for Japan and 33 percent for West Germany.

Russel, W. M.*
"Advantages to the Community of a Progressive Secondary Material Collection Program"
Paper Presented before the Technical Association of the Pulp and Paper Industry, New York, 1966

In 1966, an estimated 10,000,000 tons of paperstock (waste paper) were recycled and became raw material for new products. The U. S. Forest Service predicts the volume will reach 17 million tons by the year 2000. Employment to collect this material and get it to the market place involved 10,000 employees (1958) with a payroll of $45,000,000. Waste paper provides about 25 percent of the raw material for the paper and paperboard industries. The Garden State Paper Company in Garfield, New Jersey manufactures new newsprint from old newspapers. A second mill is in Los Angeles. A new mill will be built in Chicago in 1968. The total value of paperstock (waste paper to consuming mills) is greater than $300 million per year. A beneficial effect on conservation was the fact that 12,800,000 cords (13,000,000 acres) of trees did not have to be cut in 1966 because of the 10 million tons of waste paper that were used in place of wood (i.e., raw material).

In the paperstock (waste paper) collecting system, the dealer collects, processes, packs, sells, and ships the commodity.

*The copy itself bears no author's name — the paper was enclosed with a letter by W. M. Russel to Professor P. H. McGauhey, Sanitary Engineering Research Laboratory, University of California, Berkeley.

Anon.
"Paper Stock Standards and Practices"
Paper Stock Institute of America. Association Headquarters, 350 Madison Avenue, New York, New York, 10017--Circular PS-66, Effective 1 January 1966

As the title indicates, the brochure describes standards (i.e., grades of waste paper) and practices to be followed by dealers and buyers. Forty-five grades of waste paper are defined and described. Methods and standards for baling and shipping are given.

Anon.
"New Methods in Scrap Industry"
Los Angeles Times, 24 July 1966

Junked cars are fed into a fragmentizing machine that reduces them to fist-sized pieces within 30 seconds. The capacity of a shredding plant is about 250,000 automobiles per year. The product is a high quality scrap because it is 99 percent steel.

Anon.
"Solid Wastes"
Environmental Science and Technology, 1:100, March 1967

The article reports on a survey of government projects to determine how wastes can be utilized. Included in the article are references to several projects by the Bureau of Mines concerned with successful junked automobile salvage, reuse of iron and other metals, zinc mine wastes, coal dusts, coal mine wastes (culm dumps), and fly ash. Of the 20 million tons of fly ash produced per year, only 4 percent is used in the U. S. France uses 50 percent and Britain 40 percent. It can be used in making cinder blocks (97 percent fly ash and coal ash), in strengthening concrete, and in road building.

Anon.
"200-350 Tons of Tin Salvaged Monthly"
Refuse Removal Journal, Solid Waste Management, 10:26, March 1967

Tin cans are salvaged from four sanitary landfill operations by the Los Angeles By-Products Company of California. From 200 to 350 tons of tin are recovered at each of the four sites. Copper also is salvaged from the cans. The revenue is as much as several hundred dollars per site per month.

Freed, V. H., R. R. Groner, and J. F. Barbour
"Chemical Transformation of Solid Wastes"
Progress Report, Department of Agricultural Chemistry, Oregon State University, Corvallis, Oregon, 31 December 1967

The following is a direct quotation of the section Summary and Application of the report:

"Both laboratory studies and literature survey have pointed up the possibility of recycling solid wastes through chemical transformations. The cellulosic part of solid waste which comprises large proportions of such wastes is amenable to a variety of reactions. The products of these reactions would have potential usefulness as fuel, plastics, adsorbents, soil amendments and certain types of animal feeds.

"Cellulosic waste may be solubilized by formation of the xanthate which may be utilized as a base for a plastic. Cellulose may also be precipitated as a powder from the xanthate recovering part of the reactants for further utilization. Powdered cellulose may then be further utilized in the reduction reaction to yield liquid products or treated to form various types of plastics.

"To the present, reduction of cellulosic wastes have been shown to yield a variety of liquid products. Some of these products may be useful as chemical intermediates for the total product employed as fuel. It is felt that further studies on appropriate catalysts for this reaction may extend the usefulness of it.

"Destructive distillation of cellulose under reducing condition, yields varying quantities of a condensible liquid. The liquid seems to be comprised of organic acids, alcohols and ketones, all of which may have potential use as chemical intermediates. It is conceived, for example, that a plant carrying out destructive distillation of cellulose would have a supply of organic acids that could be further reacted with untreated cellulose to yield plastic-like materials with a potential use in the fabricating of pipes or as a surfacing material. At the same time there would be generated a number of gases that might provide thermal energy for the operation of such a plant.

"Other transformations of the cellulose that have been examined include the fixation of various elements including nitrogen to afford a useful product.

"Various metals found in solid wastes have been shown to be readily converted to corresponding acid salts such as nitrates or chlorides. Such metals can be recovered by appropriate refining or in many instances can be used as inorganic fertilizer. Another potential transformation of metals would be the formation of carbides at high temperatures and under reductive conditions. Such carbides could then be used as a source of acelylene, of utility as a fuel, or in the synthesis of benzene and other chemical intermediates.

"Studies of the chemical transformation of solid wastes to date have opened up a number of interesting possibilities. It is felt that further investigation will help point out the feasibility of such transformations on a large scale as a means of economic recycling or salvaging of solid wastes."

Anon.
"Great '68 Dump Rush? Trash Heaps May Aid Shrinking Gold Supply"
Wall Street Journal. (Date is missing from clipping. However, it may have been in an early January 1968 issue.)

The article tells of the valuable metals found in incinerator residue. By treating fly ash (possibly with cyanide), $7,000,000 of gold and silver (10 percent of annual domestic industrial and commercial demand) could be recovered per year. According to Carl Rampacek, Division of Bureau of Mines, Metallurgy Research Center, College Park, Maryland, ash going up an incinerator flue contains from 2 to 9 oz of silver per ton; and from 0.02 to 0.05 oz of gold per ton. (The concentration in copper ores averages only 0.004 to 0.08 oz per ton.) Incinerator residue contains as much as 30 percent iron; 1.5 percent nonferrous metals (Al, Zn, Pb, Cu, Sn, and 44 percent glass). Gold and silver comes from burning of rubbish containing such articles as films, solder, costume jewelry, flatware, etc.

Anon.
"Magnetics Process Old Car Scrap"
Solid Wastes Management, Refuse Removal Journal, 11:11, February 1968

The process involves the use of magnets in the separation of nonferrous materials from junked automobiles. In the processing, all saleable items are removed. The car is then dropped into a press and is compressed into a block that is about as long as the original car, but only 23 inches high and 34 inches wide. It is then chopped into a half-dozen segments by a shearing machine. Next, the segments are passed over a picking table where obviously unwanted chunks of material are removed. The segments are macerated into fist-sized particles and are put through a magnetic separator. The ferrous material is transported by conveyor belt to a long, rotating cylinder. Here, gas-fired flames burn off any particles of combustible material which might have been securely caught on the jagged pieces of the shredded vehicles. Quenching with cold water follows. The macerated bits are then ready for shipment.

Hibbard, W. J., Jr.
"Mineral Resources: Challenge or Threat?"
Science, 160(3824):143, 12 April 1968

> "Two reforms are urgently needed to extend the use and to expand the reuse of valuable materials, even though they may seem to run counter to the affluent status our society seems to be trying to maintain. 1. We should design our durable, mineral-containing products to last longer before they go out of style or wear out, and 2. we should design such products to make it easier to collect and separate their mineral content for recycling after they are discarded.
>
> "I propose that in designing automobiles and refrigerators, ranges, and other metallic consumer products, manufacturers should . . . anticipate the need for recycling. If engineering design were to include this concept, valuable materials could then be readily saved when the product is obsolete or worn out. This is a stiff requirement but a necessary one. The annual addition to the scrap market of millions of tons of metal is such a valuable potential resource that we cannot afford to overlook any means of making it easier to salvage.
>
> "There is no reason why, with skill in design and materials application, we cannot make products more durable while we salvage every bit we can from our unusable and discarded products, and thereby extend the mineral base of the nation."

The author insists upon the need to "mine" all types of wastes to recover minerals and thereby reduce mineral losses. Efficient techniques must be devised for reclamation and reuse of mineral-based materials that currently are wastefully discarded. Technology must be developed for mining the wastes of all types, even though this may give rise to costs which would have to be passed on to the consumer. "Nevertheless, the problems arising from mineral supply cannot be treated apart from environmental degradation stemming from the mining, treatment, or use of any mineral substance."

Anon.
"Aluminum Can Reclamation Project No. 2"
Package Engineering, 13:10, May 1968

The second program involving the reclamation of empty all-aluminum cans has been initiated in Los Angeles. The first has been operating for about a year in Miami. The Los Angeles venture offers groups and individuals an opportunity to earn money by turning in all-aluminum cans. (Tinplate cans and other cans with aluminum ends are not acceptable.) Reynolds pays $0.08 per pound. This works out to be $0.02 per five cans. The redemption venture is adjacent to the Reynolds Aluminum Supply Company in the City of Commerce in the Los Angeles area. Cans that are collected are shredded, weighed, and shipped to another point for processing and reuse. According to the Vice President of the Company, current use of aluminum cans for beverages would produce 29 million pounds of scrap per year. The scrap would be worth $2.3 million. The companies currently using aluminum cans in Los Angeles — Anheuser Busch, Coca Cola, and Theo. Hamm — are cooperating in the reclamation program.

Anon.
"Gold, Silver Content Seen at $14 per Ton"
Solid Wastes Management, Refuse Removal Journal, 11:78, May 1968

According to the Department of the Interior's Bureau of Mines, the gold and silver content of refuse might be as high as $14. On a national basis this could amount to a $7-million dollar recovery business. The gold and silver so found could easily pay for the $1.50 per ton required for the disposal of fly ash. Assays of samples of fly ash indicated a concentration of 2 to 9 oz of silver per ton, and from 0.02 to 0.05 oz of gold per ton.

Sliepcevich, E. M.
"Effect of Work Conditions Upon the Health of the Uniformed Sanitationmen of New York City"
University of Michigan Doctoral Dissertation, 1955. Doctoral Dissertation Series Publication No. 20,008, University Microfilms, Inc., Ann Arbor, Michigan

The purpose of the study was to investigate the effect of work conditions upon the health of the uniformed sanitation employees of the city of New York. To do this, the investigation was designed in two parts, a vertical study and a cross-sectional study. The vertical study was a long-term investigation of the effect of work conditions upon the health of a group of 500 workers. The cross-sectional investigation involved a determination of the health status of a group of 8,528 men at any one moment.

Conclusions based on the study are:

1. There is a relationship between respiratory diseases and the season of the year. The rate of incidence of these diseases was greater during the winter and early spring than during the summer and fall.

2. There is no relationship between hemorrhoids, cardiovascular diseases, and skin diseases with the season of the year.

3. Arthritis may be classified as an occupational disease of refuse collectors.

4. Cardiovascular diseases may be classified as occupational diseases of refuse collectors inasmuch as the incidence of these diseases in the sanitation group exceeded all other groups of similar ages.

5. There is a positive relationship between the age of the workers or years of service and arthritis and cardiovascular diseases.

6. The prevalence of muscle and tendon diseases is very high, particularly muscular ailments affecting the back. These may be classified as occupational diseases.

7. Skin disease and hernia may be classified as occupational diseases for refuse collectors.

8. Injuries to the hand are the most common injuries.

9. The injury frequency rate decreases as the years of service increase.

10. Sanitation workers have an extremely high injury frequency rate exceeding that of all other occupations previously studied except logging.

Anon.
"70,000 Flies Per Cubic Foot of Garbage"
The American City, 80:36, February 1965

A maximum of 70,000 flies can be expected to propagate and emerge from a cu ft of garbage. These flies can push their way through five feet of loose material, but cannot pass through compacted soil of 2-5/8 inch in thickness or more, according to Ralph J. Black of the Public Health Service. In New York State there are 60 incinerators, 60 landfills that can be classed as sanitary, and 1,600 unsanitary open dumps. About 50 percent of the people outside New York City have inadequate and unsanitary refuse disposal facilities.

U. S. Government Printing Office for the Committee on Interstate and Foreign Commerce
"Compilation of Selected Public Health Laws" March 1966

Chapter headings in the publication are: Public Health Service Act; Clean Air Act; Solid Waste Disposal Act; Mental Retardation Facilities and Community Mental Health Centers Construction Act; Federal Water Pollution Control Act.

Orange County Health Department, Santa Ana, California
Volumes I and II of the Report "Fly Control Research on Poultry Ranches"
June 1966

Studies were made which involved the development of reproducible methods for sampling and measuring fly infestations and the acquisition of knowledge concerning the natural history of Fannia sp., the type of fly most numerous around poultry operations. These studies are reported in Volume I.

In Volume II is reported a study of four methods of treating poultry manure to control fly breeding. In essence, the study demonstrated that prompt handling of poultry droppings have an excessive moisture content, removing the manure according to a regular schedule, and either storing it under plastic tarpaulins or composting it, reduced fly release into the community almost to the vanishing point. Of exceptional practical importance are the results dealing with the use of natural enemies of immature forms of the Fannia sp. in the control of the fly. The predators were brought in from Trinidad, Puerto Rico, Jamaica, and Wisconsin.

Gilbertson, W. E.
"Services and Facilities to Meet the Environmental Health Challenge"
Paper Presented at the 94th Annual Meeting, American Public Health Association, San Francisco, California, 31 October 1966

The paper is another review of the Task Force's report "Changing Environmental Hazards: Challenges to Community Health." It also discusses the criticism of Mr. A. Wolman in relation to the same subject.

See Wolman's paper "Changing Environmental Hazards" for another treatment of the subject.

Wolman, A.
"Changing Environmental Hazards"
Paper Presented before the 94th Annual Meeting, American Public Health Association, San Francisco, California, 31 October 1966

The paper is a review of G. W. Anderson's report "Changing Environmental Hazards: Challenges to Community Health." It presents a very detailed discussion of the work done by the Task Force.

Hanks, T. C. (M.D.)
"Solid Waste/Disease Relationships - A Literature Survey"
Report by Life Systems Division, Aerojet-General Corporation (Contract No. PH 86-66-151) to U. S. Department of Health, Education, and Welfare, Public Health Service, Bureau of Disease Prevention and Environmental Contaminants, National Center for Urban and Industrial Health, Cincinnati, Public Health Service Publication No. 999-UIH-6, 1967

Although there is a paucity of past work on the etiologic factors of solid waste, an attempt was made to cover the field comprehensively enough to meet the needs of public health practioners. Facts brought together in the report are widely scattered in literature. The authors have not limited the text strictly to solid wastes, but have drawn upon data from other etiologic modes in order to arrive at possible connections of solid waste and its by-products to disease transmission. Their inability to present a "proof-positive" solid waste/disease relationship stems from the fact that our present state of knowledge is not sufficiently standardized to make possible the preparation of a concise account of the subject. The problem of identifying direct health effects is not unique for solid wastes, but occurs throughout the fields of environmental health. However, the postulations made and the evidence cited in support provide potential means for interpretation of waste/disease relationship via different pathways.

Pourbaugh, J. H., J. R. Anderson, and J. F. Burger
"The Insect Inhabitants of Undisturbed Cattle Droppings in Northern California"
California Vector Views (California State Department of Public Health, Berkeley, California), 15:17, March 1968

The insect community occurring in fresh, undisturbed, cattle droppings is described, and methods for the survey and assessment of natural populations are presented. A list of 151 insects attracted to and reared from cowpats during a three-year study is provided along with an annotated key to the California diptera known to pass their larval stages in fresh cow dung. The seasonal occurrence and relative abundance are presented for the major fauna in Marin County.

Other factors discussed are the dispersion of the dung fauna about an area and the dynamics of the colonization of fresh pats and subsequent larval predation and mortality. Mortality of Coprophagous diptera larvae in cowpats is concluded to be almost totally due to entomophagous insects; it is proposed that high numbers of horn and face flies in an area are attributable to a scarcity of natural enemies in the droppings. Two explanations are presented as to why these two pests generally are more abundant in the United States than in Europe from where they were introduced. The face fly should soon invade and flourish in California in areas where the existing cowpat community is uncrowded and relatively free of natural controlling agents.

AIR POLLUTION

Extent

Anon.
"The Air Resources of Kansas"
Pamphlet – U. S. Department of Health, Education, and Welfare, Public Health Service and Kansas State Board of Health, September 1962

Although air pollution is not at present a pressing problem to the state of Kansas, the Kansas State Board of Health directed the Division of Sanitation to recommend steps the State should take to avoid the aggravation of air pollution problems to the extent found in many currently unsatisfactory situations.

The topographic and climatologic characteristics of Kansas are such that dispersion of atmospheric pollutants is usually favorable. However, air pollution problems are reported in many areas of the state, and it is certain that more cities will have air pollution problems as the population continues to increase and concentrate in urban areas.

Concentrations of suspended particulate matter were measured in the three largest cities, and were generally found to be low. However, fairly high concentrations occur occasionally. Soiling index values were generally light, but moderate soiling was detected in Kansas City during peak hours.

The major air pollution problems encountered were: dust and odor from alfalfa dehydrators; dust from grain elevators, cement plants, etc.; malodorous conditions associated with commercial cattle feed lots; smoke and refuse at city dumps and in backyard incinerators; and odors from oil refineries and rendering plants. Alleged health damage from air pollution was reported in three cases and property damage was reported in four cities.

Present Kansas laws do not provide for effective air pollution abatement or prevention. One of the recommendations of the Divisions of Air Pollution was for the State to provide for the establishment of legislation to permit the formation and financing of air pollution control districts in any part of the state. It was also recommended that local agencies furnish complete refuse collection and disposal service to eliminate backyard burners and burning dumps.

Hochheiser, S. and R. E. Wetzel
"Air Pollution Measurements in Indianapolis -- June-July 1963"
Pamphlet – U. S. Department of Health, Education, and Welfare, Public Health Service, July 1964

Atmospheric samples were collected and analyzed for gaseous and particulate pollution from 26 June to 23 July 1963. The mobile air-sampling laboratory was situated in the center of the city and represented the average air pollution in the mid-town commercial district. Additional air sampling equipment was located at another location downtown and at the Indianapolis Airport.

From these studies, the City of Indianapolis attempted to: 1. determine the nature and extent of air pollution, 2. relate levels of air pollution to factors influencing concentration such as topography, population density, population sources, climate, meterorological conditions, and other influences, 3. relate levels of air pollution to its effects on health of humans and animals, quality of vegetation, and other economic and aesthetic losses, 4. determine the effect of control programs, 5. determine trends in air pollution, 6. provide the public with protection from hazardous levels of pollution.

Observed pollution levels were considered to be average for Indianapolis during the summer. Conclusions based on results from the study include:

1. A year-round continuing air monitoring program should be instituted at strategic sites throughout the area to determine seasonal variation in pollution levels.

2. A potential for the occurrence of adverse concentrations of photochemical smog was demonstrated, and with the expected growth of fuel consumption and motor vehicle use, a control system should be set up.

3. Pollution due to particulate matter was found to be heavy a good part of the time, and soiling capacity is expected to grow during the winter heating months.

4. The resources of the Indianapolis Bureau of Air Pollution Control should be expanded, and a technical advisory committee to the Bureau should be established.

Griffin, C. W., Jr.
"The Air Around Us"
The Reporter, p. 39, 10 September 1964

Smog already is a hazardous problem in the urban areas of the United States today, and will continue to grow at a rate faster than that of population increase unless some definite measures are taken soon. There are two kinds of smog. The first is composed chiefly of sulfur dioxide gas and smoke released from the burning of bituminous coal or low-grade fuel oil. The second type mainly consists of gaseous hydrocarbons released from petroleum refineries and motor vehicles. Smog found in London is a good example of the sulfur-compound type; while that occurring in Los Angeles is of the hydrocarbon variety. Smog has been linked with many deaths. Most widely known examples are: 1. the 17 deaths which occurred during a 4-day period of heavy smog in Donora, Pennsylvania, in 1948; 2. four thousand deaths in London during a 5-day period in 1952, and 750 deaths in London in December of 1962.

The incidence of smog and respiratory diseases is definitely related, according to many doctors. On the other hand, this fact is denied by many oil and other related industries. The death rate from pulmonary emphysema increased more than four times during the years 1950 to 1959. Death rates from major respiratory diseases were 64 percent higher in the highly polluted sections of Nashville, Tennessee, than in the slightly or moderately polluted areas. The economic losses from air pollution were estimated at $11 billion annually, but even this huge estimate does not include working time lost from illness due to smog-caused diseases.

Air pollution control efforts, except for a very few instances, have been woefully lacking in the United States. Los Angeles has gradually eliminated home incinerators and has cracked-down on industry. The State of California has attempted to bring about a significant reduction in the amounts of auto exhaust. The Federal Government recently passed the Clean Air Act, whereby power is given to the Department of Health, Education, and Welfare to investigate pollution from auto exhaust

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and sulfur-contaminated heating fuels. It also was given some authority in cases involving interstate pollution problems.

California recently approved the use of afterburners on automobile exhausts, yet the large auto manufacturers are still trying to get around the law. Many people, too, remain skeptical of the existence of a relationship between air pollution and poor health. To combat the problem, political boundaries must be set aside, and regional air pollution control districts must be established. A temporary approach to reduction in the amount of pollution in the air is to tax those who pollute the air. Taxes enforced thus far are not enough to make industry cut-back on its pollution level. Something must be done soon, for the longer the struggle for clean air is postponed, the greater will be the price in terms of costs, health, and even of lives.

Medalia, N. Z. and A. L. Finknew
"Community Perception of Air Quality: An Opinion Survey in Clarkston, Washington"
Public Health Service Publication No. 999-AP-10, U. S. Department of Health, Education, and Welfare, Public Health Service, Division of Air Pollution, June 1965

The cooperative program for aerometric study in the Lewiston-Clarkston region included a public opinion survey of Clarkston to determine the extent of annoyance with air pollution expressed by persons in that city of 7,000. Clarkston is approximately four miles downwind from a pulp mill. The survey was taken to analyze the environmental stress of air pollution on a sample of household heads and spouses, along the attitudinal dimensions of awareness and concern. Of those interviewed, 91 percent perceived air pollution in Clarkston as a malodor problem, 74 percent perceived it as a problem of visibility, and 62 percent perceived it as a problem of nose-throat irritation. A Guttman-type scale showed high concern with air pollution among 48 percent of the sample, low to moderate concern among 31 percent, and minimal concern among 21 percent. Although exposure to air pollution was about equal for all members of the sample, their concern with air pollution was found to vary directly with social status and attitude characteristics such as civic pride, desire to ameliorate the situation, length of residence in the community, and occupation prestige of the household head.

In the report's seven appendices are included, a description of the sampling procedure, a manual of instructions for interviewers, interviewer-suggested revisions of the survey questionnaire, interviewers comments, a content analysis of newspaper clippings, the estimation procedure, sampling errors, and 95 percent confidence limits for selected sample proportions.

Kimball, T. M.
"Air Pollution"
<u>National Wildlife</u> (Reprint), <u>4</u>, March 1966

Two-thirds of the population of the United States live in the 7,000 urban areas afflicted with polluted air. Of the 250-mile envelope of air surrounding the earth, only the bottom 12 miles is dense enough to be useful, and a thin layer 2,000 feet thick supplies most of the air we can use and breathe. This is six quadrillion tons of air, which is a large, but finite amount of air.

Air pollutants consist of smoke, gases, and odors.

In December 1952, a "killer smog" settled over London for four days. The total toll of those whose deaths were directly attributable to its effects and of those having ailments which were aggravated fatally is estimated to have been between 3,500 and 4,000. In 1948, a stagnant air mass over Donora, Pennsylvania, choked its 15,000 residents with fumes from blast furnaces and a zinc reduction mass, killing 20 and sickening 43 percent of the population. Incidents of a lesser dramatic impact have been experienced in Washington, D. C. and in Los Angeles.

The average adult inhales 6,000 gallons of air daily and 10 billion particles of foreign matter if he lives in a city. Inhalation of the particulate matter has been linked to a number of diseases. The total national property loss from air pollution is estimated as being $11 billion per year – or $65 per capita. Control of air pollution is possible with presently known techniques and would cost $3 billion, a saving of $8 billion on our current $11 billion air pollution cost.

The increasing CO_2 content of our atmosphere may raise temperatures sufficiently to affect the weather adversely. Air pollution also causes crop damage.

Bunyard, F. L. and J. D. Williams
"Interstate Air Pollution Study--St. Louis Area: Air Pollutant Emissions Related to Actual Land Use"
Paper - 59th Annual Meeting, Air Pollution Control Association, San Francisco, California, June 1966

Air pollutant emissions are related to three land-use categories: 1. residential, 2. institutional, and 3. industrial. Sources of pollutants receiving consideration are: 1. power generation, 2. fuels used for space heating, 3. solid waste disposal, and 4. industrial processes. The pollutant emissions which are discussed are particulates and sulfur oxides. The paper gives cumulative frequency distributions based on acres of land use and corresponding emissions per unit area. These frequency distributions--actual emission conditions that can be related to known air quality levels--provide a basis for performance standards and a guide for planners and others in future city developments. The use of land area as a factor in establishing the required degree of air pollutant control, a factor inherent in emission performance standard zoning, gives a wider spectrum of choice to individual users of the air space.

Miller, M. E. and G. C. Holzworth
"An Atmospheric Diffusion Model for Metropolitan Areas"
Paper - 59th Annual Meeting, Air Pollution Control Association, San Francisco, California, June 1966

An urban diffusion model is presented in the development of which it is assumed that continuous pollutant sources are uniformly distributed over the urban area. This permits them to be treated as a series of uniform cross-wind line sources. It also was assumed that vertical diffusion occurs until the effluent from each line source reaches the top of the mixing layer. Relative concentrations as a function of mixing depth and wind speed are derived. Rough estimates of relative concentrations at the times of maximum and minimum atmospheric dilution are made. The model was tested with data from Los Angeles, Nashville, and Washington, D. C. Reasonably good results were obtained. When a representative pollutant concentration is known, the model may be used to determine the apparent "uniform" source strength.

Koogler, J. B., R. S. Sholtes, A. L. Danis, and C. I. Harding
"A Multivariate Model for Atmospheric Dispersion Predictions"
Paper 66-27 - 59th Annual Meeting, Air Pollution Control Association, San Francisco, California, June 1966

An atmospheric dispersion model is presented which describes the dispersion of a gaseous pollutant in either an urban or a nonurban environment. The input parameters are wind speed and direction, the atmospheric stability classification, and the pollutant emission rate from area and point sources. These factors can be varied over any integral multiple of an hourly period up to 24 hours. The output is the ground level concentration of the pollutant computed for 225 points defined by a 15 by 15 grid, and can be averaged over any integral multiple of an hourly period without limitation.

Components and Analytical Methods

Tebbens, B. D., J. F. Thomas, and M. Mukai
"Hydrocarbon Synthesis in Combustion"
American Medical Association Archives of Industrial Health, 13:567, January 1956

Polyaromatic compounds are formed as a result of incomplete combustion of solid and liquid fuels, and are found in the combustion products of hydrocarbon gases. Because the fuels are aliphatic (methane, butene-1, acetylene, and butadiene), and the combustion products are polyaromatics of a much higher molecular weight, a mechanism for their formulation is necessary. It is suggested that organic fuels undergo a pyrolytic degradation resulting in the formation of hydrocarbons and free radicals having a low molecular weight. The latter combine to synthesize ring compounds of the condensed nuclear type. The compounds tentatively identified by chromatography and ultraviolet spectrophotometry range from anthracene to those having six or more benzene rings. A brief literature review is given.

Chromatographic methods used in the study are described in an addendum.

Tebbens, B. D., J. F. Thomas, and M. Mukai
"Aromatic Hydrocarbon Production Related to Incomplete Combustion"
Paper - Air Pollution and Engineering Section, American Industrial Hygiene Association, Philadelphia, Pennsylvania, April 1956

Evidence from the literature indicates that condensed multinuclear aromatic hydrocarbons generally are produced during the combustion of solid and liquid carbonaceous materials. Experiments show that even the simplest gaseous fuels produce them. Natural gas, butane, butene-1, acetylene, and butadiene were burned in a furnace, and the products were measured. Incomplete combustion was achieved by eliminating primary air. A minimum of 16 compounds were detected by chromatographic techniques, of which 8 were identified definitely. Of these, two were carcinogenic. Complete combustion does not result in the production of significant quantities of these hydrocarbons. The paper contains a table of data for gaseous fuels, and one of arenes of known composition.

Thomas, J. F., B. D. Tebbens, M. Mukai, and E. N. Sanborn
"Determination of Aromatic Hydrocarbons in Polluted Air"
Paper - Air Pollution Symposium, American Chemical Society 130th National Meeting, Atlantic City, September 1956

The paper gives a description of techniques for the separation of materials found in polluted aerosol samples. It is believed that most of the organic contaminants fluoresce and belong to or are derivatives of condensed multinuclear aromatic hydrocarbons. In preliminary work, the material was separated into three broad solubility classifications: neutral hydrocarbons, phenolic, and carboxylic derivatives of these hydrocarbons. Through electrophoretic and chromatographic techniques those groups were separated into more than 40 different components, most of which have been at least tentatively identified by comparison with products obtained in the separation of mixtures of compounds of known composition. Spectrophotometric methods involving absorption and fluorescent curves are a means of identification.

Wilson, K. W. and H. Buchberg
"A Controlled Environment System for Air Pollution Studies"
Paper - University of California, Los Angeles, Report 58-54, Annual Meeting Air Pollution Control Association held in Philadelphia, May 1958

The paper gives a description of the construction of a polyethylene air reaction chamber. Limitations of various materials are discussed. The operation of the system is presented. Leakages and limits on experiments due to leakage and to reaction of the pollutants with the polyethylene are discussed. The paper includes a description of an experiment concerned with the relation of engine exhaust to eye irritation, and in which an attempt was made to duplicate Los Angeles smog by reacting pollutants with light and air in the chamber.

Anon.
"Atmospheric Emissions from Petroleum Refineries"
Public Health Service Publication No. 763, U. S. Department of Health, Education, and Welfare, Public Health Service, Division of Air Pollution, 1960

The research done on this project was carried on in Los Angeles County. The report is designed to acquaint those people not conversant with the technical information concerning petroleum refineries with the problem of atmospheric emissions from such plants. It is a general report which includes a description of petroleum refining, data on atmospheric emissions from oil refineries, and an estimate of atmospheric emissions from oil refineries.

Historically, Los Angeles County has been one of the areas in the world worst hit by air pollution. As a result, the Air Pollution Control Board has set up very stringent standards for air pollution levels. Because of this, the county refineries discharge an abnormally small amount of contaminants to the atmosphere. Therefore, quantities of refinery pollutants in the atmosphere listed in the report are indicative only of those in the County, and do not reflect trends throughout the nation.

The first section of the pamphlet deals with a general description of the refining process. The four main processes of refining are described: separation, conversion, treating, and blending. A thorough explanation of the conversion and treating steps is given. The second section deals with steps in the refining process that tend to allow pollutants to escape into the air. The final section concerns sources of pollution in Los Angeles County.

The methods used to estimate emissions presented in the manual are not a substitute for actual work. This is because of different methods used at various refineries throughout the country.

Kaiser, E. R. and J. Tolciss
"Control of Air Pollution from the Burning of Insulated Copper Wire"
Technical Report 764.3, Annual Meeting Air Pollution Control Association, Chicago, May 1962, College of Engineering, Department of Chemical Engineering, New York University

Salvage yards and metal refiners annually recover at least 100,000 tons of copper from approximately 200,000 tons of scrap insulated wire. The insulation generally is removed by burning in the open and in furnaces. Air pollution caused by burning insulation consists mainly of carbonaceous particulate matter, metal chlorides, sulfur compounds, and ash dust dispersed in the combustion gases and excess air. Nitrogen dioxide, fluorides, hydrochloric acid vapor, and other substances also are produced. Flue gas and fumes from the hot burned wire have a strong odor and irritate the eyes, nose, and throat.

The state of the wire-burning art is discussed. A design is given for an incinerator which eliminates the discharge of carbonaceous smoke by complete combustion in an afterburner. The use of a scrubber to reduce other pollutants is discussed. Test procedures and results are fully described.

Crocker, T. D.
"In Polk and Hillsborough Counties, Florida"
Bulletin Atomic Scientists, 21:17, June 1965

Citrus fruits, cattle, and phosphates are the main products of Polk and Hillsborough Counties in Florida. In the fifties, the phosphate industries expanded to the extent that air pollution in the form of fluorides was poisoning both the cattle and the citrus trees. The concentration of fluorides in the air due to phosphates mining reached levels greater than 50 parts per billion by volume. Pasture grasses at times have accumulated fluoride in concentrations greater than 300 parts per million by weight in a 4-week period, with concentrations of 100 parts per million being common. In the winter and early spring months, temperature inversions occur on two-thirds of the nights, greatly reducing the air's self-cleansing capacity. Citrus groves within the polluted area at times were sold for 20 percent less than groves situated elsewhere.

Due to the efforts of the Polk-Hillsborough Air Pollution Control District and of the triple-superphosphate industry, fluoride emissions, which averaged 33,000 lb per day for the industry as a whole in the winter of 1961-62, were reduced to 13,000 lb per day during the winter of 1963-64. Nevertheless, a satisfactory level still has not been reached.

Head, R.
Pamphlet - Reprinted from "Applying Technology to Unmet Needs," Appendix Volume V of "Technology and the American Economy." Report of the National Committee on Technical, Automation, and Economical Progress, U. S. Department of Health, Education, and Welfare, Public Health Service, pp. V-135 - V-145, February 1966

Subjects covered are technological change as a cause of air pollution, nature and sources of air pollution, extent and distribution of air pollution, economic and social effects of air pollution, current status of air pollution control, barriers to effective control, four basic needs for the future, and how better controls might help to meet community and human needs.

The following are examples of important information and concepts given in this pamphlet:

1. Since World War II, new kinds of chemical pollutants are introduced into the environment at a rate exceeding the ability to assess possible ill-effects from them.

2. The fraction of pollution coming from incineration is not large. Even if small, it can be an aggravating factor or even a "breaking point." Total pollution is an aggregate of individually small contributions.

3. Pollution can affect health by way of aesthetics (e.g., dirtying clothing and offending the senses), by way of corrosion (SO_3 in the air), by way of reduction of visibility (as much as 25 percent to 50 percent), by its effect on climate (e.g., increase in incidence of fog), and consequent limitation on the suitability of our environment with respect to needed recreation, and by destroying vegetation.

The following table gives an indication of the constituents of air pollution.

NATURE OF AIR POLLUTION

Solids	Liquid Droplets	Gases	Metallic Fumes and Dusts	Photochemical Reactants
Soot	H_2SO_4	SO_4	Pb	Ozone
Dust	Mist	CO	As	Peroxacetyl nitrate
		H_2S	Be	
		NO_2	F	
			P	

The annual damage by air pollution accounts to about 12 billion dollars per year or $65 per capita per year. In its section on health, the report calls attention to the publication "Report of the Committee on Environmental Problems to the Surgeon General" (1962 Public Health Service Publication No. 908). Respiratory ailments which may be traced in part to air pollution are specific infectious upper respiratory disease, chronic bronchitis, constrictive ventilatory disease, pulmonary emphysema, bronchial asthma, and lung cancer.

The following are direct quotations from the pamphlet:

1. "Some of the pollutants which are now of only local concern may tomorrow become widespread.

2. "Air pollution is no longer confined to isolated places. This generation has altered the composition of the atmosphere on a global scale--pollution destroys beauty.

3. "Better controls can also help to prevent or alleviate the pain and discomfort of such dread diseases as emphysema and lung cancer, and to lengthen the lifespan."

Anon.
"What is Sulfur Dioxide"
The article is contained in a news sheet issued by the New Jersey State Department of Health, Air Pollution Control Program, 1967

Included is the following table on SO_2 emission.

SO_2 EMISSION INVENTORY, NEW JERSEY METROPOLITAN AREA

Source	Quantity ton/yr	Percentage of Total
Industrial Processes	61,793	8.15
Refuse Disposal	237	0.02
Gasoline Consumption	3,985	0.53
Diesel Fuel Consumption	3,222	0.43
Industrial Process Fuel	212,530	28.08
Generation of Electricity	260,448	34.41
Domestic Space Heating	73,239	9.68
Commercial and Government Fuel	141,519	18.70
	756,883	100.00

Windom, H., J. Griffin, and E. D. Goldberg
"Talc in Atmospheric Dusts"
Environmental Science and Technology, 1:923, November 1967

Talc in the atmosphere probably comes from agricultural activity where talc is used both as a carrier and diluent for pesticides. The mineral talc is found in atmospheric dusts and in the solid mineral phases of rain and snow in amounts approximating one percent by weight in the solid phases. Although the talc has been found in samples from San Diego, California; Scotts Bluff, Nebraska; Minicoy Island, India, and Bagdad, Iraq, its presence appears to reflect a local introduction rather than a generalized global fallout.

Corn, M., T. L. Montgomery, and R. J. Reitz
"Atmospheric Particulates: Specific Surface Areas and Densities"
Science, 159(3821):1350, 22 March 1968

Suspended particulates in Pittsburgh air were collected on glass-fiber filters. The specific surface areas of particulates brushed from the filter surface varied from 1.55 to 4.51 square meters per gram when measured by the Brunauer-Emmett-Teller (BET) method with nitrogen and krypton, after 8-hour degassing of the samples at 25°C. Specific surfaces of the same samples varied from 4.3 to 8.00 square meters per gram after 4-hour degassing at 200°C. Bulk densities and densities of samples were 0.49 to 0.64 and 2.0 to 2.6 grams per cubic centimeter, respectively. These data provide some basis for explanation of unpredictable responses reported after inhalation of mixtures of pollutant gases and particles by animals and man; they should also assist in interpretation of gas-solid phase reactions in the atmosphere.

Health Aspects

New Medical Materia Commentary
Pp. 5-37, February 1963

The publication contains a series of brief articles on air pollution and includes photographs of city skylines showing smog. It quotes Surgeon General Terry as stating that pollution is a "group crime" for which society must take group responsibility and ambitiously end it at its source. Until recently, pollution was considered a public nuisance; now it is considered a danger to health and physicians are increasing their role in air pollution control. A chart of pollutant levels in 189 cities is given.

Industry is willing to control pollution only up to a certain point after which it becomes reluctant because pollution control cuts too deeply into profits. The stringency of air pollution regulations is a factor in selecting a plant site.

The publication includes an eyewitness description of the Donora episode. In other sections, it is stated that physicians reported 1,600,000 cases in which air pollution was a factor in 1962. Physicians' views on air pollution are discussed. Aggregated data are given.

Goldsmith, J. R., L. Greenburg, A. P. Althsuller, W. P. Spicer, Jr., E. J. Cassell, and H. H. Landsberg
"Air Pollution and Health"
Release - American Thoracic Society, Committee on Air Pollution, February 1966

Meteorological conditions are an important factor in the dispersion of pollutants, and in the promotion of the accumulation of pollutants in the atmosphere, and in the induction of chemical changes in the air. Air stagnation, especially when accompanied by a temperature inversion, may result in the accumulation of pollutants to dangerous levels.

Measurement methods and the analysis of data are discussed.

The Meuse Valley (1930), Donora (1948), London (1952), and Poza Rico (1950) incidents illustrate unplanned severe health hazards arising from pollutant concentration due to meteorological conditions. In these incidents respiratory illnesses and deaths were above normal. Other examples mentioned are "Tokyo-Yokohama" disease in American armed forces personnel brought about by air pollution. Epidemiological and laboratory studies are briefly discussed. A summary of established information between respiratory illness and various pollutants is given.

Kinsey, D., P. Bender, and B. Gallaher
"Air Pollution and the Heart, Air Pollution and the Lung"
Reprint from Journal of the American Medical Women's Association, 21:583, July 1966

Air pollutions most damaging effects are found in the respiratory system and the heart. The human body is not designed to withstand lengthy exposure to polluted air. Without warning, constant irritation creates a vicious and irreversible cycle. Once damaged, the respiratory system loses its ability to protect itself. Meanwhile the heart works harder – sometimes doubling in size – to pump enough blood through the body to compensate for the loss of oxygen.

Bagdikian, B. H.
"Death in Our Air"
The Saturday Evening Post, 8 October 1966

This is the third article in a series on the American environment. The gist of the article is expressed in the following quote "Once a problem, now a crisis, air pollution is sickening and killing thousands of Americans and poisoning both city and suburb. Unless we act, things will get worse."

Chapman, T. S.
"Air Pollution and Our Health"
Paper Presented at the National Conference on Air Pollution, 12-14 December 1966, Washington, D. C. (Paper P-4)

In any approach to the problem of air pollution it has to be stated that the problem is basically an ecologic one. Each species, if it is to survive, must find the necessary oxygen, carbon, sulfur, nitrogen, and so on to support its existence and to allow for reproduction. Each species also must eliminate wastes in such a way that their accumulation in the environment will not approach toxic or inhibitory levels.

Anon.
"Respiratory Diseases and Air Pollution"
Environmental Health and Sciences, 1:969, December 1967

After 15 years of research Dr. P. J. Lawther, Director of Air Pollution Research at St. Bartholomew's Hospital Medical College, London, concludes that air pollution is not necessarily the cause of lung cancer and respiratory diseases, although some agent in air pollution might be a factor. "It is interesting to note that the two areas of the world with the highest lung cancer rate are the Channel Islands and Finland, both of which have no air pollution at all." (Editor's Note: Perhaps the inhabitants are "chain smokers!")

Economic Loss

Anon.
"Air Pollution"
Special Report (45 pp.) - Power, December 1960

The first section of the report deals with the air around us and what affects it, and with the wind patterns throughout the world. The influence of bodies of water on temperature, the shape of land features on movement of air, and the role the sun plays in influencing weather conditions are also considered.

The second part emphasizes the fact that as man tends to group together more and to urbanize, the amount of pollution will also tend to congregate with him. Basic industrial processes create a variety of pollutants, automobile exhausts pollute the air, incineration and other sources add contaminants, and pollution problems become much more complex when all of these sources are collected together in concentrated form.

The third section of the report deals with the effect of pollution on communities. Added expenses due to air pollution may include bigger medical bills and a reduced labor output, smaller livestock returns and a lower agricultural yield, depressed real estate values and higher cleaning costs, increased lighting costs due to poorer visibility, and extra maintenance expense and higher equipment costs. Almost all of the total losses due to these causes are not recognized by the general public; they largely feel that the problem is only one of eye irritation on hot days. But the dollar loss from the unclean air is running into billions of dollars annually, despite present controls. The report describes a procedure followed in a hypothetical situation, viz., Central City, USA. In this hypothetical city, a pollution control program was established - one which any city in the U. S. today could and should endeavor to establish.

The last chapter of the special report describes the factors to be kept in mind by business when deciding upon the location of a new plant. It is recommended that a determination be made of the potential pollutants to come from the new plant, a consideration be made of the environment in which it will be located, and of its effect upon the local situation. The possible effects of topography and local weather conditions on the pollution potential should be estimated. A suitable means for monitoring the emission from the plant should be planned.

Griswold, S. S.
"What Pollution Costs"
Bulletin Atomic Scientists, 21:12, June 1965

Various estimates of the cost of air pollution range from $1.5 to $12 billion annually, or $10 to $65 per capita. Anthony Celebrezze in his testimony in 1963 on the recently enacted Clean Air Act gave an estimate of $11 billion annually. California farmers suffered a direct loss of at least $8 million a year in crop damage from air pollution. Livestock are affected by air pollution also.

Air pollution inflicts a nuisance cost on humans. Unburned fuels waste natural resources of fuels. Building materials can be damaged by atmospheric corrosion. Some industries find pollution control a net cost, others find it results in ultimate savings. A whole new industry has developed to control air pollution.

An accurate study of the cost of air pollution is needed.

Berland, T.
"Our Dirty Sky"
Today's Health, March 1966

The problem of air pollution in the United States today is rapidly expanding, yet we are not using the proven principles that could bring about a profound reduction of this pollution. Too many cities are ignoring the first signs of coming pollution, and when they finally do act, the preventive measures are barely able to keep pollution levels from rising.

Air pollution is subtly affecting everything we do, and definitely affecting the costs of living in the city. A family of four is estimated to spend $800 per year trying to undo the damage of air pollution in New York City. Costs of farming are rising, for air pollution ruins crops and causes disease in livestock. Air pollution depreciates land values, costs for cleaning clothing and other possessions go up in polluted areas, and restricted vision due to air pollution has caused many automobile and airplane crashes.

Air pollution creates health problems also. The usual visible effects include watering eyes, sniffly nose, throat soreness, and cough. If a person suffers from a chronic respiratory illness, air pollution can make him cough, gag, pant, and suffer chest tightness. The number of people dying due to lung ailments is doubling every five years. We can never hope to clear the air completely, for nature herself adds pollutants from forest fires, volcanoes, dust, sand storms, etc. Yet compared to the amounts of pollutants put into the air by man, these sources are minor. Steps must be taken to curb the amounts of man-made pollutants, and bring pollution levels back to more natural levels.

There are essentially two types of smog--the London, reducing kind, and the Los Angeles, or oxidizing kind. The first comes from coal smoke, sulfur dioxide being a product of incomplete combustion. The sulfur combines with small water droplets in the air to form sulfuric acid, which corrodes metal, paints, etc. The Los Angeles-type smog is made up more of gases which cause watering eyes.

The Federal Government finally has decided to do something about the problem, passing the Clean Air Act. However, this bill does not go far enough, and it is up to the states and local jurisdictions to cooperate with the Federal Government in an all-out effort to rid ourselves of this problem.

Goldner, L.
"Air Pollution as Related to Agricultural and Industrial Development"
Pamphlet - U. S. Department of Health, Education, and Welfare, Public Health Service, Division of Air Pollution, 28 March 1966

In the article, the author brings up several new and interesting aspects of the air pollution problem. He first discusses the problem in general, pointing out that billions of dollars are lost annually through injury to vegetation and livestock, corrosion and soiling of materials and structures, decline in property values, and interference with ground and air transportation. Of even greater importance are the harmful effects of air pollution on human health, both acute and sudden illness in extreme incidences of pollution and the hazards of prolonged breathing over many years of polluted air.

The damage caused by air contaminants to agricultural crops is increasing as the urban sources continue to increase. The most obvious damage is done to leafy vegetables such as spinach and lettuce. There are three main types of air contaminants affecting crops--photochemical smog, fluorides, and sulfur dioxide. Agriculture is not only a victim of air pollution, but also a contributor to the problem. Open burning of agricultural wastes often contributes to community air pollution problems, and although other alternatives are not as economically feasible, burning could be refrained from during periods of adverse meteorological conditions.

Industry also is a contributor to and a sufferer from air pollution. Precision industries must have very clean air in their plants during the fabrication of ball bearings, and electronic and hydraulic devices, etc. High-salaried industries will avoid polluted areas, for they must attract the tops in their field. Good living conditions for families of employees, with adequate recreational facilities must be located, or the most qualified will move to more favorable environments.

Industry as a source of air pollution can be greatly reduced with the available technical means. The use of such equipment as scrubbers, electrostatic precipitators, centrifical separators, and filters can greatly control atmospheric contaminants. Shifts to better and more efficient fuels can also cut down on pollution.

The Clean Air Act has paved the way for an all-out fight against pollution. Many grants have been given to state and local agencies to study and control pollution under this act. The Secretary of Health, Education, and Welfare is authorized to settle inter- and intrastate disputes, and the Department of Health, Education, and Welfare has been given new responsibility in research and development. The legislation and technical know-how are now ready to allow a full-scale attack on air pollution; public interest and involvement in the effort to improve our environment is what is now needed.

Anon.
"Clearing the Air"
Time, p. 88, 20 May 1966

New York City annually sends an average of 730 lb of pollutants per person into the air. Of this total, 230,000 tons are soot, fly ash, and other particulate matter; 597,000 tons are sulfur dioxide; 298,000 tons are nitrogen oxides; 567,000 tons are hydrocarbons; and 1,536 tons are carbon monoxide. These totals make New York City the leader in pumping poisons per square mile into the air.

It is estimated that the city loses $500 million annually to air pollution costs. The city itself is one of the biggest offenders, operating eleven incinerators that send up 39 tons of filth daily. The local utility, Consolidated Edison, is another major contributor, burning ten billion tons of soft coal and more than 800 million gallons of oil within the city limits last year alone.

The city has passed several air pollution control laws which are helping to alleviate the problem, but as one city official stated, they have to race just to stand still.

Michelson, I. and B. Tourin
"Comparative Method for Studying Costs of Air Pollution"
Public Health Reports, 81:505, June 1966

In 1913, the Mellon Institute investigated the economic cost of air pollution in Pittsburgh, and the researchers came up with a figure of $20 per capita annually. Many other estimates of air pollution costs in various areas of the nation have been made, but the source of these estimates either has been unclear or they can be attributed to extrapolation of the Pittsburgh data. The recent national estimate of $11 billion per year spent on air pollution was probably an extrapolation of the Pittsburgh figures. From this, it is obvious that estimates of the effects of air pollution are vague and uncertain.

The authors of this article performed a study in the Upper Ohio River Valley in 1960 to replace any guesswork as to the economics of air pollution with more firmly established cost figures. Steubenville, Ohio, and Uniontown, Pennsylvania, were selected as cities for comparison. In 1960, Steubenville had a population of 36,400 and Uniontown had 21,000 residents. A previous study had shown that the two cities had a large variance in the amount of suspended particulates in the air. The average number of micrograms per cubic meter of air in Steubenville was 383, while Uniontown had an average of 115 micrograms per cubic meter. The following six categories were selected for study: outside maintenance of houses, inside maintenance of houses and apartments, laundry and dry cleaning, women's hair and facial care, inside maintenance of offices, and store operation and maintenance. For each of the six categories, three types of data were sought: activity frequency, or what effect air pollution had on the number of times an activity such as repainting was done; incidence, the proportion of the population to which various frequencies were applicable; and control, factors such as education level, household income, etc., which may effect the frequency or incidence of an activity. Six questionnaires were sent out, one for each category of study.

From 3 percent to 5 percent of those who fit into each category were sampled in each city. Local market values were used in calculating costs for extra expense due to air pollution. A table breaks down the extra expense by category, and the total added costs in Steubenville due to air pollution, as closely as can be calculated by the study, was $84 per capita per annum. Refinements in study techniques would give a more complete picture of the problem, and this study shows that additional effort seems to be warranted in assessing the economic damage brought about by air pollution.

Atkinson, B.
"Poison Hovers Over Our Cities"
Newspaper - Oakland Tribune, p. 1-A, 17 July 1966

Since 1930, Los Angeles commissions have unsuccessfully tried to diminish, if not eliminate smog. Air pollution is estimated to cost the nation between $11 to $20 billion in damage to property, houses, furnishings, clothing. A valve that would last 20 to 30 years in clean air lasts five years in New York City. There is evidence that among older people, air pollution accelerates the progress of hardening of the arteries, of heart trouble, of asthma, and of emphysema.

In five days in 1930, 60 people died during a temperature inversion in the Meuse Valley in Belgium. In 1948, as the result of an inversion in Donora, Pennsylvania, 43 percent of the population was sickened and 20 persons died within a period of four days. In 1952, a London fog filled the ground level of the atmosphere with sulphur dioxide and other contaminants, resulting in 4,000 deaths. In 1953, between 65 and 250 New Yorkers may have died from air pollution during a period of stagnant weather. In two weeks in 1963, air pollution was reported as a major death factor in the 647 deaths above the normal number in New York City.

The use of fossil fuels increases the CO_2 content of the atmosphere. It is estimated that if the CO_2 content of the atmosphere were doubled, the average temperature of the earth would rise 3.8°F, and the ice caps would melt, raising the level of the oceans and inundating coastal cities.

Sargent, F.
"Adaptive Strategy for Air Pollution"
Bioscience, 17:691, October 1967

Air pollution is an ecological problem. To deal effectively with air pollution, and adaptive strategy must be formulated. This strategy must treat realistically the economic costs of air quality control and the risks of the fitness of the ecosystem of setting air quality standards at levels that depart appreciably from natural pollution. Government, industry, science, and the public comprise the only consortium to formulate the strategy.

"A logical reaction to these grim prospects might be to suggest that a search be made for species of useful plants less susceptible than average to air pollutants and introduce them into areas where the potential for air pollution is particularly high." The grim prospects refer to the fact "that the vast quantities of air consumed by man's technology also place appreciable demands on the capacity of green plants to maintain the atmospheric oxygen...." The "useful" green plants mentioned in the article could be planktonic forms of green algae.

Fluorides cause a great deal of damage to plants. For example, Gladiolus can withstand concentrations up to 10 to 20 ppm; Camelia, over 3000 ppm. Plants accumulate fluorides. For example, alfalfa and orchard grass may have concentrations of fluoride of 40 ppm or more. Cattle fed solely on this material often develop fluorosis. When plants rich in organo-fluoride are consumed by domestic animals, most of them die. The introduction of fluoride-resistant plants into areas where there is a high potential for air pollution may be advantageous from the viewpoint of the plant but disadvantageous from the viewpoint of the mammals.

Dubos' definition of health: "A process of continuous adaptation to the myriad microbes, irritants, pressures, and problems which daily challenge man." The concept of health cannot be separated from the concept of environment. In setting up air standards "we must weigh the risk of man's adapting to a polluted atmosphere against the cost of regulating the atmosphere so that it fulfills man's needs and requirements."

Anon.
"Cheaper to Clean Up Than Not to Clean Up"
Environmental Science and Technology, 1:968, December 1967

The costs of living in a metropolitan area are greater in terms of cleaning up than those in the average rural area. In Washington, D. C., household cleaning and maintenance reaches $100 per year (national average, $70.00 per year). Annually the average family head in Washington, D. C. spends $335 above the national average to maintain his household in proper repair according to the Environmental Health and Safety Research Associates at the National Capitol Metropolitan Area Interstate Air Pollution Abatement Conference in Washington. The total economic penalties paid by Washington residents came close to $250 million annually. On the other hand, the cost of reducing pollution in Washington, D. C. would be $20 million annually.

Control (Political, Operational, etc.)

"Ambient Air Quality Objectives -- Classifications System"
Air Pollution Control Board, State of New York
Part 500: Ambient Air Quality Objectives
(Statutory Authority: Public Health Law, Nos. 1271, 1276)

All other uses of air must yield to the necessity for air which will not degrade, either acutely or chronically, the health and well-being of the populace. The only areas of comprise are the economic and the aesthetic. Except for a few very toxic substances, it is not suitable to specify one set of quality objectives to the entire state; the objectives must vary with the uses of the air and land in the area which affect the potential air quality. Four types of subregions are defined, and a table of air quality objectives is presented for each.

Anon.
"Cleaner Air--Without Penalties"
The American City, 75:109, March 1960

The city of Elmira, New York, has greatly reduced the incidence of air pollution by means of an all-out effort of the entire city. The public clamored for controls in 1948 when pollution began to bother and irritate them. The city set up a board with four objectives in mind: create a positive public interest in the problem, obtain industry cooperation, formulate and execute an education program, and seek the cooperation of the newspapers.

Much of the pollution was in the form of smoke from heating furnaces. The city established a teaching program for boiler operators, instructing the operators in more efficient practices in hand and stoker firings. Laws were passed concerning levels of pollution to be allowed in industry, and a 6-month adjustment period was set up. Because of this, not one fine has been levied for noncompliance with the ordinance.

Because of the cooperation of the public and the newspapers, almost everyone heard of the war against pollution, and benefited from the educational programs offered. As of the time of the article, ten years after the clean-up project, air pollution had been brought under control.

MacKenzie, V. G. and K. Flieger
"The Clean Air Act Amendments and Solid Waste Disposal Act of 1965 (P.L. 89-272)"
Pamphlet - U. S. Department of Health, Education, and Welfare, Office of the Undersecretary, 1965

Public Law 89-272 amends the Clean Air Act of 1963 (P.L. 88-206) by giving the Secretary of Health, Education, and Welfare authority: 1. to control air pollution from motor vehicles; 2. to take action to abate air pollution which originates in the United States and endangers the health of persons in neighboring countries; 3. to investigate and seek to prevent new sources of air pollution from coming into being; and 4. to construct, staff, and equip facilities needed by the department to carry out its increased responsibilities under the Clean Air Act. History of the legislation, control of air pollution from motor vehicles, historical background of the automotive air pollution problem, and the solid waste disposal act are discussed.

The Solid Waste Disposal Act is intended to enable the federal government to help create a coordinated national solid waste disposal program by bolstering the efforts of state and local governments.

Dixon, J. P.
"For Air Conservation"
Bulletin Atomic Scientists, 21:7, June 1965

Since the air supply is limited, the concept of conservation of air is beginning to replace that of air pollution control, especially since air quality is being considered a problem of the total environment rather than a local problem.

Assumptions basic to a discussion of the problem are:

1. air is in the public domain,

2. air pollution is a result of the normal processes of civilized life,

3. the conflict between man's economic and biologic concerns can be at least partly resolved by applying scientific knowledge to policy formation,

4. methods for conserving the air should not result in increased pollution between other sectors of the environment.

Techniques for control are:

1. reducing and controlling effluents as they are generated,

2. zoning to remove polluters to areas where wastes are least likely to be a pollution problem,

3. prohibiting processes which cause significant pollution,

4. substituting processes with low pollution potential for those of high pollution potential.

The unresolved question remains whether pollution is to be controlled by metropolitan agencies or by the federal government. Public understanding of the problem will remove a barrier to adequate control of pollution.

Gaffney, M.
"Applying of the Atomic Scientists"
Bulletin Atomic Scientists, 21:20, June 1965

Air should be regarded as a common domain to be managed under public tenure. Invasions of the domain must be paid for by the polluter. Air pollution control equipment should be exempt from property taxes, so as to encourage their use. A second possibility is fast tax write-off of control equipment. A third possibility is for polluters to pay a royalty for the use of the limited resource of clean air. This approach constrains directly exactly what is to be constrained without side effects, and it imposes costs upon the offenders, allowing them to escape in proportion to the abatement of the offense. A variation of this scheme is to sell licenses to pollute to a certain level. Nevertheless, conventional regulations would still be necessary.

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Long-range planning should include zoning. The substitution of electric power for fossil fuels will help. The power can be generated using the fossil fuels near their source, where pollution does not affect the population as much. Population density does not necessarily affect the pollution level. Economic incentives, including tax benefits, should be used to accelerate the pace of equipment replacement to use new low-pollution techniques.

Watters, H., T. T. Kason, and A. R. Dammkoehler
"Planning and Implementing Chicago's Package Programs"
Paper - 59th Annual Meeting Air Pollution Control Association, San Francisco, California, June 1966

The package program concept used in developing and implementing new and existing programs in the Chicago Department of Air Pollution Control are described. The package program concept assigns proper priorities for the implementation of departmental goals, clarifies organizational functions and responsibilities, simplifies budget procedures and planning decisions, facilitates operational and policy choices, and increases program portability.

The process of program planning is followed from the formulation of objectives to the cost estimates of equipment, personnel, and supplies through the budgetary decision process to the complete package. Program implementation is described for three separate programs, i.e., the Permit System, the Citizen Complaint Procedure, and the Industrial Control Schedule Program. The flow charts and some of the forms used in these programs are presented.

Yaffe, C. D. and W. F. Johnson
"Measuring the Improvements in the Control Aspects of Programs Aided by Federal Grants"
Paper - 59th Annual Meeting Air Pollution Control Association, San Francisco, California, June 1966

This paper considers indices for measuring program effectiveness and program progress. Ambient air standards are unsuitable because the factors affecting ambient air quality are often outside the jurisdiction and control of pollution control agencies. Such factors include economic and meteorological conditions. Activities of agencies are an inappropriate measure, because it is the results that are to be evaluated rather than the tools for achieving the results. The authors conclude that a suitable index should be based on weight of emissions. This would require emission inventory data. If changes in emission rates are to be used to evaluate accomplishment, it is necessary to obtain base-line numbers for the point in time from which the measurement is to be made. This approach is simple, easily understood by the public, and permits examination of effectiveness in terms of both classes of sources as well as classes of pollutants. Prevention effectiveness as measured in terms of potential pollution is presented.

Kauper, E. J. and C. J. Hopper
"Control of Emissions Through Reasonable Use of Atmospheric Dispersion, A Forecast System"
Paper - 59th Annual Meeting Air Pollution Control Association, San Francisco, California, APCA Paper 66-31, June 1966

A more practical approach to the control of sulfur oxides pollution than that involving the absolute prohibition of high-sulfur fuels is the use of high sulfur fuels only in periods when because of atmopsheric conditions, the pollutants are dispersed effectively. The latter approach would allow a more economical use of available fuels. Forecasts of expected atmospheric dispersive ability are necessary to provide necessary lead-times in making changeovers in fuel use. Such a forecast system was begun in the Los Angeles Basin in 1962. It makes predictions based on current weather parameters. Required inputs are the degree of stability present today and its amount of change in the previous 24 hours, and the pressure pattern overlying the region today and the changes from yesterday. Nomograms are constructed that display the record of past weather situations in terms of the resulting air pollution resulting 24 hours later. These are used to forecast, on a probability basis, what will happen on future occasions. The forecasts were 83 percent correct over the year. This could be improved by bringing in an experienced weather forecaster to supplement the prediction system. In the Los Angeles area, oil burning is allowed on about 150 days of the year. However, if oil-burning activity were based on the forecasts, oil could have been burned on about 202 days of the year.

Miscellaneous

"APCA Abstracts"
Published by Air Pollution Control Association in Cooperation with U. S. Public Health Service and the Library of Congress, Volume IV, No. 7, 1958

The publication contains 71 abstracts of articles dealing with air pollution. The abstracts are listed in general related categories, as for example sources of air pollution, and measurements and effects of air pollutants.

"Highlights: National Conference on Air Pollution"
U. S. Department of Health, Education, and Welfare, Public Health Service Publication No. 648, 1958

Abstracts and excerpts from the main speakers are given in the publication. Highlights of formal papers and discussion group reports are given on: extent of air pollution, sources of air pollution, health effects of air pollution, economic and social effects, control measures and procedures, and administrative aspects. A list is given of the organizations represented at the conference.

Anon.
"Meteorological Information of Proposed Open Burning Sites in Alameda County"
Pamphlet - Bay Area Pollution Control District, League of California Cities, November 1959

Data are given on wind direction and velocity for Oakland, Alameda, Piedmont, Albany, Fremont, Berkeley, and Livermore. The data are intended to be used for estimating the level of air pollution from open burning at dumps on days during which there is no temperature inversion. A discussion is given of sites in terms of whether pollution will be limited to the city in which the site is located.

An appendix contains two recommendations from the Mayors' conference of Alameda County in July 1959, on the establishment of jurisdiction over pollution by the Bay Area Pollution Control District, and on the permission of open burning of lumber when the weather permits.

Boardman, R.
"Where We Stand in the Fight Against Smog"
California Monthly, December 1959

Three steps must be taken to restore our air to a somewhat clean state:

1. public apathy must be overcome;
2. the exact composition of smog must be determined,
3. cures which are found must be backed by strong legislation.

Smog is now a major problem in Los Angeles, and it is just beginning to threaten the San Joaquin Valley. The latter produces cotton, cattle, grapes, hay, milk, sugar beets, barley, and other crops in an amount that totals almost one billion dollars per year.

One of the first smog cures considered by the University of California (Los Angeles) for the Los Angeles region was one involving the blowing away of air pollutants. To accomplish this, more power would be required than could be produced by all of California. Due to restrictions in the area, including elimination of backyard burning and dump incineration, agriculture in the Los Angeles area suffers less now from smog than it did a few years ago.

Automobiles are responsible for most of Los Angeles' smog. A plastic smog generator has been divised by the University of California (Los Angeles). The device provides controllable sources of smog from engine exhaust fumes for study and experiments. A study of health aspects is being made. Smog is thought to be a possible cause of lung cancer, and is very definitely a source of eye irritation.

"1963 Directory: Governmental Air Pollution Agencies"
Published by the Air Pollution Control Association in Cooperation with the U. S. Department of Health, Education, and Welfare, Public Health Service

A directory is given of addresses and telephone numbers of agencies and individuals working in air pollution. The directory covers the U. S. federal government agencies, 50 states, District of Columbia, Guam, Puerto Rico, and the Virgin Islands. Also included are the Canadian federal government agencies, and agencies in British Columbia, Manitoba, Nova Scotia, Ontario, and Quebec.

Thackrey, T. O.
"The Coming Struggle to Breathe"
Saturday Review, 10 October 1964

Human beings are totally dependent upon the envelope of air around the earth for life, yet the more they tend to urbanize, the more they pollute this all important natural resource. Incineration of refuse, exhaust from transportation vehicles, factory effluents, and so on all make the air that much less fit to breathe. And all attempted remedies have been too small, too shortminded, and with no regional planning in mind.

Only a few cities have taken any measures to prevent pollution, and these efforts on the whole have been insufficient. California has passed the most stringent state ordinances against air pollution, while almost all of the other states have completely ignored the problem.

The article goes on to cover all types of pollution, and describes the efforts of Phoenix, Arizona, to dispose of its refuse. Composting was tried, but the effort failed for a number of reasons. The efforts of Phoenix in all areas of pollution - water, air, and land - are given attention.

Moody, J. E.
"Coal Campaigns for Cleaner Air"
Coal-Wherever Coal is Concerned, March/April 1966

A statement describes the good intentions of the coal industry with regard to minimizing air pollution.

Fox, R. A., Editor
"New Developments in Air Pollution Control"
MECAR Symposium, P. O. Box 607, Grand Central Post Office, New York, New York, 10017, 23 October 1967

Three of the fourteen papers presented in the Symposium deal specifically with incineration of refuse. However, material treated in the remaining papers contains information which can be applied to municipal incineration. The subjects of the papers are indicated by the titles which are given below.

1. Recovery of Sulfur Oxides from Stack Gases
2. New Developments in the Control of Particulate Emissions
3. Control of Noxious Gasesous Emissions
4. Control of Solvent Emissions
5. Removal of Sulfur Oxides from Power Plant Stack Gases
6. Current Work at the Bureau of Mines on Recovery of Sulfur Oxides from Stack Gases
7. Federal Programs of Engineering Research and Development for Sulfur Pollution Control
8. Particulate Emission for Municipal Incinerators

9. Control of Particulate Emission on Electric Utility Boilers

10. European Installations

11. Advances in Noxious Gas Control

12. The Manufacturer Studies Air Pollution

13. Control by Incineration

14. Design Considerations in Solvent Recovery

Anon.
"Rising Plastics Content of Wastes Will Pose Problems"
Chemical and Engineering News, p. 13, 8 January 1968

About 3.25 billion lb of plastics per year are currently disposed of in municipal wastes. The plastic wastes consist of 38 percent polyethylene, 32 percent polyvinyl chloride, 21 percent polystyrene, and 9 percent others. By 1976, the plastics content of municipal wastes will be about 3.3 percent (9.5 billion lb per year).

According to a study carried out by the Battelle Memorial Institute for the Society of the Plastics Industry, Inc., incineration of polyvinyl chloride and other halogen-containing plastics produces hydrogen halides that corrode incinerator parts and pollute the atmosphere. Intermittent sharp increases in plastics in wastes can clog incinerators. The corrosive nature of incineration products of plastics are relatively harmless to existing incinerators, but will become a problem in those in which water-cooled metal tubes are installed in the combustion chamber to recover heat, to permit higher combustion temperatures, and to give lower exit gas temperatures. The air pollution potential of hydrogen chloride and other hydrogen halides spell more trouble. Incinerating a typical refuse containing about 0.54 percent PVC yields a stack emission of 290 ppm HCl.

WATER POLLUTION

Agricultural

Division of Instrial Services, Washington State
Institute of Technology, Pullman, Washington
Proceedings: Pacific Northwest Industrial Waste Conference, 1952

The contents of the publication are as follows:

A. Wood products section: 1. Developments in the study of toxic industrial wastes; 2. disposal of white water waste; 3. activities of the Sulphite Manufacturer's Research League; and 4. industrial utilization of ammonia base liquor.

B. Food industries section: 1. Progress in control and utilization, and disposal of wastes from the canning and freezing industry; 2. pear waste utilization; 3. utilization and disposal of wastes from beet sugar manufacturing operations; 4. chemical and nutritional possibilities in the utilization of fishery wastes; 5. anaerobic and chemical waste treatment; 6. the microbiology of sludge; and 7. progress report on pea processing waste studies.

C. Mineral industries section: 1. Waste control and utilization at Northwest Magnesite Company Plant; 2. utilizing mill tailings for mine slope filling at the Holden Mine; 3. disposal of radioactive wastes; 4. by-products recovery from Idaho Monazite sands; and 5. profit or loss by smoke control.

Stewart, B. A., F. G. Viets, Jr., G. L. Hutchinson, and W. D. Kemper
"Nitrate and Other Water Pollutants Under Field and Feedlots"
Environmental Science and Technology, 1:736, September 1967

Agricultural fields contribute significantly to ground water pollution because of percolation and runoff from fertilizers and wastes in feeding operations. In the South Platte Valley of Colorado (the test area), the amount of NO_3 moving through soil profiles toward ground water varies widely with land use in the following order: alfalfa fields < native grasslands < cultivated dry land < irrigated fields not in alfalfa < feedlots. Ground water samples under feedlots frequently contained ammonium (or a compound releasing NH_3), organic carbon, and had a very offensive odor.

Schroepfer, G. J. and R. C. Polta
"Travel of Nitrogen Compounds in Soils"
Progress Report - Sanitary Engineering Report 166-S, Sanitary Engineering Division, Department of Civil Engineering, Institute of Technology, University of Minnesota, 1 October 1967

The contents of the report are best summarized by the authors' summary statement:

"Nitrogen compounds in ground waters have public health significance as indicators of pollution but more specifically as the direct cause of infant methemoglobinemia when consumed in the form of nitrates.

"This investigation has been directed at determining the factors involved in the travel and transformation of nitrogen compounds in soils. Ground water samples obtained in the immediate vicinity of waste water stabilization ponds provided data that indicate only relatively small quantities of nitrogen enter the ground water through percolation. Only a small portion of the percolated nitrogen is transformed to the nitrate form.

"However the results obtained from the operation of a simulated soil absorption system in a medium sand common to the suburban area north of Minneapolis indicate that the ammonia nitrogen, discharged into the soil from the subsoil system, is adsorbed on the soil and then oxidized by the nitrifying bacteria to the nitrate state which is not held by the soil and moves in the ground water. Nitrate nitrogen concentrations on the order of 10 mg/l above background levels have been found as far as 140 feet from the point of discharge to the soil in the second year of operation of the system."

Trace Elements and Toxic Materials

Kilham, L., R. T. Low, S. F. Conti, and F. D. Dallenbach
"Intranuclear Inclusions and Neoplasms in the Kidneys of Wild Rats"
Journal of the National Cancer Institute, 29:863, November 1962

Nuclear inclusions have been found in kidneys of nearly 100 percent of seemingly healthy, adult wild rats captured on refuse dumps in the vicinity of Hanover, New Hampshire. A number of investigations indicated that lead was the probable etiologic agent. The source of the lead inducing these changes has not been determined. Field observations have suggested that rat populations living and feeding on burning refuse dumps have a fairly constant exposure to lead containing fumes.

Chacko, C. L. and J. L. Lockwood
"Chlorinated Hydrocarbon Pesticides: Degradation by Microbes"
Science, 154(3750):893, 18 November 1966

In culture, most of the actinomycetes and filamentous fungi tested, degraded PCNB; several actinomycetes dechlorinated DDT to DDD; but no microorganism degraded dieldrin. Streptomyces aureofaciens degraded PCND to pentachloroaniline.

Gunn, S. A., T. C. Gould, and W. A. D. Anderson
"Incorporation of Selemuim into Spermatogenic Pathway in Mice"
Proceedings of the Society for Experimental Biology and Medicine, 124:1260, 1967

Studies were conducted on tissue distribution of high specific activity Se-75 in CD-1 male mice. As a tracer (1 μc Se-75; 0.03 μg Se) and in the presence of carrier (72 μg Se) Se-75 showed a cumulation pattern in the testisepididymis complex indicative of association with the wave of spermatogenesis.

Gunn, S. A., T. C. Gould, and W. A. D. Anderson
"Specific Response of Mesenchymal Tissue to Cancerigenesis by Cadmium"
Archives of Pathology, 83:493, June 1967

Cadmium, even in soluble salt form, was shown to be a potent cancerigen. As little as 0.17 to 0.34 mg of cadmium ion as a single injection of cadmium chloride solution for male Wistar rats produced pleomorphic sarcomas at the injection site 10 to 16 months following administration. These doses were cancerigenic only in tissues of mesenchymal mesodermal origin, such as subcutaneous, subperiosteal and intramuscular sites. No tumors formed in any of the ectodermal, endodermal, or epithelial mesodermal sites. In comparable molar dose levels, cobalt and zinc did not produce tumors in any of the tissue sites tested for cadmium. The observations suggested that the neoplasia was derived from the injured fibroblasts. Increasing the dose provoked the development of more specialized derivatives of mesenchymal mesoderm as local areas of cartilage, bone, vascular tissue, and strap-like cells.

Meehan, W. R. and L. E. Smythe
"Occurrence of Beryllium as a Trace Element in Environmental Materials"
Environmental Science and Technology, 1:839, October 1967

Foodstuffs, human organs, plants, soil (water), and marine life from an Australian environment contain trace amounts of beryllium. In almost all cases, concentrations are below 1 ppm. The Morin method, which has a practical value below 2×10^{-5} mg Be per mℓ, was used. Values for foodstuffs generally range from 0.01 to 0.1 ppm, with oyster tissue and mushrooms having the highest values. The highest value for the human organs is for lungs. There was little evidence of any beryllium concentration mechanisms in plants.

Stokinger, H. E., Editor
"Beryllium: Its Industrial Hygiene Aspects"
Academic Press, Inc., New York, New York 10013, 1966
Reviewed in Environmental Science and Technology, 1:943, November 1967

This collaborative effort represents the most recent thinking in the field of beryllium and industrial health by observers whose experience over the course of years gives them the right to speak with authority on the subject. Although the title suggests that the scope of the monograph is restricted to industrial hygiene, the volume has a comprehensive coverage of historical, chemical, and toxicological aspects as well.

Turekian, K. K. and M. R. Scott
"Concentrations of Cr, Ag, Mo, Ni, Co, and Mn in Suspended Materials in Streams"
Environmental Science and Technology, 1:940, November 1967

Industrial contamination of U. S. rivers east of the Mississippi River may be responsible for the regional differences in the concentrations of trace elements such as Cr, Ag, Mo, Co, and Mn in more than 20 rivers. Although these differences may be due in part to a greater amount of a trace-element soil component, they apparently are not due to any cation-exchange capacity. Of possible economic interest, about 45 tons of silver per year are deposited as detrital material.

Janssen, W. A. and C. D. Meyers
"Fish: Serologic Evidence of Infection with Human Pathogens"
Science, 159:547, 2 February 1968

Specific antibodies to several bacteria pathogenic to humans were detected in the serums of white perch adjacent to heavily populated areas on Chesapeake Bay. White perch from surface waters adjacent to sparsely populated areas were free of such antibodies. It is suggested the fish may become actively infected with human pathogens by exposure to contaminated water and may constitute a hazard to public health.

Anon.
"A Strange and Terrible Death"
San Francisco Chronicle, p. 3, Wednesday, 22 May 1968

A painful malady has been afflicting inhabitants of the valley of the Jintsu River in northwestern Japan for many decades. Over the past two decades somewhere between 100 and 200 persons have died of the disease. Hundreds more suffer from it today.

The Japanese ministry after a four-year investigation has discovered the source of the malady. In the 1800's a metal mine was opened in the upper reaches of the Jintsu River. For a century it has been pouring wastes and drainage in the river. The mine pollution contained a high level of cadmium.

The overdose of cadmium to the people came through the eating of rice and soya grown in paddies irrigated with the river water and through drinking the water. The manifestation of the poisoning is an increase in brittleness of the victim's bone, often to the extent that ribs splinter and limbs break easily. The disease in its chronic form sometimes develops over a period of 30 years.

MANAGEMENT

Black, R. J.
"A Report on an Investigation of the Fly Problem at the Stockton State Hospital Farm"
Report - State of California Department of Public Health, Bureau Vector Control, November 1951

An investigation was undertaken in November 1951 at the Stockton State Hospital Farm to determine the best method of handling the manure produced there. The manure was creating an odor and fly problem, and was disturbing neighbors in a new housing development nearby.

On the farm were 800 hogs (expected to be increased to 2,500 hogs), 485 cows, 6,000 hens, and 10 horses. No regular pattern was followed in disposing of the wastes; although eventually they were piled in windrows to compost. The wastes were stored on concrete slabs before being windrowed, and this was a major source of fly production.

The Bureau of Vector Control was consulted in the hope that it could find a more efficient means of disposal. Two main recommendations were made by the Bureau, viz., the development of a more efficient collection system, and the use of "controlled" composting. The collection system would have to enable the delivery of putrefactive wastes to the disposal site before the large numbers of fly larvae in them could have an opportunity to develop. A daily collection system would be most satisfactory, but during the winter a collection every other day might suffice. The most promising method of disposal is controlled composting. It embodies the following principles: shredding to increase surface area and aid microbial oxidation, moisture control, adding straw or water as needed to provide optimum conditions for microbial life, aeration for complete decomposition, and mixing to bring about the kill of any fly larvae in the compost pile.

Hart, S. A.
"Problems in the Management of Livestock Manures"
Paper - Annual Meeting American Society of Agricultural Engineers, Ithaca, New York, June 1959

Making use of livestock manure as a fertilizer is a possibility for farm and dairy owners, but the problems involved in such a program often exceed any potential profit. The problems involved include harvesting and transporting the manure, storing or processing it, and utilizing or disposing of it.

At dry lot dairies, the main disposal problem is feeding area defecations. Mechanical harvesting seems appropriate to the removal of manure from these areas. An experimental mechanized pickup machine for droppings at chicken farms has been tried. If the mechanized system proves successful, it could reduce cleanup time by one-half. In all instances, frequent clean-out is necessary to prevent fly breeding and insure sanitation.

After the manure is harvested, it sometimes can be applied directly to croplands, but lack of land often requires storage. Fly-tight storage bins have been developed, and manure can be sanitarily stored there until enough has accumulated for economical disposal. Processing of wastes has interested farmers as a possible means of disposal, but the steps that have to be taken usually make any such system economically unsound. Artificial drying costs about one cent per pound of water removed, and composting would not work unless straw was added to raise the C:N ratio, which sometimes means added expense. Drum composting or digestion, or spraying the wet manure over fields in 1-2-inch layers of liquid are possible methods of disposal. Manure processing is the most difficult problem facing those concerned with agricultural sanitation.

Disposal eventually will be on croplands in most cases, but hauling costs make this an expensive operation. Pumping liquified wastes is now being considered where the wastes can be sprayed rather than spread over croplands. No matter what steps are taken, waste disposal at farms and dairies probably will never be a profit-making part of the farming enterprise. But, through proper handling and management, the net cost of disposal can be minimized and sanitation requirements can be met.

In an appendix is given the design criteria for the controlled composting recommended for the farm.

Hart, S. A., R. J. Black, and A. R. Smith
"Dairy Manure Sanitation Study: Part I: Engineering Aspects"
California Vector Views, 7:43, July 1960

This article is the first of two reports on studies done at a Marin County dairy farm in which a large number of cows were confined on a limited acreage. The manure which attracts flies is defecated while the cows are in the feeding area. It creates a serious sanitation problem. Manure cleanout and sanitation is essentially a materials handling and processing problem. Dairy handling involves manure collection, manure transportation, manure storage and processing, and final disposal.

The manure usually is collected by a tractor and blade. The best means of transport is by pumping after water is added to the manure. Manure can be pumped readily by means of a centrifugal pump if its moisture content has been raised to 93 percent. The manure slurry is pumped into a tank truck or into a conveying pipeline.

If the collected manure is immediately spread thinly over farmland, maintaining sanitation becomes no problem. Raw fresh manure can be stored if it is made unattractive to flies or if flies are not around. Piles of solid or semisolid manure can be covered with fly-tight plastic mesh tarps or layers of soil and dry manure. The most efficient method of avoiding fly infestation was that of spreading the manure from the feeding area thinly on special beds, and tilling the area frequently. A drying area of about 200 sq ft per cow appears to be necessary.

Most dairy manure is and will be disposed of on farmland where it has a value as fertilizer. Dry lot dairies with insufficient pasture or cropland to utilize all of the manure produced on the lots, must move it from the premises. It is highly unlikely that a financial gain can be made from the sale of the manure. However, by getting rid of it, the farmer will be able to continue in business and obtain his livelihood from the primary operation.

Smith, A. R., R. J. Black, and S. A. Hart
"Dairy Manure Sanitation Study: Part II: Entomological Aspects"
California Vector Views, 7:70, December 1960

Dry lot operations often are accompanied by troublesome manure disposal problems. The manure is very attractive to flies, and its moisture content is too high for it to be handled as a solid, but too low for handling as a liquid.

Studies were conducted at a Marin County farm which had a history of fly control problems. The feeding areas were the source of the most serious problems. Leaving the manure in piles to dry until it could be handled as a solid served as an invitation to the flies to come, and come they did. The researchers determined that a moisture content of 93 percent was necessary for the manure to be transported as a liquid. The liquid manure was spread on beds of absorbent material and rapid drying was accomplished by frequent stirring.

Three bed materials were tested, viz., sawdust and shavings, topsoil, and previously dried manure. The test beds were 40 ft wide and 100 ft long, and initially were 6 inches deep. One-inch layers of liquid manure were applied weekly to all beds, and the beds were stirred daily with a rotary tiller. All beds proved to be satisfactory, being effective in manure drying and supporting only a minimum number of fly larvae. The combination of adequate fly control and satisfactory handling serve to make this system of manure disposal practical and recommendable.

Anon.
"An Industrial Waste Guide to the Fruit Processing Industry"
Bulletin - U. S. Department of Health, Education, and Welfare, Public Health Service, Division of Water Supply and Pollution Control, Washington, D. C., Public Health Service Publication No. 952, 1962

This is one of a series of guides to various food and clothing industries concerning the disposal of industrial wastes. The pamphlet covers the general processing of fruits, and the sources of wastes in the process, and offers solutions to the problem of the disposal of these wastes.

The first section is a comprehensive picture of the cannery and describes the steps in the process, viz., cutting and pitting, mechanical peeling and coring, hot lye peeling, spray washing, slicing, canning and syruping, closing, processing, cooling, and casing and shipping. The main sources of liquid wastes (the most difficult to dispose of) are the spillages in the canning and syruping step, and the wastes water from cooling after heat processing. Many canneries fail to reuse the water after cooling, and simply discharge it, overburdening sewer systems. This water can be reused as a primary wash for raw fruit, for plant cleanup operations, and for a number of other operations. The additional use of the water would result in the saving of large amounts of money.

The many methods of treatment and disposal of cannery wastes are discussed. Screening to remove gross solids from effluents and the types of mechanized screens available are mentioned in detail. Disposal by spray irrigation is discussed. It is pointed out that spraying in an area having a cover crop and on level ground allows the maximum disposal of water. Methods of analysis of wastes are covered, and methods of preserving grab and composite samples are evaluated.

Hart, S. A.
"Sanitary Engineering in Agriculture"
Paper Presented before the Kansas Sanitary Engineering Conference, University of Kansas, Lawrence, 8 January 1964

Waste management on the farm is becoming increasingly important as our nation's farms become larger and more specialized. Topics receiving attention are manure management, collection, processing, storage, utilization or disposal, and other agricultural wastes problems.

Hart, S. A. and P. H. McGauhey
"The Management of Wastes in the Food Producing and Food Processing Industries"
Food Technology, 18:30, April 1964

The most significant portion of agricultural wastes are crop residues and animal manures. Livestock produce from 6 to 25 lb manure per lb weight gain, or a total of 1.09 billion cu yd manure per year. Manure is handled so as to control fly breeding, odors, dust, and disease hazards to animals.

Crop wastes (stalks, stems, leaves, and cull fruit) far exceed the tonnage of crop harvested and hauled to market. These wastes must be disposed of to prevent fly breeding and other sanitation problems, and to allow the farmer to prepare his fields for subsequent crops. Three disposal methods are followed: plowing under, burning, and surface spreading. Plowing is expensive and creates soil fertility problems due to the nutrient imbalance of the residues. Burning results in air pollution. Leaving the residues on the field fosters disease and insect development.

Modern food processing industries produce large amounts of wastes, a small fraction of which is reclaimable in the form of by-products. Liquid wastes are often sprayed as irrigation water onto land used for agriculture. Other means of disposal are only moderately successful. Solid cannery wastes present a problem not only of costs, but also of inadequate process technology. Composting may become the eventual solution.

After consumption, food products present a municipal waste problem. Liquid wastes are adequately dealt with, but solid wastes, largely packaging materials, are still a problem.

The core of the problem lies in the decentralization of decision-making concerning waste disposal: each producer tries to pass on his waste problem to the next member in the production hierarchy. The solution to the problem is twofold: 1. a program of education of the citizen, his elected representatives, and the food producer and processor; and 2. a program of research into technologically feasible methods of community waste disposal.

Hart, S. A.
"Future Research in Animal Wastes"
Management of Farm Animal Wastes, Proceedings National Symposium, American Society of Agricultural Engineers, St. Joseph, Michigan, May 1966

The need is stressed for modernizing farm sanitation processes to meet future needs before the needs become critical. Examples are given of how modernization in production methods have aggravated the sanitation problem. The switch from range and litter housing of poultry to cages has aggravated the sanitation problem. The author suggests modernizing the litter house so that it can compete with cages.

Strict confinement of swine and dairy cattle should be modified so that wastes would not be concentrated in a restricted area. The advisability of developing uses for farm wastes is emphasized.

Hart, S. A., J. A. Moore, and W. F. Hale
"Pumping Manure Slurries"
Management of Farm Animal Wastes, Proceedings National Symposium, American Society of Agricultural Engineers, St. Joseph, Michigan, May 1966

The study was conducted as a means of understanding the performance of different kinds of pumps under various conditions. Practical considerations of dilution probably are more important than the kind of pump and the theoretical maximum operating conditions.

Centrifugal pumps do have much greater capacities and they cost considerably less than diaphragm or positive-displacement pumps. They can and should be used where appropriate.

Hensler, R. F., R. J. Olsen, O. J. Attoe, and S. A. Witzel
"Progress Report on Soil Fertility Aspects of A.E.S. Project 1238 on Farm Animal Waste Disposal"
University of Wisconsin, Madison — Report to Office Solid Waste, Grant No. RTG-8-R01-SW-00042-03 and Water Resources Grant No. 14-01-0001-858, 1967

The handling of dairy cow and steer manure in liquid forms holds considerable promise in conserving plant nutrients and in using them effectively in fertilizing a corn crop. Recovery of N and P by crops was highest for anaerobic liquid manure. Recovery values for K are less well defined. Allowing manure to dry for one week before incorporation usually gave lower yields and recovery values for N, P, and K. Total yields for manure without bedding were somewhat higher for fresh and liquid manures than for ordinary fermented manure. Total recovery of manure-N generally was highest for ordinary fermented manure. Drying manure resulted in a 12 percent loss of N at pH 5.5, and no loss at a pH less than 5.0.

Preliminary results of field tests showed that the recovery of fertilizer-N ranged from 48 percent to 64 percent, and that recovery under fallow conditions was 99 percent. The most pronounced movement of NO_3 occurred at the 300-lb rate of nitrogen application. NO_3 and NO_2 content of spring waters: 1. In areas characterized mostly by crop farming, the NO_3 concentration was 1.3 mg per ℓ; NO_2, 0.1 mg per ℓ. 2. In an area adjacent to a road next to a cropped area, the NO_3 concentration was 2.4 mg per ℓ; NO_2, 0.01 mg per ℓ. 3. In a pasture, the NO_3 concentration was 7.8 mg per ℓ; NO_2, 0.1 mg per ℓ. 4. In forested and pastured areas, the NO_3 concentration was 1.7 mg per ℓ; and the NO_2, 0.1 mg per ℓ.

The following tables contain data on characteristics of various manures.

TABLE I

DAILY PRODUCTION IN TERMS OF POUNDS PER 1000 POUNDS OF ANIMAL

Item	Dairy Bull	Dairy Cow	Beef Cattle
BOD	0.76	1.32	1.02
COD	4.19	5.78	3.26
Total Solids	4.21	6.80	3.62
Volatile Solids	3.26	5.68	3.17
Fixed Solids	0.95	1.12	0.45
NH_3-N	0.15	0.23	0.11
Organic-N	0.09	0.14	0.15
Total Kjeldahl-N	0.24	0.37	0.26

TABLE II

CHARACTERISTICS OF SETTLEABLE SOLIDS*
(lb per 1000 lb animal)

Item	Dairy Bull	Dairy Cow	Beef Cattle
BOD	0.09	0.36	0.42
COD	1.48	2.88	1.47
Total Solids	2.94	5.60	2.89
Volatile Solids	2.57	4.97	2.67
Fixed Solids	0.37	0.63	0.22

*Wastes diluted with water (1:1) and settled within 1 hour.

Table III contains data concerning the production of animal wastes in terms of "people equivalents." Determination of the "people equivalent" in terms of animal waste production was based on an assumed sewage output of 100 gal per capita per day. In terms of wastes (liquid manure containing wash water) from a dairy bull, the equivalent is 23.4 gal per day/100 gal per day or 0.234 persons. The equivalent is 0.086 for the dairy cow, and 0.0145 for beef cattle. The following equivalents for various characteristics of animal wastes are based on 1000 lb of animal body weight.

TABLE III

PEOPLE EQUIVALENT OF ANIMAL WASTES PER 1000 LB OF ANIMAL WASTES

Item	Dairy Bull	Dairy Cow	Beef Cattle
BOD	4.0	7.7	6.0
Suspended Solids*	9.2	21.0	29

*Based on 0.21 lb suspended solids per capita per day for domestic sewage.

The nitrogen in the manure is mainly in the form of bacterial cells. A predominance of proteolytic bacteria was noted in lagoon disposal. Generally, in lagoon disposal, the flora is a well balanced population for carrying out the decomposition of a highly nitrogenous waste. Facultative bacteria are the most numerous. Very few "pollutional" bacteria are found in lagoons.

The recovery of N, P, and K by corn plants in pots is indicated by the data in Table IV.

TABLE IV

PERCENT RECOVERY OF N, P, K IN MANURE BY POTTED CORN

	Steer Manure				Dairy Manure			
Item	Fresh	Fermented	Liquid Aerobic	Liquid Anaerobic	Fresh	Fermented	Liquid Aerobic	Liquid Anaerobic
N	70	55	13	58	57	52	18	56
P	27	26	15	26	20	24	21	29
K	88	75	37	73	43	51	48	61

Hart, S. A.
"Agricultural Wastes Management in the Future"
Paper Presented before the 1967 Winter Meeting American Society of Agricultural Engineers, Detroit, Michigan, Paper No. 67-933, 12-13 December 1967

The management of livestock manures, crop residues, and other wastes of intensive agriculture will become an even more critical problem in future years. Additionally, as municipal wastes become ever more of a burden to the city, there will be activity to convert these municipal wastes into compost and use them as agricultural land. Thus research toward solving these problems is necessary today.

Wadleigh, Cecil H.
"Wastes in Relation to Agriculture and Forestry"
Miscellaneous Publication No. 1065, U. S. Department of Agriculture, Washington, D. C., March 1968

The report provides terse consideration of ten major categories of entities that contaminate the environment in relation to agricultural and forestry endeavor. A brief discussion is also presented on the economic situation. Comment is made on each category about the importance of the problems, the extent to which agriculture and forestry are involved, contributions that have been made to ameliorate the problems by research in agriculture and forestry, and an indication of the need for new or better information and technology toward meeting pressing problems. Complete discussions of each of the subjects are presented in four appendices.

A few of the many interesting items reported in the publication are as follows:

1. Domestic animals produce over 1 billion tons of fecal wastes per year. Their liquid wastes come to over 400 million tons.

2. Used bedding, paunch manure from abattoirs, and dead carcasses make the total annual production of animal wastes close to 2 billion tons.

3. The waste production of domestic animals in the U. S. is equivalent to that of a human population of 1.9 billion. As much as 50 percent of this waste production may be produced in concentrated supply.

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4. Use of lagoons for disposal has not been found satisfactory, chiefly because they tend to be underdesigned, overloaded, and misused. (Editor's Note: The provision of surface aeration by means of floating mechanical aerators has been proven very effective in reducing the intensity and amount of odors emanating from anaerobic ponds.)

5. Twenty-five million tons of logging debris are left in woods during the average year. This is a reservoir for tree diseases and insects.

6. At the present time, research has produced no economically feasible technique to dispose of forest trash en masse other than by controlled burning.

7. The oxidative requirements of the effluent from the woodpulp, paper, and paperboard industries exceeds those of the raw sewage from all of the people in the U. S.

8. In a year's time, the canning industry produces effluent with oxidative demands that are double those of the raw sewage from Metropolitan Detroit; the meat-packing industry, double those of Metropolitan Chicago; and the dairy industry, four times those of Metropolitan Boston.

9. Research has contributed to the abatement of processing wastes by (a.) developing a commercially useful product out of that which had been a waste – the manufacture of insulating board out of sugarcane bagasse; (b.) improving the procedure so that less wastes are produced – a new polysulfide modification of the kraft process of pulping results in greater pulp yields, less waste, and reduced air and pollution; and (c.) developing methods of waste treatment before disposal in streams – development of oxidative lagoons for potato-processing wastes.

10. Within the last 6 years, 43 California dairy farms having a total of about 12,000 cows have had to relocate from the Los Angeles area to the Bakersfield area, a distance of about 80 to 100 miles, because of their incompatibility with the activities of the expanding metropolitan Los Angeles area. The total relocation cost was over $1.6 million.

11. In 1961, Michigan beef feedlot operators spent $3.43 per head marketed; and dairymen, $9.29 per head for waste removal and spreading. In Illinois, annual operating costs in hog raising was from $0.62 to $1.28 per hog. A million-bird laying operation in Mississippi involved an expenditure of $100,000 or $0.10 per bird for waste handling.

12. A feedlot carrying 10,000 head of cattle has about the same sewage disposal problem as a city of 164,000 people.

13. Population equivalents of animals in terms of BOD of feces produced per day: horse, 11.3; cow, 16.4; sheep, 2.45; hog, 1.90; hen, 0.14.

14. Much effort should be allocated to identify the odor-producing organisms prevalent in manures and to develop techniques to destroy such organisms.

PRODUCTION

Hart, S. A.
"Fowl Fecal Facts"
World's Poultry Science Journal, 19:262, April 1963

The article gives the following facts:

1. About 1-1/2 billion cu ft of poultry manure are produced each year in the U. S.

2. Four hundred and twenty-five million cu ft comes from 365 million egg-laying chickens; 750 million from 1-1/4 billion fryers; and 160 million from 80 million turkeys.

3. Freshly defecated manure from normal healthy White Leghorn chickens averages about 30 percent total solids. On this basis a 5-lb hen voids about 0.2 lb wet manure per day.

4. Chicken manure has a specific gravity of about 1.75.

5. The volume of wet manure per hen (5-lb) per day is about 5.7 cu in.

6. BOD as mg BOD_5/mg of VS averages 0.30.

7. BOD of coarse matter (retained on 200-mesh screen) is 0.12; of fine matter (passing through a 200-mesh screen) is 0.44.

8. Human sewage amounts to 0.18 lb BOD per capita per day; chicken excrement, 0.015 lb BOD per hen (5-lb) per day (12 chickens = 1 human).

9. COD is about 1.1 mg of oxygen per mg VS.

10. Chemical analysis is as follows: N = 1.8 to 5.1 percent; P as P_2O_5 = 3.7 to 6.6; K as K_2O = 1.1 to 3.3.

DISPOSAL (Exclusive of Composting)

McGauhey, P. H.
"Disposal of Agricultural Wastes"
Paper - Central California Agriculture Forum, Bakersfield, California, May 1953

Agricultural wastes have several things in common:

1. They are biochemically unstable, capable of being converted into a humus or into animal feed.

2. They are seasonal in occurrence.

3. They are diverse in nature, making a single treatment procedure incapable for the adequate treatment of all types of wastes originating in a single plant, such as a cannery.

There are several ways to dispose of agricultural wastes, but of these, the most feasible are landfill and composting. A newer method still under investigation is the growing of green algae sybiotically with bacteria to convert the organic matter in sewage into algal cell material. The problem of finding a consistent market for the humus end product of the composting process is the main drawback to that method of disposal.

The economics involved in the disposal of agricultural wastes on a small-farm scale is an aspect that cannot be given a definite answer. There may be a market for the humus, or landfill may be the most expedient means of disposal — it all depends on the individual farmer.

One of the drawbacks in composting is that agricultural wastes are often carbonaceous, and nitrogen must be added to the humus to make it a useful fertilizer. Other than the nitrogen, the wastes need no inoculum for successful composting. The disposal of agricultural wastes is a pressing problem, but there is at present no simple, universal answer.

Schulze, K. L.
"New Developments in Dairy Waste Treatment"
Presented at the Ninth Industrial Waste Conference, Purdue University, 10-12 May 1954

Dairy wastes are high in BOD and also have a very high immediate oxygen demand. The demand may be as high as 1.38 mg O_2 per ℓ per minute. Supplying oxygen at such a rate is still one of the major problems in the aerobic treatment of dairy wastes. Another problem is the tendency of porous materials used in air diffusion today to clog. The remainder of the article gives a very detailed account of the equipment that was designed to cope with two problems, i.e., with providing an air supply and prevention of clogging. The aeration method which was developed seems to have been very efficient, and no trouble with clogging or foaming was encountered. With this method it is believed 95 percent BOD removal can be attained.

Monson, Helmer
"Cannery Waste Disposal by Spray Irrigation"
Compost Science, 1:41, Spring 1960

At the time of the article, the Green Giant Company had been disposing of cannery wastes by means of spray irrigation for eight years. Matters of prime importance in this method of disposal include application rate, permeability, and irrigation frequency. These variables cannot be fixed in a formula for a farm's operations; rather, trial and error and experience with a particular situation will tell what amounts can be irrigated, and when this disposal can take place. There are great difficulties in the practical application of this method of disposal: in one farm in Minnesota it was found that variations in permeability in one soil ranged from 0.2 to 7.7 inches per hour. It has been found that planting the irrigation farms with grass results in an improvement in infiltration and in soil structure.

The Green Giant Company installed an experimental tiling system, but the years following its installation were so abnormally wet that informative data could not be gathered. Pumping the liquid wastes from the plant to the spray nozzles involves the use of standard equipment. Solids that are kept reasonably small, about 1/8 inch in particle size, will have no difficulty in passing through the system. Solids separation is successfully completed with either rotary or vibrating type screens.

Dietz, R.
"Cannery Waste Disposal by Gerber Products"
Compost Science, 1:21, Autumn 1960

The Gerber Products Company, Freemont, Michigan, conserves fruit and vegetable cannery wastes by spray irrigation on 140 acres located 3-1/2 miles from the plant. The wastes contain up to 300 ppm of 5-day BOD and the pH varies from 4.3 to 11.5. The sprinkler system applies one inch of irrigation in 4-1/2 hours. Two to four inches of wastes are applied per week. The soil consists largely of fine sand.

Different crops have been tested on the irrigated fields. The yield of such cover crops as alfalfa was much greater on the irrigated soil. Several types of trees thrived with moderate application rates of irrigation and the Danish Willow withstood heavy spray irrigation. Irrigation can be continued in winter by controlled spraying over a small area. Therefore, lagooning is unnecessary in cold weather. The operating cost is relatively low in comparison to other methods of disposal.

Mercer, W. A.
"Ocean Disposal of Cannery Waste by Oakland Scavenger Company, California"
Report - National Association of Canners - Monitoring Inspection and Sampling Data, 7 September 1960

The report summarized information concerning the ocean disposal of cannery wastes by the Oakland Scavenger Company. On 16 and 18 August, halves, small fragments, and pits of peaches in water were disposed of in the ocean about 20 miles from the mouth of San Francisco Bay near the Farallon Islands. Large pieces of fruit continued to float for an undetermined period of time after discharge from the barge. However, fruit in the disposal area was not seen on the next trip of the barge two days later. There was no persistent discoloration of the water other than that of the floating pieces of fruit.

Experiments were run to determine just how long the wastes floated in ocean water. Into drums containing water from San Francisco Bay were placed pieces of clingstone peaches, both pealed and unpealed. All pieces of fruit sank within 12 hours, and the unpeeled, whole fruit sank last. Infiltration of salt water into fruit tissues is most important in causing the fruit to sink.

Hart, S. A.
"Digestion Tests of Livestock Wastes"
Journal, Water Pollution Control Federation, 35:748, June 1963

1. Chicken manure and dairy manure can be stabilized satisfactorily in high-rate digesters adequately equipped with sludge mixing equipment.

2. Practically, there is little benefit to be derived from, or general need for, anaerobic digestion of most dairy manures.

3. The extent of the destruction of volatile matter in digesting chicken manure closely approximates that taking place in municipal sludge digestion.

4. Although the nitrogen levels of chicken manure are high, on the order of 5 percent, digestion does not result in loss of nitrogen, but rather, nitrogen is lost through the destruction of organic matter. It is concentrated to 8 percent to 9 percent in the digested sludge. The nitrogen is changed from predominantly organic in the fresh manure to primarily ammoniacal in the digested sludge.

5. BOD and COD are best expressed in terms of mg O_2 per mg volatile solids for the high solids content of manures and manure sludges.

6. On the basis of mg O_2 per mg volatile solids, the COD increases during digestion.

Water Resources Engineers, Inc.
"Cannery Waste Treatment: Utilization and Disposal"
Literature Review, Prepared for the State Water Quality Control Board, September 1965

The report is comprised of two major components: 1. a narrative analysis of important applied and theoretical research relevant to each major division in the spectrum of waste treatment, utilization, and/or disposal techniques; and 2. a comprehensive list of references (349) in which each item is categorized as to the nature of its content and its relevancy to each of the subject headings under 1. as above.

Hart, S. A.
"Lagoons for Livestock Manure"
Journal, Water Pollution Control Federation, 37:1578, November 1965

A description and discussion are given of experiments conducted with the use of 8 small "lagoons" (concrete cylinders 4 ft in diameter and 7 ft in length sunk into the ground to a depth of 6 ft). Manures which were fed to the "lagoons" were chicken, swine, and dairy. The results are the bases for the design criteria given by the author in his paper "The Design of Waste Stabilization Ponds for the Treatment of Agricultural Wastes" (1966).

Egbuniwe, N.
"Disposal of Chicken Wastes"
Course CE 298-5, University of California, Berkeley, Spring 1966

Of all the methods of stabilization of chicken manure considered in this paper, it seems that manure lagoons are the most economical way of disposing of chicken wastes. Skilled labor and expensive equipment are not involved. Ponds require a minimum of operation and maintenance, and can be applied to small farms. Adherence to sound principles of construction and operation of these ponds is essential. Lagoon development should be supervised by a sanitary engineer. Public health hazards posed by the lagoons can be minimized with good design, construction, and attention.

Hart, S. A. and M. E. Turner
"The Design of Stabilization Ponds for the Treatment of Agricultural Wastes"
Paper Presented as part of the Special Lecture Series on Advances in Water Quality Improvement, University of Texas, Austin, 4-7 April 1966

The main difference between stabilization ponds used for sewage and industrial waste water and ponds used for the disposal of livestock manures is that the former must accept large quantities of relatively lightly polluted waters; while the latter are expected to accept large amounts of organic solid matter. Because of the heavy loading, manure ponds generally are operated as anaerobic systems; and therefore volume rather than surface considerations should be followed in their design.

Some criteria for design are as follows:

1. Odors must be minimal or nonexistent.

2. Fly and mosquito production must be controllable.

3. Pollution of subsurface water must be prevented.

4. The appearance of the pond must be acceptable; otherwise, it should be screened or hidden.

The following are some specifications to be followed in determining the required pond volume: For swine, from 67 cu ft (Hart and Turner) to 475 cu ft (Clark) should be provided per hog. Three volumes are given for chickens, viz., 6 cu ft per bird (Cooper), 13.6 cu ft per bird (Hart and Turner), and 14.6 cu ft per bird (Dormbush and Anderson). About 800 cu ft should be provided for each 1000 lb of beef animal (Hart and Turner). Witzell et al. prescribe 1547 cu ft per bull (1600 lb).

The ponds should be deep. Influent should be discharged to the center of the pond, preferably under water. Since only part of the manure is converted to gas, sludge will accumulate at the pond bottom. The water should be maintained at the design level, even if it entails the addition of make-up water. Side slopes of the bank should be 1 vertical and 2 to 2-1/2 horizontal for the water side, and 1 vertical to 1-1/2 to 2 horizontal for the outside beam.

Mosquito production is possible only in lightly loaded ponds. Larvae of the drone fly, Turbifera tenax, survived in the ponds.

Hart, S. A. and W. Hillendahl
"Düngerteiche für die deutsche Landwirtschaft?"
Sonderdruck aus Landtechnische Forschung, Heft 5, 1967
Hellmut - Neureuter - Verlag, Wolfratshausen

The collection and biological decomposition of liquid manure in manure ponds or lagoons represents the most simple form of manure disposal from the viewpoint of construction, while, financially, it is the cheapest form. West German farmers have put the question whether and under what conditions this simple procedure can be used for their purposes. An evaluation of the experimental results and practical experiments with manure ponds in the U. S. A. showed that manure ponds cannot be introduced without hesitation into Germany because of the comparatively high population density, prevailing built-up areas, and the unfavorable climatic conditions. Its distribution in Germany, which is only thinkable in agreement with the legislation of water cleaning, will therefore be limited to exceptional cases.

Gramms, L. C.
"Anaerobic Decomposition of Animal and Poultry Manure under Laboratory Conditions"
A Report Presented in Partial Fulfillment of Requirements for a M.Sc. Degree, University of Wisconsin, Madison, May 1967

The laboratory studies on anaerobic decomposition described in the report were initiated to determine the effect of loading rate and detention time on the reduction of pollutional strength and volatile solids of animal and poultry wastes. Additional studies were concurrently conducted to determine the settling and dewatering properties of the anaerobic sludge effluent.

Results show that:

1. Loading rate and detention time had an apparent effect on the digestion of hog and chicken waste, but no appreciable effect on that of bull waste. Examples of pertinent facts are as follows: loading: volatile solids, 0.06 to 0.24 lb per cu ft per day; detention time (hydraulic), 10 to 15 days.

2. The reduction in volatile solids for hog (50 percent to 61 percent) and chicken wastes (57 percent to 68 percent) compared favorably with that obtained in "high-rate" domestic digestion; but the reduction in bull waste solids was substantially less (26 percent to 28 percent).

3. The reduction in COD was appreciable for the hog (34 percent to 55 percent) and chicken wastes (69 percent to 78 percent), but was nominal for the bull waste (24 percent to 34 percent).

4. The dewatering properties of digested hog and chicken sludge were similar to those of domestic anaerobic sludge. However, the filtering properties of digested bull manure sludge were considerably poorer. The variance in values of percent COD for the bull manure was ± 13 percent to 20 percent; hog manure, 4 percent to 11 percent; and chicken manure, 2 percent to 5 percent. Gas production per pound of volatile matter destroyed was as follows: for hog manure, it was 8 cu ft at a loading of 0.12 lb volatile solids per cu ft, and 13 cu ft at 0.24 lb volatile solids per cu ft. For chicken manure, it was 7.3 cu ft at a loading of 0.12 lb per cu ft and a detention period of 10 days. At the same loading, but with a 15-day detention period, the production was 8.6 cu ft. For bull manures it was 2.1 cu ft at a loading of 0.06 lb per cu ft and a 15-day detention period to 8.8 cu ft at 0.24 lb per cu ft and a 15-day detention period (3.9 cu ft at 0.24 lb per cu ft).

The following conclusions were reached:

1. For bull manure, the ultimate permissible loading would be in excess of 0.24 lb volatile solids per cu ft. It is amenable to anaerobic degradation.

2. For hog manure the ultimate loading is in excess of 0.24 lb per cu ft per day. Volatile solids reduction was greatest at a loading of 0.12 lb per cu ft per day and with the detention period at 15-days. Aerating the digester effluent added another 30 percent to 40 percent reduction in COD. The digestion of chicken manure was inhibited at loading rates of 0.24 lb per cu ft per day, and a 15-day detention period. Under these conditions, the NH_3-N concentration became excessive.

Wallize, J., T. E. Hazen, V. C. Speer, and W. P. Switzer
"Swine in Confinement — The Story of a Model"
Iowa Farm Science, 22:3, July 1967

The article describes the advantages and problems attendant upon growing pigs in confinement. One of the important problems is waste management. In the Iowa State University system, a combination of anaerobic lagoon-oxidation ditch is used. The wastes of 700 pigs are equivalent to those of 2000 people. Design facts are as follows: Anaerobic Lagoon: The volume per animal should be 2 cu ft per lb of animal weight. The minimum depth should be 5 ft. The inlet should be submerged. The pond should be securely fenced. Aerobic Lagoon: About 1-1/2 sq ft of surface area should be allowed per lb of animal weight. The inlet should be submerged.

Anon.
"Kansas Has a Serious Water Pollution Problem"
Civil Engineering, American Society of Civil Engineers, 38:33, January 1968

According to an official in the governor's office, it is unsafe to drink or swim in any of the streams and rivers of the state. The State Board of Health attributes the situation to the more than 200 feedlots spread throughout the state. The daily output of wastes from 5.5 million cattle, 1.5 million hogs, and 452,000 sheep in the state is equivalent to that which would be produced by a human population of 70 million. Health Department statistics show that the wastes accumulate within feedlots for as long as 3 to 6 months, and that this is washed into streams during periods of surface runoff from rain. This type of pollution was responsible for 60 percent of the 93 fish kills in Kansas rivers and streams between 1963 and 1965.

NEW PUBLICATIONS

(abstracted too late to be included in body of report)

Anderson, L. E. and A. K. Nigam
"Comprehensive Studies of Solid Wastes Management — A Mathematical Model for the Optimization of a Management System"
University of California, Berkeley, Sanitary Engineering Research Laboratory, Report 68-1, February 1968

The report covers the phase of the solid wastes management study which relates to the development of a mathematical model for the optimization of the flow of wastes from collection points to the treatment plants or transfer stations to the final disposal points in a typical community. A typical system is represented by a network. A method is developed by which the overall operation of a generalized wastes system can be optimized within the limits of capacity restrictions. Specifically, it develops a procedure for shipping, at minimum cost, all wastes from their source to a sink by way of intermediate points as required.

The first section of the report deals with the specific problem of transporting solid wastes from communal transfer stations via transfer vehicles. A modification to the progressive search and evaluation procedure is developed. Applied to the transportation problem, the separation procedure systematically enumerates the feasible shipping schedules, and the evaluation procedure directs the search toward the minimum cost arcs. In addition, a heuristic node ordering is utilized to eliminate the examination of uninteresting activities and to facilitate convergence.

The second section of the report deals with the entire system of waste collection, treatment, and disposal. The system thus developed was in general a multicommodity network flow problem, but the consequent limitations were avoided by incorporating fixed flow ratio dividers to segregate commodities and to allow optimization by nearly conventional methods. The system was optimized by applying a parametric out-of-kilter procedure modified to include the special behavior at the fixed flow ratio divider nodes. The algorithm is developed in all generalities to account for problems as backtracking of flow through the fixed flow ratio divider nodes.

Remson, I., A. A. Fungaroli, and A. W. Lawrence
"Water Movement in an Unsaturated Sanitary Landfill"
Journal of the Sanitary Engineering Division, American Society of Civil Engineers, 94:307 No. SA2, Proceedings Paper 5904, April 1968

Understanding of the moisture regimen of a sanitary landfill is basic to a knowledge of the character and quantity of the water-borne contaminants it generates. Moisture-routing methods based upon the equation of continuity are extended to provide an approximate method for predicting vertical moisture movement through and out of sanitary landfill. The method is based upon climatological techniques of soil-moisture routing and incorporates the hydraulic characteristics of unsaturated permeable materials. Using the routing method, predictions were made of the effect of emplacement season and initial conditions on the moisture regimen of a hypothetical sanitary landfill. The results show that the time that elapses before the appearance of the first leachate depends upon the season of emplacement and the initial moisture content. Different landfill-management objectives may be attained by controlling landfill moisture regimen through selection of emplacement season, initial moisture content, and related factors.

Ludwig, H. F. and R. J. Black
"Report on the Solid Waste Problem"
Journal of the Sanitary Engineering Division, American Society of Civil Engineers, 94:355 No. SA2, Proceedings Paper 5909, April 1968

The need for investigation in all areas of solid wastes problems is described, and management of these problems is discussed. Areas discussed in detail are: air pollution control, open-windrow composting and markets; precompacting refuse for landfills, grinding and sewer transport, salvage and reclamation, reduction of quantity, collection and hauling methods, environmental resources management, odor and dust control, ground water contamination, land resources, utilization, incineration, and extent of available technology. Recommendations include: altering decision-making public administrators to the problem; recognition through a national conference; full implementation of Public Law 89-272, the Solid Waste Disposal Act; study of salvage markets; development of new collection and disposal methods; reducing air and water pollution; review of legislation for improvment after first year of program.

AUTHOR INDEX

AUTHOR INDEX (Continued)

AUTHOR INDEX (Continued)

AUTHOR INDEX (Continued)

AUTHOR INDEX (Continued)

AUTHOR INDEX (Continued)

AUTHOR INDEX (Continued)

AUTHOR INDEX (Continued)

AUTHOR INDEX (Continued)

AUTHOR INDEX (Continued)

ORGANIZATION INDEX

ORGANIZATION INDEX (Continued)

ORGANIZATION INDEX (Continued)

SUBJECT INDEX

SUBJECT INDEX (Continued)

SUBJECT INDEX (Continued)

SUBJECT INDEX (Continued)

SUBJECT INDEX (Continued)

SUBJECT INDEX (Continued)

SUBJECT INDEX (Continued)

SOLID WASTE MANAGEMENT

ABSTRACTS AND EXCERPTS FROM THE LITERATURE

Volume 2

July 1969

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PREFACE

The report herein presented is in the nature of an auxiliary report covering a survey of current literature on various aspects of solid wastes management and carried on as a part of the major research effort, "Comprehensive Studies of Solid Wastes Management," made possible by a grant (UI-00547-03) to The Regents of the University of California by the Bureau of Solid Waste Management, U. S. Public Health Service.

The report is a collection of abstracts and excerpts of literature reviewed during the third year of the research project.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

PART I
INTRODUCTION

NEED FOR STUDY

The opening statement made in the first volume of Abstracts and Excerpts (SERL Report No. 68-3, June 1968) holds true today: "One of the distinguishing characteristics of the research activity concerned with solid wastes now being prosecuted so vigorously in the United States is the influx of a large number of workers having little or no past experience, or even acquaintance, with solid wastes management." The lack of experience is manifested by a certain degree of naiveté found in many of the approaches and solutions proposed by them, especially with respect to practical day-to-day aspects. The reason is still the same. Interest in the subject, which had been relatively restricted, or at least dormant, prior to the past few years, continues to be aroused to a high pitch by the current concern over the threat to man's environment resulting from man's mismanagement of his wastes.

To compensate for his lack of knowledge and experience, the newcomer to the field of solid wastes management is compelled to make a vigorous search and examination of the literature. It is here that he encounters the first of the many frustrations which he will meet in the pursuit of his newly-found interest – the absence of a well-organized body of literature. This last statement was made in the introduction to the first volume of Abstracts and Excerpts, and unfortunately it remains applicable at the time of this writing. Texts dealing with the subject of solid wastes management are limited in number, and are often either out-of-date or are characterized by platitudes, generalities, and some folklore. However, there is sound information scattered in journals, magazines, proceedings of conferences, difficult-to-obtain reports, and a variety of unpublished papers. In his search for this information, so difficultly available from the literature, the newcomer generally consults one of the "authorities" on solid wastes to obtain advice on where to search for it. Since all too frequently the "authority" he consults has been only newly elevated to that position, the scope of the recommended literature is apt to be limited to the publications of that "authority." The upshot of the situation is that much time is lost in determining where to look, in collecting, and in finally "wading" through the constantly increasing accumulation of publications to glean the knowledge he is seeking.

Judging from the various publications now becoming available, there is a need for greater communication between the various researchers in the field; and, more so, a need for the new researcher to become more fully conversant with work that has been done and reported in the past. The reason for this observation is the not-infrequent appearance of papers and reports on subjects which have already been well explored, and in which practically identical discoveries were made by the earlier researchers, although their discoveries perhaps may not have been expressed in the sophisticated terminology used by their more recent counterparts. These needs can be fulfilled somewhat by collections of abstracts and, if possible, by pertinent excerpts from those publications which are difficult to obtain.

NATURE AND RATIONALE OF THE STUDY

The collection presented in this report represents a summary of literature gathered by the Sanitary Engineering Research Laboratory of the University of California during the period following the publication of the first volume of Abstracts and Excerpts. It is a part of a program of definitive research in the planning, systems, economics, health, and technological aspects of solid wastes management.

During the past year of the project "Comprehensive Studies of Solid Wastes Management," some two hundred papers, articles, and reports were collected and abstracted. In this volume, excerpts especially pertinent to the subject were made from the majority of the publications reviewed; and, in a few cases, an evaluation of the quality of an article was made by the author of this report. The collection is by no means exhaustive; nor is it claimed that the material reviewed in it is necessarily the best of the literature in solid wastes. For example, only a limited amount of foreign literature is reviewed. Many reports of subjects purely local in nature are included, as, for example, a description of an incinerator constructed by City X, or the experience of City Y in operating a landfill. While individually such papers may be highly localized in their application, the data and experience contained within them are useful for extrapolation or application to other situations; and collectively, they are useful in indicating trends or in compensating for lack of breadth of experience on the part of the reader. On the other hand, the collection does contain abstracts and excerpts of many reports not readily available to the researcher newly embarked upon work concerned with solid wastes.

OVERALL EVALUATION OF THE LITERATURE

The reader is referred to the previous volume of Abstracts and Excerpts (SERL Report No. 68-3, June 1968) for a survey and evaluation of the literature existing prior to and at the time of that printing. The survey and evaluation made herein deals with the body of literature as it presently exists.

The prediction made in the previous report concerning the coming transition from a condition of scarcity of literature to one of superabundance apparently is being borne out. References to the solid wastes problem, especially with respect to its effect on man's environment, have appeared in magazines and publications in which one would not expect to find such material. This should not be surprising in view of the rising popularity of the subject. It does not take much of a search to come across startling ("horrendous") facts and fancies which make prime material upon which to base an article for the reading public.

The more serious literature on solid wastes is growing more specific and concrete in its content. It is characterized by fewer platitudes and generalizations than was the case in much of the earlier literature. In other words, it is becoming less hortatory in nature, and instead is beginning to deal with solutions, or at least approaches to solutions.

Another improvement is the lessening of the dependence upon the speculations of others. The result of this trend is an increasing realism in the facts and figures given in the various publications. Examples of this trend are the waste production or waste generation figures found in the more recent literature. Thus, the formerly widespread estimate of 4 lb/capita/day waste production is being scaled up to as high as 10 to 20 lb/capita/day for total production because of new and more reliable information gathered in recent studies. A shortcoming of the modern literature, however, is that the data often are not presented in a manner suited to the widest possible use. Generally, the presentations of data and findings, especially those garnered from surveys, are geared to the engineer more than to the planner and the economist.

A serious deficiency in the modern literature is the scarcity of data from the private sector of solid wastes management. The sector referred to here is that concerned with collection, haul, and disposal — not the equipment manufacturer nor the entrepreneur. The deficiency is not the fault of the researcher, whether he be a member of a university research team or of a public agency. It arises from the extreme difficulty of obtaining figures of any kind from private organizations engaged in collection and disposal. The seriousness of this lack is in the bias it gives to conclusions made on the basis of what should hopefully have been complete surveys. This bias has been the source of repeated complaints by spokesmen for the private sector; despite the fact that they offer no solutions to the problem of how to obtain the missing information.

Reference to bias in the preceding paragraph brings to mind another shortcoming in the literature, fortunately a fault that is becoming less frequent in its appearance. The problem in mind is the uncritical nature of many papers. This uncritical approach leads to the writing of research results in a paper having the earmarks of an advertising brochure. The uncritical paper is generally the mark of the work of a "true believer," i.e., of one who has a "pet process" or approach which he has fathered or to which he has been won over. Such reports or papers contain all of the favorable results and very few of the unfavorable. This characteristic usually is found in new areas of research and tends to disappear as the field becomes more developed. An example of a welcome exception to this type of report is the interim report on the Gainesville compost plant, which is abstracted and excerpted in this report. It places equal emphasis on its successes and failures, and arrives at frank conclusions.

In the past year or two, a rash of publications of the newsletter type has sprung up. In general, their news coverage is extensive, albeit fragmentary. They also are quite expensive. If one is content to be patient, he generally can obtain the same information from the public media and certainly in more detail by reading the magazines and journals named in the following paragraph.

Among the current magazines and journals worth reading are Public Works, The American City, Solid Wastes Management/Refuse Removal Journal, Western City, Compost Science, Public Cleansing, and Environmental Science and Technology. The American City and Public Works generally have one or two articles on solid wastes each month. Usually, they are written in popular style and are concerned with some local installation, operation, or experience. Solid Wastes Management/ Refuse Removal Journal is primarily a trade journal, and emphasizes collection and haul. Despite a strong bias against public operations and against composting, its coverage is good on its field. Its especial value is in its reporting of new developments in equipment and of new processes. Compost Science is factual, and despite the bias one would expect from its title, the editor of the journal is not blind to the difficulties besetting composting. On the contrary, he is using the journal as a vehicle for proposing changes in the approach to composting which are more in keeping with modern times. Public Cleansing is a journal published in England. In general, its articles are brief and written in a popular vein. An excellent text on solid wastes disposal is a book published by the American Public Works Association, namely, "Municipal Refuse Disposal" (American Public Works Association, Public Administration Service, Chicago, Illinois, 1966). The association and the Bureau of Solid Wastes Management (U. S. Public Health Service) have been issuing many useful publications, some of which are reviewed in this report.

One of the difficulties encountered in a search of the literature for reports or papers on strictly research aspects of solid wastes management is the absence of a particular journal specific to solid wastes. For instance, papers on cellulose degradation or conversion to useful chemicals would perhaps be found in a chemical journal or perchance in a bacteriological journal. The point is, that a number of journals would have to be perused in order to glean the few papers that have been published on the subject. The problem is compounded by the fact that many such papers are perforce published in little-known journals or end up as limited circulation reports, because journals which are published by the major scientific societies may find the papers a bit too "applied" in nature to suit their tastes. Consequently, despite the concomitant necessary evil of adding one more journal to the existing proliferation of journals, there is a need for one devoted exclusively to solid wastes, one in which not only articles directly applicable to practice but also papers concerned with relatively fundamental research with perhaps only far-off applications could be published.

ORGANIZATION OF THE REPORT

The organization of the present report is much like that of the previous Abstracts and Excerpts. Ease of reference is promoted by grouping the abstracts and excerpts (Part II of this report) into major divisions and subcategories according to the subject matter given the most emphasis in the material under review. Because in most of the articles a number of subjects may have been given attention, it was often difficult to fit an article into any one category. In such cases, the classification was based on the subject which was treated at greatest length or was regarded as being the most significant. For example, an article on design of incinerators will also contain information on economics of incineration. This should be kept in mind when seeking information on a given subject in this report.

The major categories into which the articles are grouped are Management, Collection and Transport, Disposal, Salvage, Environmental and Public Health, Pollution, and Agricultural and Food Processing Wastes. Subcategories are given in the Table of Contents. The entries are arranged in chronological order under each category.

The report has three indexes — author, organization, and subject. The subject index probably could be more aptly termed a "subject-key-word index," inasmuch as both are given for the convenience of the user of the report. The choice of key words is a bit arbitrary, since no official list has been set up. Undoubtedly, when such a list is established, it will be as arbitrary as the one used in the present report.

A REQUEST

Inasmuch as work will have been begun on a third volume of Abstracts and Excerpts by the time this one is ready for distribution, and since the editor of these reports is confronted with the difficulties discussed in the preceding section in rounding up material to abstract and excerpt, he would receive with a high degree of gratitude spare copies of reports or papers on work done by readers of this report. Material received on loan will be returned within a period of two weeks after arrival at the Richmond Field Station. Please address the material to:

Dr. Clarence G. Golueke
University of California
Richmond Field Station, Building 112
1301 South 46th Street
Richmond, California 94804

MANAGEMENT

THE PROBLEM

"Cities vs Garbage — Who Will Win?"
U. S. News and World Report, p. 116, 23 October 1967

"On top of other troubles, cities are caught in a garbage crisis. Many are out of places to bury refuse. A report on what's being done about it." These are opening statements in the article. It goes on to report the following items: 1. In Washington, D. C., the incinerator had to be closed. 2. Philadelphia has let a 10-year contract to haul 1200 tons of refuse/day to strip mines in Central Pennsylvania. 3. In Massachusetts, the majority of dumps in the eastern part of the state will be filled in four years. 4. New York burns most of its rubbish. Stopping 40 percent of the city's 20,000 apartment houses from burning their rubbish increased the truck demand by 800 extra units. 5. An estimated 3 billion dollars were spent in 1966 in the U. S. to collect and dispose of 165 million tons of solid waste. This year (1967) the amount is expected to be 260 million tons. 6. In Hempstead, New York, an incinerator produces power and desalinates 4,000,000 gallons of seawater/day. 7. In one community, garbage is ground into sewers, thereby reducing trash collection costs by two-thirds, and frequently to once every two weeks.

California Solid Waste Planning Study
"Status of Solid Waste Management in California"
Volume 1, Interim Report, California State Department of Public Health, Berkeley, California, September 1968

The report presents findings and conclusions made as a result of an intensive statewide study and analysis of current solid waste management practices in California. It is in the nature of a factual progress report or summary data bank on the existing system of solid waste management. Subjects covered in the report are indicated by the chapter headings, which are as follows: I. Introduction; II. Summary and Findings; III. Solid Waste Production; IV. Administration and Control; V. Solid Waste Collection; VI. Solid Waste Disposal; VII. Environmental Effects of Solid Wastes; VIII. Solid Waste Planning — Current Status. Titles of appendices are: A. Statewide Industrial Classification; B. Summary of State Laws and Regulations; C. California Disposal Sites 1967; D. Distribution and Location of Disposal Sites with Related Data by County.

A few excerpts are as follows: 1. During 1967, California's municipalities, industry, and agriculture generated an estimated 70 million tons of solid wastes, an average of 20 lb/person-day. In an uncompacted condition this mass of wastes may be visualized as a collection of solid wastes 100 ft wide and 30 ft high, stretching from Oregon to Mexico. 2. Five basic areas of deficiency are presently evident: a) Fragmented authority and lack of cooperation and coordination; b) inadequate planning; c) nonexistent or inadequate standards; d) primitive technology; e) inadequate financing. 3. Most of the municipal solid wastes in California is disposed of in 716 general-use disposal sites, of which 71 percent are open burning dumps. Less than 10 percent can be classified as sanitary landfills. Only 16 of the 58 counties have undertaken any solid waste study or planning activities, and many of these plans ignore the needs of the incorporated cities and adjacent counties.

"Solid Wastes Pile Up While Laws Crack Down and Engineers Gear Up"
Engineering News-Record, 182(23):28, 12 June 1969

The problem of disposing of the 3.5 billion tons of wastes discarded in the U. S. is an urgent one. "Unlike the design and construction of highways and schools, there is no complete list of proved solutions for the problem of what will be done to efficiently, economically, and safely dispose of the 3.5 billion tons of solid wastes generated in the U. S. each year.

"Although the problem has been growing for years, attention was emphatically drawn to it in the past few years as a result of the federal and state air pollution laws against the burning dump and the smoking, inefficient incinerator. Water pollution laws are already cracking down on dumps and landfills that leach pollutants into ground and surface waters."

Although the dump is an unsatisfactory disposal method, it is widely used in the U. S. – only 6 percent of land disposal sites have acceptable sanitary landfills. The reason is that the overall average cost of operating a sanitary landfill is $1.27/ton, while operating a dump averages about 96¢/ton. According to the Public Health Service figures, it would cost about $244 million for equipment and $81 million for additional operating funds to upgrade all of the U. S. dumps to the level of the sanitary landfill. As an example, the equipment needs increased 36 percent when Kansas City, Missouri, switched from open dump to sanitary landfill disposal. Another difficulty is that a sanitary landfill uses land at a rate 70 percent faster than would a dump. Attempts are being made to reduce land requirements by resorting to compaction. In Chicago, a compaction unit is being tested that produces bales of refuse having a density of 60 to 80 lb/cu ft.

According to Public Health Service, 70 percent of the 300 incinerators in the U. S. lack adequate air pollution control devices. The 300 incinerators handle about 10 percent of the wastes produced in the U. S. The average cost per ton is $4.50. The big problem is the lack of proper design criteria. For example, "Houston's new $5 million incinerator has a water scrubbing pollution control device that has been used effectively in industrial plants that burn dry wastes. But when the temperature is raised enough to consume 800 tons a day of wet garbage, it clogs the baffles and the smoke control equipment. To cut air pollution, the city runs it at reduced capacity."

The usual reaction to a proposed location for an incinerator is one of outrage on the part of the neighbors to the proposed incinerator. Mostly this opposition stems from the generally unfavorable past history of incineration operations. There is the possibility, however, that the opposition can be lessened by a guarantee (and a later fulfillment of that guarantee) of setting up a well-run operation. An example of such a procedure is one in North Hempstead, New York. The success of this operation is attested by the fact that a row of $60,000 houses was built within 300 yards of the incinerator after it began operating in 1966. "The people who live in those houses didn't know this was an incinerator until they asked somebody," says Wegman (of North Hempstead).

Another method of managing wastes is to transport it to a suitable destination by rail haul. A number of such operations have been proposed, but as yet there are no reports of any in actual operation.

Proposed wastes handling and disposal methods include compaction and baling, transportation of wastes by pipeline, high-temperature incineration, and incineration so that the residue can be used for paving.

The article concludes with this true statement: "No matter who pays, or what disposal methods are used, it is obvious that solid waste disposal is an expensive and urgent problem that will require a major engineering effort in the next 20 years."

APPROACHES

Klee, A. J. and G. A. Garland
"Decision Trees in Solid Wastes Planning"
Public Works, 99(7):74, July 1968

The article explains the technique of "Decision Tree Analysis" by way of an example involving a mythical, moderate-sized community. The problem facing the planning commission of this mythical city is that of recommending a new solid waste disposal for the city. Incineration, landfill, and composting are to be considered, and the cost estimates for each are at hand.

Since the cost estimates for each disposal system depend on a number of "if's," a decision process must be devised. The alternatives arising from the "if's" and their consequences are reduced to a graphic structure known as a "decision tree." The tree is made up of nodes and branches, each node being of two basic types: squares denoting decisions; and circles, denoting chance events. In the example, a node with branches "Expand Incinerator" and "Add Landfill" is a decision node; one with branches "Demand High" and "Demand Low" is a chance event node. Branches coming from decision nodes represent alternatives available to the decision-maker; branches from chance event nodes are alternative outcomes of these events.

The article explains the mechanism for arriving at an optimum solution, i.e., that path which, in terms of costs, minimizes total expected system costs. One way to find an optimal path is to consider only optimal returns from each decision node. The application to the mythical city is given as an example. The rollback technique is used. It involves starting from the right (farthest in time) by calculating values at each node: a) If the node is a decision point, the values of the nodes leading from it are examined; and the optimum is selected; b) If the node is a chance event, an expected value is calculated using all of the nodal values at the ends of the branches emanating from it and their probabilities.

To explore the range of possible outcomes for a particular decision, it is necessary to make a risk analysis: a) If the node is a decision point, calculate the nodal value in the previously described manner; b) If the node is a chance event, examine nodal values leading from it and select the least optimum; c) Continue until the end (the decision at time = 0) is reached. For each alternative, a value will have been calculated that represents the highest risk of the alternative. By multiplying together the probabilities obtained in (b), the probability of that risk is obtained.

The authors are on the staff of the Systems and Operations Planning, Solid Wastes Program, National Center for Urban and Industrial Health, U. S. Department of Public Health Service, Cincinnati, Ohio.

Hickman, H. L., Jr.
"Planning Comprehensive Solid Wastes Management Systems"
Proceedings of the American Society of Civil Engineers, Sanitary Engineering Division, Paper No. 6303, Volume 94, No. SA6, December 1968

Solid wastes have not received proper recognition as a national problem, and therefore have not received thoughtful planning, design, construction, careful operation nor strong public support. Engineers charged with management of solid wastes have managed to continue to serve the public without suitable support. However, the magnitude of the problem and increasing public and private interest is beginning to give the engineer the resources he needs to plan and manage comprehensive solid wastes systems. All available management tools must be used by the engineer in planning for the system. Planning must be approached by effective problem-solving teams. These teams must consider the definition of goals; plan the development of the study area; recognize political and socioeconomic constraints; evaluate existing systems in the study area; determine the configuration of the future system; decide how to implement the resultant plan; and find ways of meeting the costs and financing of the system. These efforts coupled with a sound public relations program to gain acceptance of the system will assure success.

Golueke, C. G. and P. H. McGauhey
"Comprehensive Studies of Solid Wastes Management — Second Annual Report"
Sanitary Engineering Research Laboratory and School of Public Health, University of California, Berkeley, SERL Report No. 69-1, January 1969.

The two authors listed above were responsible for the compilation of the report and wrote the following sections: <u>Introduction</u>, <u>Reevaluation of the Problem</u>, <u>Public Health</u>, and <u>Summary</u>. Authors of the other sections are: S. A. Rao, <u>Planning</u>; H. Stern, A. Nigam, and C. R. Glassey, <u>Operations Research</u>; R. Dawson, S. A. Hart, D. B. Chan, R. Rosenbluth, C. R. Wilke, J. Bicho, D. L. Brink, and P. K. Basu, <u>Economics</u>; S. A. Hart and A. K. McFarland, <u>Composting</u>; J. Bicho and D. L. Brink, <u>Wet Oxidation</u>; D. L. Brink, <u>Incineration-Pyrolysis</u>; R. Rosenbluth and C. R. Wilke, <u>Biological Fractionation</u>. The above listing of section titles is indicative of the subject matter of the report.

Among the interesting facts and conclusions presented in the report are the following: 1) The report emphasizes that the number one problem as viewed by public officials at the time the report was written was "finding any location at which to do whatever it is you need to do, whether it be to establish a transfer station, an incinerator, a landfill, a processing plant, or even a transport route." 2) Three types of problems exist with respect to the relation of public health to solid waste management. They are: a) problems which are reasonably well solved, but remain so only by constant vigilance; b) problems which are unsolved, but are incapable of resolution independent of technological, political, and planning problems; and c) problems which remain either unidentified or unrelated in relation to other environmental research. 3) The planning aspect of the research as reported in the publication is particularly concerned with: a) the development of structural models with which, on the basis of related variables and land-use projections, it is possible to predict in detail the solid wastes which will be generated in a community or region; and b) the exploration of the implications of changes in transportation and disposal technologies in solid wastes management and resource use in a community or region. 4) In the section on <u>Operations Research</u> are developed a series of models concerned with: a) optimal location of treatment plants and disposal sites; b) determination of the least-cost flow pattern of wastes from origin, via transportation networks, to treatment plants, and ultimately to disposal sites; and c) optimum operating policies for treatment plants with randomly varying waste loads. 5) The section on <u>Economics</u> treats in some detail: a) the interrelationships of regional economics and the amount of wastes generated; b) economies of scale in solid wastes management; and c) an economic analysis of the five technologies being studied in the project, viz., a low-cost biostabilization (compost) system, anaerobic digestion of solid wastes, biofractionation, wet oxidation, and incineration-pyrolysis. 6) The work brought forth ample evidence for a need for two types of research; namely: a) an accurate summary of the kind and amounts of individual materials or compounds which occur in the wastes of each of a vast number of human activities; and b) a study of the nature and amount of conversion products resulting from wastes management processes, particularly incineration. 7) In experiments on anaerobic digestion, it was found that: a) garbage-fed digesters (loading, 100 percent garbage) are highly adaptable to varying proportions and quantities of feed — more so than are sludge-fed digesters; b) paper pulp digested readily provided the C:N ratio was less than 45:1; c) Monterey pine proved to be essentially inert to the digestion process, but not, however, to be inhibitory; and d) in all experiments in which cellulosic materials were added, the fuel value of the digester gas dropped by 7 to 10 percent. The activities in the work on the remaining technologies were concerned mainly with equipment assemblage and conduct of preliminary experiments. 8) The pyrolysis unit, when completed, will have the capacity to process 200 lbs solid wastes/hr. The plant is designed to operate at temperatures as high as 900° to 1000°C, and to process Kraft black liquor, as well as solid wastes.

"1981 – Computer Gives the Answers"
Public Cleansing, 59(2):67, 1969

A report covering the activities of the Wirral Working Party and those of the two municipalities, Chester City and Ellesmere Port, is reviewed in this article. Three methods of pretreatment prior to final disposal by landfill were considered; namely, composting, pulverization, and incineration. Composting was dropped from consideration because of the absence of a market for the product. Calculations were made of the number of pulverization and incineration plants, and of their siting and capacity required in 1968, 1981, and 2000. The sites suggested were found to be the same for both incineration and pulverization. The costs projected for incineration indicated that in terms of money savings it would be the cheapest solution to build two incinerators for use during the 1968 time period. However, by 1981, the number would have to be increased to three plants.

The report makes a comparison between the use of various disposal plants and that of controlled "tipping." As might be expected, controlled tipping was shown to be the cheapest. However, according to the predictions, all known tipping sites would be filled by 1982. Pulverization apparently is next cheapest and the tipping sites will last until 1986. Incineration is the next cheapest, and its use would extend the acreage for tipping sites until 2003.

According to the report, collection costs vary from £1.76/ton to £8.13/ton.

Stern, H. I.
"Comprehensive Studies of Solid Wastes Management – Optimal Service Policies for Solid Waste Treatment Facilities"
Sanitary Engineering Research Laboratory and School of Public Health, University of California, Berkeley, SERL Report No. 69-6, May 1969

The investigated system consists of a stochastic periodic stream of raw waste, a processing operation with controllable deterministic service rate, and adequate storage capacity. Superimposed on this system is a cost structure composed of processing and holding costs. A service rate rule that minimizes the infinite horizon discounted expected total cost is found. The problem of finding such a rule is formulated as a stochastic Markovian Decision process with continuous state space, continuous decision space, and finite transition times. Existence and uniqueness of long-term optimal cost and policy functions are shown. Since the optimal policy cannot be expressed explicitly, an approximate solution was found. An error bound on the optimal cost associated with this solution is exhibited.

In the approximate version of the problem, the cost structure is described by: a) a quadratic processing cost rate charged when the waste level is positive, and b) a linear holding cost charged at the end of each period. The arrival stream is periodically interrupted and divided into alternating "on" and "off" intervals of fixed length. The distribution of the cumulative quantity of waste that arrives during each "on" interval is represented by its first two moments (allowing a distribution free analysis). During each "off" interval, no raw waste is introduced into the system, but the processing facility is allowed to operate for more efficient

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use of fixed capital outlay. A service rate is selected at the start of each "on" and "off" interval.

Employing Bellman's principle of optimality to the approximate problem, the optimal service rates are found to be linear in the waste level at the start of each "on" interval and piecewise linear in the quantity of waste present at the start of each "off" interval. The optimal discounted expected total cost is quadratic in the waste level at the start of each interval. Typical problems were solved on a CDC 6400 digital computer. Results indicate relative cost errors below three percent.

"Solid Waste Management. 1. Areawide Approaches"
National Association of Counties Research Foundation, prepared for the Bureau of Solid Waste Management of the U. S. Public Health Service, no date (distributed, 1969)

The publication is the first of a series of ten guides written for local governing boards in nontechnical language to describe what constitutes good solid wastes management and what must be done to develop such a system.

Guide No. 1, "Areawide Approaches," covers the relationship of solid waste management to environmental quality control and points out the need for an areawide approach to insure the adequacy of a comprehensive program. In it are discussed the advantages of intergovernmental cooperation. The definitions given in the guide are extremely useful in promoting intelligent discussion of solid wastes management. Solid wastes includes anything thrown away, such as garbage, trash, litter, junk, and refuse from any source. Garbage refers to food wastes. Rubbish and trash include combustibles such as paper, wood, etc., and noncombustibles such as metals, glass, and dirt. Litter is any piece of discarded waste which is exposed and uncontrolled. Junk refers to anything currently valueless. Refuse includes garbage and trash as well as all other solid or semisolid wastes such as sewage sludge, abandoned motor vehicles, dead animals, demolition rubble, and street sweepings.

The area to be included in a comprehensive solid wastes management system should encompass the largest feasible geographical area of present and predicted solid wastes generation and include disposal sites for at least 20 years. In determining the unit of government to plan and administer a solid wastes system, two factors are important: 1) The unit of government should have authority over the geographical solid wastes production and disposal area; and 2) It should have sufficient political power to effect a good program. Generally, the county governmental unit is large enough to meet these conditions. In large metropolitan areas in which solid wastes problems cross jurisdictional boundaries, councils of governments may be set up as vehicles to stimulate local officials to think in broad terms of mutual problem areas and to encourage jurisdictions to effect a mutually complementary system for solid wastes management.

Where state restrictions make it necessary, or other unit of government is possible, special-purpose governments must be established. "In such cases, the district is preferred to the public authority because the district embraces a distinct constituency, not merely a group of absentee bondholders." Existing special-purpose governments should be used in preference to establishing new ones. Cooperation between jurisdictions can be accomplished by way of contract for service, by joint solid wastes management, and by transfer of function.

Advantages of areawide cooperation are: 1) Elimination of duplication in use of consultants for initial surveys. 2) Greater flexibility in locating disposal sites. 3) More easily obtained support of local news media. 4) Greater discounts for volume orders of collection and disposal equipment. 5) Coordination of air and water pollution abatement activities. 6) Better chance for federal assistance, and

7) Economies of scale in such things as administrative costs, land acquisition, and construction costs.

The publication includes a selected bibliography in which are named eight publications of particular use to those interested in areawide management.

"Solid Waste Management. 3. Planning"
National Association of Counties Research Foundation, prepared for the Bureau of Solid Waste Management of the U. S. Public Health Service, no date (distributed, 1969)

This is the third of a series of guidelines written for local governing boards. The publication includes not only information pertinent to planning but also gives case histories. Especially useful is a check list for data collection.

Planning for solid wastes management, from storage to eventual disposal, must be approached systematically. To protect the environment effectively, the plan should encompass a broad solid wastes generation and disposal area. A solid wastes management plan should include a statement of its objectives; physical description of the area; survey and inventory of solid wastes as to quantities and characteristics; analysis of land use and population trends; examination of state laws, regulations, and ordinances; evaluation of revenue sources; and proposals for action.

Implementation is the most important part of the planning process. Without capital budgeting and the active support and interest of the elected officials, the solid wastes management plan will never become a reality.

The publication includes a procedure for formulation of a solid wastes management plan. Excerpts are as follows: a) Consider alternative solid wastes management systems for the study area. b) Consider the alternative systems in the light of public health protection; prevention of environmental pollution; public sentiment; aesthetics; political and jurisdictional effects; and anticipated growth and shift in solid wastes generation, population, industry, etc. c) Compare the alternative systems on an economic basis, including the costs and benefits of environmental and public health protection. d) Select a system. e) For the recommended system, include capacities, cost, source of revenue to operate the system, functions, organization, general locations, operating scheme, staging of construction, and design technicalities. f) Recommend needed legislation (standards, rules, and regulations) at the local and state levels. g) Provide for expansion and flexibility and allow for adjustment of the system. h) Recommend what the elected officials should implement immediately.

A list of five recommended publications is given for additional reading.

"Solid Waste Management. 4. Organization"
National Association of Counties Research Foundation, prepared for the Bureau of Solid Waste Management of the U. S. Public Health Service, no date (distributed, 1969)

This is the fourth of a series of guidelines written for local governing boards. It gives examples of a number of organizational setups taken from various municipal organizations. Methods and criteria for establishing organizations are given.

The guide discusses the major functions of a comprehensive wastes management system. These functions are policy-making, public information, budgeting, planning and review, adoption and enforcement of standards, and operation of the system. When organizing a system, local officials should keep the following criteria in mind: a) The system must function properly no matter who operates it. B) The system must fit local needs. c) The organizational pattern must be flexible enough to cover the largest feasible political and geographical area for solid wastes management.

"A solid wastes management system can work well with many organizations involved, or it can be a disastrous 'buck-passing' operation. Advantages of a separate department of solid wastes are: Possession of a separate budget; having a greater degree of visibility to the public and to the governing body; direction of total attention to the problem; no sharing of equipment and personnel; it is directly responsible to the governing board; and the possession of a higher priority status. Disadvantages are a further fractionation of local government; solid wastes may not coordinate with related programs; and it may create duplications of kinds of personnel."

A selected bibliography of six publications is given.

"Solid Waste Management. 5. Design and Operation"
National Association of Counties Research Foundation, prepared for the Bureau of Solid Waste Management of the U. S. Public Health Service, no date (distributed, 1969)

Design and operational guidelines are the subjects of the fifth of a series of publications intended for use by local governing boards. It discusses methods of storage and collection, long-distance transportation systems, and volume reduction and disposal methods. A number of field reports are given ranging from a paper sack storage system in Junction City, Kansas, to progress and problems in cleaning up dumps. (Ed. note: Inasmuch as the discussions on the various collection and disposal systems are general in nature and are covered in the general literature, a few selected excerpts from the publication are made rather than an overall summarization of its contents.)

The advantages of plastic and paper bag systems are disposability and no need to clean; collection is speeded; spillage is lessened; the bags are lightweight and easy to handle, thus reducing back injuries and insurance costs; and their collection is quieter than that with the can system. Disadvantages are their vulnerability to attack by animals if no metal guard is used; arrangements must be made to provide holder and container guards; the user or local government must pay for a continuing supply of bags; the homeowner must be instructed in the use of the holder and the storage requirements; closure of overfilled bags often is faulty; and the bag is in itself an item of solid waste.

In the section on composting, a table is given in which is shown the 1968 status of U. S. composting operations. Of the 18 plants named in the list, only five are operating, and two of the five are being operated for research purposes. Those in operation in 1968 were the Fairfield-Hardy process at Altoona, Pennsylvania (45 tons/day); the Metro process at Gainesville, Florida (demonstration plant — 200 tons/day capacity), and at Houston, Texas (300 tons/day); the PHS-TVA Cooperative Program at Johnson City, Tennessee (operation for research — 50 tons/day capacity); and the Briquetting process at Mobile, Alabama (presently operated as a windrow process — 300 tons/day capacity). (Ed. note: In general, the plants are not being operated to the full extent of their capacities.)

The following check list is given for transfer, processing, and disposal operations: a) All-weather access and egress roads. b) Dust control measures.

c) Posted regulations. d) Employee facilities — washrooms, lunchrooms, and lockers. e) Scale-house and weigh station. f) Fenced grounds. g) Designated place and container for wastes to be received after hours at the gate. h) Landscaping and litter control. i) Employee safety program. j) Firefighting equipment available. k) No open burning practiced. l) Communications. m) Adequate screening. n) Banning of scavenging. o) Efficient record-keeping.

"In the operation of a comprehensive solid wastes management system, the management of industrial and agricultural wastes and hard-to-handle items ... should not take a back seat to the collection and disposal of residential and commercial solid wastes."

"Solid Waste Management. 8. Citizen Support"
National Association of Counties Research Foundation, prepared for the Bureau of Solid Waste Management of the U. S. Public Health Service, no date (distributed, 1969)

In this publication, one of a series of guidelines for local governing bodies, are discussed ways of winning citizen support. It discusses the need for action in developing a program image and in handling complaints. It explains ways of going to the public for support by way of established organizations, of delivering the message, and of dealing with the sources of opposition. A section is devoted to using the communication media. Finally, a series of seven excellent field reports is given.

"A sound public information program is an essential aspect of solid wastes management." It is needed to win the public support so essential to the implementation of a new solid wastes management system or to the substantial modification of an existing system.

The public information phase should be backed up by a record of accomplishment in the management of solid wastes by the local government. In the time it takes to complete a detailed comprehensive solid wastes management plan, local government can involve organizations and private industry in solid wastes management through community improvements such as the cleanup of illicit dumps, control of litter, improved solid wastes storage, and removal of abandoned automobiles.

As many public information tools as are available should be used. Among these are meetings at which slides and films are shown; inspection trips; personal contact by telephone and door-to-door canvass, speakers' bureaus, brochures, and flyers; radio, television, newspaper, and newsletter coverage and announcements; and other communcations media.

Among films which can be used are: a) The Third Pollution and A Day At The Dump — documentaries about the status of solid wastes (Stuart Finley Productions, Inc., 3428 Mansfield Road, Falls Church, Virginia 22041). b) Collector's Item — sponsored by the International Harvester Company and discussing the Los Angeles County collection system (International Harvester Company, 400 N. Michigan Avenue, Chicago, Illinois). c) A Decent Burial — a 12-1/2 min color film put out by the Caterpillar Tractor Company, and deals with the proper operation of a sanitary landfill (Advertising Division, Caterpillar Tractor Company, Peoria, Illinois). d) The Eternal Harvest and The Endless Search — two films on loan by the Institute of Scrap Iron and Steel, which are concerned with the work of the iron and steel industry in recycling solid wastes materials (Institute of Scrap Iron and Steel, 1729 H Street, N. W., Washington, D. C. 20006).

The following field reports are given: a) A professional awareness campaign in Broome County, New York. b) Winning support for improved collection in Tucson, Arizona. c) Mobilizing community resources to promote public acceptance in Madison

County, Alabama. d) Using leadership and example to win support in Waukegan, Illinois. e) The direct attack in Baltimore County, Maryland. f) Overcoming opposition to a sanitary landfill site in Hamilton, Ohio. g) Stimulating involvement through humor — Kennebunkport, Maine.

"Solid Waste Management. 9. Personnel"
National Association of Counties Research Foundation, prepared for the Bureau of Solid Waste Management of the U. S. Public Health Service, no date (distributed, 1969)

This, the ninth in a series of guidelines for local governing bodies, is concerned with the personnel involved in any solid wastes management system. In a chapter on personnel practices are discussed recruitment, compensation, working conditions and safety, and labor-management relations. The section on training programs covers local, state, federal, and private applications. Selection and payment are the subjects dealt with in the section on consultants. Three field reports are given, the first under the heading "providing personnel for a growing solid wastes system" (DeKalb Company, Georgia); the second is termed "a continuous safety program" (National Disposal Contractors, Inc., Barrington, Illinois); and the third is entitled "a proposed safety and merit program" (Wichita Falls, Texas).

Collection and disposal employees should be screened to make certain they are qualified. To recruit and retain qualified men, wages must be comparable to or better than those paid for similar work in private or public agencies. (Underlining by this editor.) "Fringe benefits, including hospitalization, retirement, and uniforms should be provided." "All workers should be carefully trained to perform their jobs safely and efficiently. Solid wastes collection is one of the most hazardous of occupations, and local governments are responsible for protecting their employees." (Ed. note: The same applies to private collectors and their employees.)

Elected governing board members should make provision for the proper handling of employee complaints and suggestions, and they must develop policies and procedures for dealing with employee unions.

"In setting up a new solid wastes system, the first step is to hire a competent administrator to coordinate planning efforts and work with consultants."

Steps in choosing a consultant are: "1. Elected officials appoint temporary selection board. 2. Firms submit qualifications. 3. Board evaluates consultants' qualifications. 4. Board investigates consultants' past projects. 5. Board interviews prospects. 6. Consultants are ranked in order of preference. 7. Fees are negotiated. 8. Consultant is engaged." Any state association of registered professional engineers can supply a list of qualified engineers. Other sources of lists are: 1. American Institute of Consulting Engineers, 345 E. 47th Street, New York, New York 10017; and 2. Consulting Engineers Council, 1155 15th Street, N. W., Washington, D. C. 20005.

"Solid Waste Management. 10. Action Plan and Bibliography"
National Association of Counties Research Foundation, prepared for the Bureau of Solid Waste Management of the U. S. Public Health Service, no date (distributed, 1969)

The tenth and last publication in a series of guidelines for local governing bodies contains both guidelines and a bibliography containing 67 references. In the introduction are discussed the problem and the local government's role, and a summary of the guides. A series of sections follow which are discussed in the order given, viz., "What Should Local Government Do?"; "What Should State Government Do?"; and "What Should the Federal Government Do?"

To the question "what should local government do?" are given a series of 25 steps, the listing of which would be too long to fit within the format of this report. The list of activities pertaining to the state government is less extensive. The first step is for the state to provide comprehensive enabling legislation to manage solid wastes in coordination with other environmental programs. Second, a state agency responsible for solid wastes management should be established. Third, a statewide comprehensive solid wastes management plan should be prepared in consultation and coordination with local government. A fourth activity is to provide technical and financial assistance to local solid wastes management programs. The fifth activity is to offer training to local government and private industry in solid wastes management. Finally, the state should permit and encourage cooperation among local governments in establishing areawide solid wastes management systems.

Regarding the activities recommended for the federal government, first and foremost, it should continue financial and technical assistance to state and local governments. It should conduct research on all aspects of solid wastes management. It should promote national awareness of the necessity of maintaining and improving the environment through proper solid wastes management. Innovation in design and operation should be publicized and encouraged. Training in solid wastes management should be accomplished. Finally, the federal government should set an example for state and local governments by practicing good solid wastes management in all federal installations.

REFUSE PRODUCTION (GENERATION)

General

"Systems Analysis for Solid Waste Disposal by Incineration"
FMC Machinery/Systems Group, Engineered Systems Division, FMC Corporation, Santa Clara, California 95052, prepared for the City of San Jose and the County of Santa Clara, Project 75291, Document R-2697, 1 November 1968

The report deals with information gained in a survey of solid waste sources and quantities in Santa Clara County. In it, projections are made of the annual solid wastes quantities expected in the years 1970, 1980, and 1990 by source and geographic location. Potential incineration facility sites were selected for system cost and environmental evaluation. On the basis of estimated hauling costs, a final ten disposal system configurations were selected for estimating cost evaluation and combined (or system) cost evaluation. During the solid waste system survey, a survey was also made of resource recovery processes as possible supplements to the incineration disposal system.

By 1970 the annual solid waste production in the survey area is expected to be 3.4 million tons, and over 13.8 million cu yd (noncompacted). The survey of resource recovery processes indicated that caution should be exercised in any attempt to recover materials from solid wastes after reaching disposal sites.

The detail into which the report goes is indicated by the following random listing of subjects covered in the list of tables: a) Multipliers for wastes from residences, highways, neighborhood parks, metropolitan and regional parks, schools, colleges, and for demolition and construction debris. b) System cost evaluations for 1970, 1980, and 1990. c) Rubbish multipliers for large manufacturing concerns. d) Manufacturing processes solid wastes multipliers. e) Solid wastes multipliers for certain commercial sources. f) Multipliers for tree and vine waste production. g) Animal waste production multipliers. h) Various forecasts on wastes accumulation. i) Haul times to various disposal sites.

Baffa, J. J. and N. Bartilucci
"Bulky and Demolition Wastes"
Report on studies on oversize waste disposal conducted in part in connection with the New York State Solid Wastes Program, and in part as a joint venture with the consulting engineering firms of Alexander Potter Associates, M. Rosenblatt and Sons, Naval Architects, and John J. Baffa Consulting Engineers, 140 N. Cedar Street, New York, New York 10006, 1969

The data and considerations presented in the paper are based upon two engineering planning studies on oversize waste disposal made for Suffolk County, New York (population, one million) and for the city of New York (population, eight million).

Bulky wastes as defined in the paper are those which cannot be collected in the normal packer trucks; are not accepted at incinerators without preparation for burning because they are too large to fit into charge openings, or do not burn within the residence time afforded by grate travel, or burn too slowly, or burn with black smoke, or produce noxious gases; and cannot be compacted at landfills. Oversize items have a bulk in excess of 10 cu ft or a single dimension exceeding 5 ft. Slow-burning timber usually is in excess of 12 in. in diameter. Large loads of grass clippings as well as large loads of rejected agricultural crop rejects markedly lower furnace temperature and thus come under the category of problem wastes delivered in bulk. Demolition debris are considered as being bulky wastes.

Characteristics of Bulky Wastes: a) Residential bulky waste is 70 percent burnable. Of this 70–75 percent is shreddable. The unburnable portion is 80 percent unshreddable. b) Commercial bulky material is estimated to be 65 percent burnable. Of this fraction, 95 percent is shreddable. The unburnable material is 95 percent unshreddable. Weight per unit of volume in terms of lb/cu yd of various components of bulky wastes are: household bulky, 166.4; tree cuttings, 229.3; wood (pallets, driftwood, etc.), 356.0; construction wastes (burnable), 430.8; mixed construction waste, 269.2; rubbish and street dirt, 423.5. The overall density (lb/cu yd) equals 321.1 lb.

In New York City, the generation of bulky wastes is increasing at the rate of 8 percent per year. The institutional portion of bulky wastes increased 11 percent during the past three years. Commercial and industrial bulky wastes increased 4-1/2 percent per year. Variations in bulky wastes deliveries were quite large; thus the variation in amount of delivered construction and demolition wastes ranged from 140 percent in terms of maximum/month to 750 percent in terms of maximum/eight-hour shift. The variation for residential bulky junk ranged from 140 percent on a monthly basis to 250 percent on an eight-hour shift basis. For charitable and institutional wastes the variation was from 120 percent on a monthly average to 300 percent on an eight-hour shift basis. The variations in commercial and industrial wastes were not as extensive as those for the above two wastes – ranging from 115 percent when averaged per month as compared to 250 percent.

The averaged production of commercial bulky wastes in Suffolk County was 720 lb/capita-yr. The range of values was from 450 lb/yr (5 communities) to 1,000 lb/yr (5 communities). Pounds per capita per year of residential bulky wastes averaged 250 lb, and the range of output was from 200 lb/capita-yr (5 towns) to 300 lb/capita-yr (5 towns).

It was found that it takes twice as many (240) man-min/ton to collect bulky wastes as it does for ordinary refuse (120 man-min/ton).

Capital costs for hogging bulky refuse are $6,780/ton-day (installed capacity) exclusive of land; for baling, $550/ton-day exclusive of land; for incineration, $7,900/ton-day exclusive of land; and for landfilling, $2,500/ton-day including land for bulky material mixed with ordinary refuse. The operation costs per ton processed for each of these items are in the order named: $2.50, $0.60, $4.20, and $1.34. The baling operational cost includes placing the bales in fill.

Packaging

Editorial Staff
"The Waste-High Crisis"
Modern Packaging, 41(11):102, November 1968

The article is the result of a year's research by Modern Packaging editors in the U. S. and abroad in which they interviewed industry executives; federal, state, and local officials; and members of research institutions. The problem was to find answers to a series of questions concerned with the role of packaging in aggravating the refuse management difficulties, the assistance of the packaging industry in minimizing littering made possible through the use of "one-way" containers (termed "packaging pollution") and the development of degradable or easily disposed of containers. Traditionally, packaging has concerned itself with containers only during the period of use. A result is more container per unit of product and greater durability than would really be needed. A second result is that packages become more complex, more resilient, smaller (which means more packaging material for the same amount of product), and more durable. (See "Role of Packaging in Solid Waste, 1966 to 1976," published by the U. S. Department of Health, Education, and Welfare, a study by Midwest Research Institute (MRI), Kansas City, Missouri.) The article tells of a 17-page table in the MRI study in which every container form and packaging material is rated with respect to ease of disposal by conventional disposal methods and salvage. Disposal resistance was measured on a scale of 100 (no resistance) to 500 (unsuitable). The overall average in 1966 was 132. The predicted average for 1976 was 148. Per capita consumption of packaging is surpassing population growth. In 1958, the per capita use was 404 lb; in 1966, 525 lb; predicted for 1976, 661 lb. Expressed in tons, the amount in 1966 was 51.7 million tons, of which 46.5 million tons were discarded. The amount represented 13 percent of all wastes, excluding those from agriculture, mining, demolition debris, and junked automobiles. The expected total for 1976 is 73.5 million tons, of which 66.2 million would be handled as solid wastes. The remainder would be salvaged and recycled. The costs of collecting and disposing of these wastes are impressive:
a) In 1966 — $419 million (cleaning up litter cost an added billion dollars).
b) In 1976 — $595 million. During the ten-year period, $135 to $190 million will have to be invested in new collection vehicles to pick up the increase. Litter (discarded bottles, etc.) costs 60 to 90¢ per item to pick up.

Legal: A total of 35 ban-the-bottle/can bills were introduced in various state legislatures in 1967; none were passed. In 1953, Vermont passed an outright ban on beer and ale and no-return bottles. It was repealed in 1957, because the ban had not lessened the quantity of roadside litter.

Recommendation: Design packages for their period of disuse. The idea is to design containers that self-destruct, rapidly degrade, or which can be reclaimed and processed into new containers or by-products.

Progress: Dow Chemical and Continental Can claim they can produce self-destruct plastic bottles. Eastman Chemical has more than one patent on self-destructing plastics. The trigger is a narrow wavelength in the ultraviolet light spectrum.

Other Approaches: a) Make the packaging material attractive to soil microorganisms. b) Water-soluble packaging. c) Soluble-edible film of high-amylose cornstarch or glyceryl triacetate. d) Other soluble substances — provinyl alcohol and five or six other polymers.

Reuse: a) Either as raw material for other containers, or burned for heat energy. b) Ground glass for cullets in the glass industry, or reflective material in paint, in textural plaster, and an aggregate in cement.

Governmental Policy: Stress reuse.

"The Role of Packaging in Solid Waste, 1966-1976. Part I — The Outlook for Packaging, 1966-1976"
Midwest Research Institute, 425 Volker Boulevard, Kansas City, Missouri 64110, prepared for the Solid Wastes Program, Public Health Service, Cincinnati, Ohio, 22 March 1968, (Review copy); (Issued in 1969 as Publication SW-5C under authorship of A. Darnay and W. E. Franklin by the U. S. Department of Health, Education, and Welfare, U. S. Public Health Service, Bureau of Solid Wastes Management, Rockville, Maryland)

In this report an overview of packaging is presented first, followed by an analysis of general trends affecting the future of packaging as a whole. Thereafter, separate sections are devoted to each basic packaging material category. Finally, the forecasts are summarized in the concluding section of the report. Chapter headings in the report are: I. Introduction. II. An Overview of Packaging. III. Basic Trends in Packaging. IV. Paper and Paperboard. V. Glass. VI. Metals. VII. Plastics. VIII. Wood. IX. Textiles. X. Miscellaneous Packaging Materials. XI. Summary.

Overview: Packaging is a service activity intrinsically connected with the mass distribution of goods in the U. S. marketplace. Packaging as a service activity touches virtually all aspects of the nation's economic life. In 1966, the public, commercial organization, and industry spent in excess of $25 billion on packaging — 3.4 percent of the Gross National Product. Of this, $16.2 billion were spent on packaging materials; $225 million on machinery to form the packages; and $9 million in value added to the materials by the package manufacturers.

Role in Solid Wastes: a) Most of packaging makes only a single trip; i.e., waste after only one use. b) The $16 billion materials purchased in 1966 weighed 46 million tons. c) About 90 percent was discarded, and equalled 12 percent of the total U. S. wastes. d) Important factor: The package manufacturer almost always combines dissimilar materials to make a package. e) About 77 percent of packaging is for consumers; the remainder is for industrial and commercial uses. f) The packaging market accounts for 18 to 20 percent of all plastics sold on a tonnage basis. (The polyvinyl plastics play only a minor role in plastics.) g) Paper and paperboard dominate the packaging materials field, accounting for 55 percent of all packaging in 1966. About half of the paper and paperboard output is used for packaging, i.e., 46.6 million tons in 1966.

Glass: a) Production has increased from 20.2 billion units in 1958 to 29.4 billion units in 1966. b) For food products — 10.8 billion units; for beverages — 12 billion; for drugs and cosmetics — 5.8 billion; industrial and household chemicals — 0.8 billion. c) About 2.7 billion are returnable units (average, 19 trips/yr). Use of 2.7 returnable units is the equivalent of 75 billion nonreturnable units. d) By 1976, nonreturnable containers will have virtually replaced the deposit-type bottle, and since each returnable bottle makes about 20 round trips before it is retired, each returnable bottle eliminated means the production of 20 nonreturnable containers, glass or metal. e) Weight of glass containers in 1966: 16.5 billion lb — increases at 3.7 percent per year.

Metals: 1966 — 14.3 billion lb of metal converted into packages, 75 percent of which became cans. The annual increase should be 1.6 percent. Of this percentage, aluminum usage will increase at 15.6 percent per year.

Plastics: In 1966, 2.2 billion lb were used in packaging. Formed plastics will amount to 1.4 billion lb in 1976, representing an annual increase of 11.2 percent. Polyvinyl chloride is on the threshold of a breakthrough. The increase in its use for bottles was from 5 million lb of resin in 1965 to 12 million lb in 1966. It will be the competitor for glass.

Wood: Wood represents only a minor segment of all packaging materials — 8.6 percent (7.9 billion lb) of total weight of all packaging materials. It is mostly used for agricultural and industrial packaging.

Textiles: Its use is declining at about 5 percent/yr; i.e., from 804 million yd in 1966 to 480 million in 1976. The major use is for bagging.

Summary: The per capita use of packaging materials will increase from 525 lb in 1966 to 661 lb in 1976.

"The Role of Packaging in Solid Wastes, 1966-1976. Part II — The Disposability of Packaging Materials. Part III — Mechanisms for Mitigating Problems Caused by Packaging Materials in Waste Disposal"
Midwest Research Institute, 425 Volker Boulevard, Kansas City, Missouri 64110, prepared for the Solid Wastes Program, Public Health Service, Cincinnati, Ohio, 22 March 1968, (Review copy); (Issued in 1969 as Publication SW-5C under authorship of A. Darnay and W. E. Franklin by the U. S. Department of Health, Education, and Welfare, U. S. Public Health Service, Bureau of Solid Wastes Management, Rockville, Maryland)

Part II: The objective of Part II of the report was to evaluate projected qualitative and quantitative changes in packaging materials from the waste disposal point of view. The analysis was not an easy task because of the paucity of information and an almost complete absence of precedents and guidelines at the starting points. Three aspects of disposability are discussed: 1) quantities of materials to be disposed of; 2) collection problems associated with these materials; and 3) the resistance of the materials to processing by present disposal techniques.

Interesting facts and observations: a) About 90 percent (41,000,000 tons of all packaging materials produced) end up as waste (1966). Packaging wastes constituted (1966) about 18 percent of residential wastes and 7 percent of industrial wastes. b) By 1976, it is expected that packaging wastes (42 million tons) will be about 19 percent of the total wastes. The cost of handling these wastes will exceed $9/ton. c) Per capita consumption in 1966 was 467 lb; in 1976 it will be 584 lb. d) Per capita gains in packaging materials consumption from 1966-1976 in pounds will be:

Material	Per Capita Increase — 1966-1976	
	lb	% of 1966 Volume
Plastics	17.0	152
Paper	76.6	30
Glass	23.4	28
Metals	3.1	4

e) Compactibility was made one of the criteria for evaluating collectability: A fully compacted (i.e., no air spaces remaining) 1966 ton of packaging material would average 29.9 cu ft; the 1976 ton will take up 31.2 cu ft. (However, complete densification cannot be attained by compaction.) f) Expressing the relative technical difficulty of compacting various packaging materials in the period 1966-1976 on a scale of 100 to 500, the following may be noted: the average compactibility of packaging materials would equal 196 in 1966 and 197 in 1976. (An appendix is given in which are listed the compaction and resistance indices of a wide variety of packaging materials.) g) The relative ranking of each major category in the years 1966-1976 are in the order listed, beginning with the most easily disposed of: Paper and paperboard, textiles, wood, plastics, metals, glass. h) A discussion is given of the amenability of packaging materials to the major types of disposal. With respect to incineration: all packaging materials, except glass and metal containers, will burn; and a ton of packaging materials containing representative proportions of all materials will leave a residue of 705 lb after incineration. Of this, 90 percent will be accounted for by metal and glass containers. Because of its tendency to liquefy, glass constitutes a problem, especially at incineration temperatures above 1300°F — plastics do so at lower temperatures. i) Densities of some of the more common packaging materials in terms of lb/cu ft are as follows: aluminum, 168; steel, 480; glass, 156; paper, 44-72; cardboard, 43; wood, 37; plastics (average), 71. j) In cu ft/ton of material: wood, 54; cardboard, 46.5; paper, 27.7-45.4; plastics, 19.4-35.7; glass, 12.8; aluminum, 11.9; steel, 4.1. k) Salvage of packaging wastes is unattractive because of their mixed contents. Separation and cleansing would be too expensive. Quality and uniformity are becoming increasingly important to the uses of scrap material. The market for scrap tin cans is in copper manufacturing, and hence is limited largely to the southwest. To be a good source of supply of secondary aluminum, a city would have to supply between 100,000 and one million lb of aluminum/month. (Miami at best could produce only 4,000 lb/month.) The picture for aluminum will change by 1976 because of an increase in the use of aluminum and a reduction in its magnesium content. Although in terms of percentage recovery, the reuse of paper is declining; in terms of tonnage, it is gaining. The increase has been from 8.8 million tons in 1956 to 10.2 million tons in 1966. So far as packaging material is concerned, only corrugated boxes play a significant role in reuse. About 20 percent of the 12.5 million tons of paperboard produced in 1966 was reused.

Part III: In this section are discussed five types of mechanisms, viz., 1) research and development; 2) eductional effort; 3) incentive and subsidy programs; 4) taxes; and 5) regulation. These mechanisms are evaluated as possible means to: a) Reduce the quantity of packaging materials used. b) Reduce the technical difficulties involved in processing packaging waste. c) Reduce the destruction of valuable natural resources. Two types of taxes should be considered: A use tax and a deterrent-type tax. The purpose of the tax would not be to reduce packaging production, but rather to pay for disposing of the wasted material. The deterrent tax should be limited to the discouragment of the use of objectionable types of packaging materials.

Barriers to action in packaging controls are: a) Technoeconomic — large number of materials and production technology. b) Socioeconomic — pervasive nature of packaging and self-service merchandizing. c) Cultural — free enterprise philosophy. d) Demographic — population growth, affluence, and desire for convenience.

Darnay, A. J., Jr.
"Throwaway Packages — A Mixed Blessing"
Environmental Science and Technology, 3(4):328, 1969

This article is based on a report on packaging issued earlier by the Midwest Research Institute (see abstract for "The Role of Packaging in Solid Wastes, 1966-1976," report by Midwest Research Institute).

In 1966, 46.5 million tons of packaging material was discarded, and subsequently collected at a cost of at least $373 million. In 1966, the per capita discard of packaging materials was 121 lb greater than that in 1958. In 1976, the discard will be 136 lb/capita more than it was in 1966. By 1976, the packaging consumption will be 73.5 million tons/yr. About 90 percent of the total packaging production enters the waste stream; the remainder is recycled. During the 1966-1976 period the increase in discarded packaging materials will increase by 42 percent. Forecasts indicate that packaging material will be less dense in 1976, and consequently will require more space.

In a table showing the relation of packaging to aspects of solid waste problems, the author suggests automation of collection and on-site volume reduction and disposal as a means of alleviating the impact made by packaging on refuse collection. The contribution of packaging to the waste processing problem comes from the nondegradability of the material by natural processes. A threefold solution is offered: 1) Retool the financial support for waste processing. 2) Develop new disposal technology. 3) Modify packaging materials to make them more degradable. The aesthetic blight from littering, of which packaging is a major component, can be minimized by intensive antilitter publicity, rigorous enforcement of antilitter laws, and by providing economic incentives for returning containers.

The author feels that one solution to the solid waste problem, and specifically with respect to the contribution in the form of discarded packaging, would be a more sophisticated system of waste disposal than is now available. To achieve this goal, an increase money outlay is needed. He feels that the average householder's expenditure of $1.75/mo for waste disposal should be increased to match more closely the $10/mo spent by him for water services.

Salvaging of the materials in packaging is not a promising avenue of recycling the natural resources tied up in packaging. The consumption of secondary paper fiber is trending down when, to anticipate shortages in the long term, it should be trending up. The reason is that the costs of handling secondary paper are rising partly because of rising labor costs and partly because wastepapers are more and more contaminated. To make a ton of cullet (broken glass of uniform color) from waste glass, a dealer has to handle between 1900-4600 bottles; whereas for $15 he can obtain a ton of the best.

He concludes by stating "There is no doubt that the contribution of packaging to solid waste problems cannot be assessed without also passing some judgment on current practices for handling solid wastes. Large inputs of packaging materials into the solid waste system cannot be blamed for all the distress signals which are perceptible. Rather, the problems illustrate that the entire field of solid waste handling is a neglected area and should now be overhauled."

"Mayor of New York Joins in Battle of Bottles"
Solid Wastes Management/Refuse Removal Journal, 12(6):18, June 1969

The widespread use of the nonreturnable beverage bottle is creating a problem of major proportions for the sanitation industry. In addition to the problem of where and how to dispose of the bottles, there is the one of economics. In New York, it costs 30¢ for each bottle to be picked up, or seven times the average cost of producing such a bottle. Estimates are that within two years the production of nonreturnable bottles will amount to 12 billion, or 33 million/day.

With respect to collection, many refuse collection trucks have been badly damaged by crews unacquainted with the extra heavy weight of broken glass. Compaction blades have been seriously marred by the abrasive action of heavy glass loads as well. So far as public welfare is concerned, the advent of the nonreturnable bottle has been accompanied by an increase in the incidence of broken glass on streets, beaches, and in parks. The latter has prompted Mayor Lindsay of New York to send a letter to the president of a nationwide soft drink company, urging him to bring about a return to the "deposit" bottle. An additional advantage of such a return would be that collecting and returning these bottles could be a source of income to the youth in underprivileged areas.

REGIONAL REPORTS AND CASE HISTORIES

"One Way to Avoid Refuse Disposal Problems"
The American City, 83(4):26, April 1968

The town of Middletown, Ohio, is anticipating the increase of refuse disposal problems by making efforts to provide for areawide refuse disposal facilities. The town has joined other interested municipalities in Butler County in a countywide study to determine available sites for landfill operations and to subsequently acquire the land and set it aside. Under this procedure, prospective property buyers would know where a landfill site is planned.

Peterson, R. J. and R. G. Glenn
"Report for the Des Moines Metropolitan Area – Collection and Disposal of Solid Waste"
Prepared by Hennington, Durham, and Richardson, Inc., and the engineering firm of Veenstra and Kimm; delivered to Mr. Leo L. Johnson, Project Manager, City Hall, Des Moines, Iowa 50309, 16 May 1968

The preparation of the excellent study and report was financially aided in part by a grant from the U. S. Public Health Service. The existing population of the study area is estimated at 288,000, and is expected to reach 361,000 by 1980 and 418,000 by 1990. The total amount of all solid wastes presently being disposed of amounts to 1,016,000 cu yd after compacting (562,000 tons) per year. During the years 1967 through 1990, the accumulation is estimated to be 29,500,000 cu yd or 15,870,000 tons.

Subjects covered ty the report in Part I are: scope, description of study area, existing solid waste facilities – i.e., collection and disposal, population, and land use. Part II is concerned with a survey of the wastes and includes a commercial and industrial survey, a residential survey, and a series of special studies dealing especially with junked automobiles. Additional subjects of Part II are special tree wastes; packing house wastes; sewage solids; landfill surveys; volume, weight, and vehicle analyses; origin of landfill wastes; and present and future quantities of various types of wastes. Collection of solid wastes receives attention in Part III. Subjects treated in this part are general comments on collection, basic collection systems, scope of collection service, description of existing collection systems, analysis and recommendations for existing systems, cost comparisons, and future collection systems. The overall concern of Part IV is the disposal of solid wastes. In it are present general comments, a description and evaluation of available methods, a recommended disposal method, a discussion of existing disposal operations, suggested interim improvements to existing operations, ways of financing interim improvements, a selection of general areas for new sanitary landfill sites, a selection of specific parcels of land, a discussion of the development of a site in the southwest area, and a presentation of landfill cost estimates. The subject matter of Part V is the Metropolitan Solid Waste Agency. This part is concerned with discussing ways of making the Agency functional. Consequently, it treats of general aspects, the legal basis, the formation, operation, and financing of the Agency, and lists the interim activities. Alternate collection by contract is discussed.

Johnson, D. E.
"Road Commission Operates County Refuse Disposal Sites"
Public Works, 99(6):126, June 1968

The task of organizing a countywide system of operating disposal sites in St. Clair County, Michigan, was delegated to the Road Commission of that county. The generally unsatisfactory and disorganized approach to disposal and operation of disposal sites served as the motivating force in establishing the new setup. A 120-acre parcel of land was acquired. About one-half of the parcel consisted of an open-pit mine 30 ft deep.

All types of wastes are accepted, i.e., from domestic to industrial. (Exceptions are fly ash from Detroit Edison's coal-burning operation and junked automobiles.)

Operation: Cover is obtained from the bottom of the excavation. Cover for the second lift is obtained from the sides of the pit.

Legal: Written contracts are required for all cities, villages, and townships wishing to use the facility. Proof of residency in a contracted jurisdiction is required for public dumping (i.e., by individuals).

Fisher, F. E.
"We Put Progress Above Politics"
The American City, 83(7):13, July 1968

The people in the state college area in Pennsylvania discarded the idea that political boundaries are sacrosanct, and working with five other governmental agencies solved a difficult refuse collection and disposal problem. The action meant converting the borough's sanitary landfill to receive refuse from the region. However, it does not have to worry about the scourge of 20th century urbanism, namely, the open dump.

Development: To eliminate intercommunity rivalry, a Central Regional Planning Commission was established, which in turn developed a regional comprehensive plan. The development of the plan led to the recognition of the solid wastes problem. As a result, a Regional Sanitary Landfill Study Committee was appointed and was charged with the task of collecting information and providing recommendations. As was to be expected, all members of the region received the committee's report warmly, that is, as recommended by the committee, except the township in which the fill would be located. But the affected township people were won over by the argument that the more intensively their facility was used, the sooner would come an end to their hosting of the region's refuse disposal activities. Of course, the other members had to contribute in keeping with their share of the costs.

Collection was continued under private ownership but under conditions imposed by the region's governing body.

The key document to the establishment of the regional program was the uniform ordinance enacted by each of the five participating townships: a) It forced the property owner to patronize the licensed collectors. b) It made it unlawful to haul, collect, remove, and dispose of solid wastes without a license. c) It provided for revocation of the license upon failure of the contractor to comply with the provisions of the ordinance or any of the regulations of the Pennsylvania Department of Health. Revocation by one township meant automatic revocation by all. d) Before a license is issued, the contractor must: submit an application with the proper fee; secure a performance bond in the amount of at least $12,000; and provide the townships with certificates of public liability insurance in an amount not less than $100,000, and property damage not less than $25,000. e) It established a maximum fee schedule. f) It established regulations which must be followed by the hauler. g) It provided that refuse be disposed of only at sites approved and designated by the township supervisors, and that the contractor bear the cost of disposal, stipulating that he pay this amount six months in advance.

Other provisions are listed which are too detailed to be repeated here.

<u>Costs</u>:	Year 1:	Personnel	$16,470
		Trenches	7,000
		Equipment repairs, amortization, etc.	8,500
		Scales and weighhouse	2,750
		Supervision, engineering and administration	3,000

Disposal costs – about $1.33/ton

Gray, A. C., Jr.
"Solid Waste Disposal at State University of New York, Albany Campus"
Thesis submitted in partial fulfillment of the requirements for the degree of Master of Engineering, Rensselaer Polytechnic Institute, Troy, New York, August 1968

The thesis deals with an investigation of the problem of refuse disposal on a university campus. In the course of the study, some 125 colleges and universities were contacted. Only about half returned the questionnaire. Where available, information is reported on quantities of refuse handled and the costs involved. Alternate plans for refuse disposal at the Albany campus are discussed, and cost calculations for these methods are made.

Two main general types of refuse are produced at the Albany campus, viz., office and dormitory trash, and kitchen or food service garbage. Approximately 13,140 lb of trash and 28,405 lb of refuse were produced/day in 1968.

Original plans called for handling the trash produced by two of the buildings (Dutch and Colonial Quadrangles) by way of the "Somat Process." (The Somat process involves passing the refuse through a pulping machine to produce a slurry, and transporting the slurry by pipeline to the eventual point of disposal, where the solid material is discharged and the liquid vehicle – water – is returned to the machine for reuse.) The process did not function properly because the trash contained many materials not compatible with the process. The cost of removing the material would have negated the benefits of the process. Consequently, trash is collected and disposed of by conventional means. The garbage is handled through three Somat units located in the kitchen of each dining facility. These units are connected by a pipeline to an extractor which discharges into a Dempster container. The garbage is disposed of in a landfill dump at Menands, New York. Cost analysis indicates that a disposal system incorporating Somat units costs three times that of a system employing compactor trucks only.

Reported costs of refuse removal ranged from $0.30/cu yd (University of Oaklahoma) to $4.00/cu yd (University of North Carolina).

The cost of using the service for Somat effluent and incinerating the remaining refuse in a central incinerator at the Albany campus would be $7.38/ton; composting all of the wastes would come to $8.00/ton; discharging Somat effluent to sewers and incinerating trash in building incinerator, $4.88/ton; disposing of all of the wastes in a central incinerator, $9.90/ton; and disposing of all refuse to a landfill, $4.67/ton.

"Regional Solid Wastes Studies Receive New Impetus"
Environmental Science and Technology, 2(9):653, September 1968

The following news items were given in the "Environmental Currents" section of the subject journal: 1) A contract was made by the New York State Pure Waters Authority with Metcalf and Eddy (New York) for the latter to make a study aimed at the establishment of a solid waste management system to meet the needs of Westchester County (New York) through 1980. The contract calls for the identification of current solid wastes by source, quantity, and type; for the evaluation of existing techniques and capabilities in the United States; and for the review and updating of actual and predicted quantities of solid waste. The study will begin with an investigation into the feasibility of rail haul transportation of the wastes to potential landfill sites. 2) A similar study was the subject of contract between the Kansas City Metropolitan Region and the Environmental Systems Division of Aerojet-General Corporation and the consulting firm of Black and Veatch (Kansas City, Missouri). This contract calls for the development of an optimized computer program for the disposal of solid wastes.

Armogida, S. A.
"Report on Solid Waste Management and Systems in San Mateo County"
Report prepared for the Board of Supervisors of San Mateo County, California, September 1968

In San Mateo County, approximately a total of 27,500,000 tons of municipal solid wastes will have to be disposed of between now and the year 2000. The disposal of this refuse will be best accomplished by way of sanitary landfill – interposing, where necessary, transfer stations and public rubbish points. The total land area that will be required will be about one square mile less than 1/4 of 1 percent of the county area. The cost of the final disposal operation itself will approach $35,000,000. Including transfer and haul costs, it will increase to about $62,000,000. Disposal by incineration would come to $178,000,000. Collection costs will total $350,000,000.

The report relates case histories which show the evils of the fragmented approach to wastes management. For example, the status of a very important disposal facility is quite uncertain, due to divided jurisdictional control and lack of agreement between a disposal district and a city. It also emphasizes the importance of long-time planning for the location of sites, the urgency of rigid zoning to protect these sites for disposal, and the desirability of purchasing the sites as soon as possible. A major reason for the urgency is to keep homes from being built in these areas. As Mr. Armogida points out, the construction of only a few homes in or adjacent to a site planned for disposal is enough to jeopardize that site as far as disposal is concerned.

"In considering the proper role of government in an evolving system of waste management, the many difficulties still to be encountered by the elected officials in discharging their responsibilities as policy-makers and funding authorities have not been overlooked. A sound disposal system requires public understanding and

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support of their elected representatives. Mutual agreement must be achieved in order to effectively control operations of the disposal system at local governmental level under regional standards."

Wilson, D. G.
"Summer Study on the Management of Solid Wastes"
Urban Systems Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, Final Report, Volume 1, September 1968

The publication reports the work done by one of three study groups working at M.I.T. during the summer of 1968. The topic selected by the group was the broad one, "The Management of Solid Wastes." The approach to the study was based on the expertise and interests of the individual members of the study group. In line with this approach, the group takes care to point out in the section "Purposes and Scope of the Study" that none of them "individually had broad experience of the whole field of waste management." To quote them further: "We did not pretend to be able to, nor did we wish to, address ourselves to the whole field. We decided to investigate those areas of solid waste management in which, individually or collectively, we felt able to make some contribution. We felt that we might, along the way, be able to point out other areas, outside our immediate skills, where work needed to be done." These qualifications should be kept in mind when reading the report and in evaluating the conclusions given in it.

The report covers three areas: immediate recommendations to cities and towns; future organization and procedures for managing wastes; and promising areas of research. A second volume (not available to this reviewer) contains the "raw trip reports and meeting reports in the form in which they were issued during the study." The first volume has appendices in which are given individual views and recommendations not necessarily shared by the study group as a whole.

The study group came to the not unexpected conclusion that the solid waste field presents "a picture which was confused for a large number of reasons." Apparently, some waste treatment systems are emerging which may prove to be better than the traditional landfill and incineration processes. The latter two also are subject to much improvement. The matter of refuse collection needs much attention. The group concludes correctly that there is no panacea; "great improvements in the solid waste management scene will arise simply by the use of high-quality traditional engineering coupled with sound economics in details as well as in the larger scale."

The group strongly recommended that "there be brought into being by some means large firms, groups, consortia, or utilities which can handle waste management as a service to municipalities on a large scale, with all the attendant efficiencies which large-scale operation implies."

Zaun, W. L.
"The Orange County Refuse Disposal Program"
Orange County Road Department, A. S. Koch, Road Commissioner, and County Surveyor, prepared for the Orange County Board of Supervisors, September 1968

The present report was written to review a Master Plan of Refuse Disposal adopted on 4 November 1959. The intent of the review was to determine what changes, if any, are required to meet the ultimate refuse disposal requirements of Orange County as determined at this time.

The nature of the contents of the report perhaps is best illustrated by its table of contents, which is as follows: Section I – Purpose of Report;

Section II — The Present Situation, subheadings: Disposal Policy, Collection Practice, Master Plan Studies, Master Plan Facilities Now in Operation, and Description of Facilities; Section III — Orange County's Ultimate Needs; Section IV — Methods of Disposal, subheadings: Incineration, Composting, Sanitary Landfill, In Summary; Section V — The Cost of Transfer, In Summary; Section VI — Review of Unit Costs, subheadings: Sanitary Landfill — Operating Costs, Amortization, Maintenance, and Other Costs; Transfer Stations — Unit Costs, and Summary of Unit Costs; Section VII — Total Capital Investment; Section VIII — Summary and Recommendations; Addendum: I. The 1968 Situation, subheadings: Population and Waste Generation, Operation of the Refuse Disposal Program — Administration, Landfill Section, Transfer Section, Resumé of Annual Tonnage, and Resumé of Annual Operating Costs; II. The Future; Exhibit — Existing Disposal Facilities.

The plan calls for disposal of the wastes as a public activity, while collection is to be left to private enterprise. Costs for disposal are defrayed from the general revenue, i.e., by taxation. The disposal of approximately 2,200 tons of trash/day is presently being administered by the county's Refuse Disposal Division under the direction of the Road Commissioner. The Division includes a *Refuse Disposal Engineer, one Public Works Foreman III, two Public Works Foreman II,* twenty-six custodians and laborers, and fifty-nine equipment operators. The equipment complement consists of fourteen crawler tractors (30,000 and 35,000 class), two self-propelled earth movers, one steel-wheeled compactor, two motor graders, three packer-loaders, two power sweepers, sixteen truck tractors, and twenty-two sets of double trailers.

The present annual budget is more than $1,400,000. Of this, $740,000 goes for operation and maintenance of the disposal sites. This brings the present cost of disposal at the landfills to approximately $0.90/ton. The cost for operating a packer truck (average payload, 5.5 tons) ranged from $0.60 to $0.65/mile, including labor. The average cost/ton-mile (5.3 ton basis) was $0.114. A summary of estimated unit costs is as follows: a) Three Landfills: Operating costs (labor and amortization, operation and maintenace of equipment) — $0.47/ton; Amortization of capital investment — $0.05; Total Unit Disposal Cost — $0.52/ton. b) Four Transfer Stations: Station operation and amortization costs — $0.72/ton; Transportation costs — $0.92/ton; Total Unit Transfer Cost (excluding haul to transfer station) — $1.64/ton.

RESUMÉ OF ANNUAL OPERATING COSTS — 1965 THROUGH 1968[a]

Fiscal Year	Annual Cost			Unit Cost/Ton Waste Handled		
	Landfill	Transfer	Division	Landfill	Transfer	Combined in Place
1965-1966	$669,300	$ 671,600	$1,340,000	$0.57	$2.05	$1.14
1966-1967	659,200	911,600	1,570,800	0.57	1.98	1.35
1967-1968	771,800	1,106,300	1,878,100	0.42	2.30	1.02

[a]Costs include labor, equipment, materials and supplies, overhead, buildings, and capital projects.

Black, R. J., A. J. Muhich, A. J. Klee, H. L. Hickman, Jr., and R. D. Vaughan
"The National Solid Wastes, an Interim Report"
Presented at the 1968 Annual Meeting of the Institute for Solid Wastes of the American Public Works Association, Miami Beach, Florida, 24 October 1968, (U. S. Department of Health, Education, and Welfare, U. S. Public Health Service, Solid Wastes Program Brochure)

The data listings, reporting forms, and specifications for the survey were developed over a period of more than five months. To provide maximum flexibility in conducting the survey and recording results, three reporting forms were devised - one to report on the "Community" itself and the other two for disposal sites only. The Community Description Report covers four broad areas: storage, collection, disposal, and budget and fiscal. The Land Disposal Report and the Facility Investigation Report focus on description and evaluation of site, on quantitative data, and on fiscal data. The facility form also contains a separate section on the design features and operational characteristics of incinerators.

Thus far, 6,259 communities representing an estimated 92.5 million persons or approximately 46 percent of the total population of the U. S. have been surveyed.

Some facts and figures are as follows: Approximately 33 percent of the population lives in communities operating separate collection systems. Approximately 56 percent live in communities having combined collection, and 11 percent in communities operating both types of systems simultaneously. For systems with a combined pickup, 48 percent have once-a-week collections, 32 percent twice per week, and 20 percent at some other frequency. With separate collection systems, 61 percent have once-a-week collection, 29 percent twice per week, 3 percent at some other frequency.

One solid waste collector or driver is employed for every 590 persons. About 53 percent of these people are publicly employed. For the public sector, 75 percent were involved in household and commercial wastes collection, 5 percent in industrial waste collection, and 20 percent in street cleaning. In the private sector, 65 percent were concerned with collecting household and commercial wastes, and only 8 percent with street cleaning.

The data show that there is one compactor truck for each 2,100 persons, and other collection trucks, one for every 1,100 persons. Of the compactor trucks, 47 percent are public and 53 percent private. Of the other vehicles, 80 percent are private and 20 percent public.

AVERAGE SOLID WASTE COLLECTED
(lb/person-day)

Item	Urban	Rural	National
Household	1.26	0.72	1.14
Commercial	0.46	0.11	0.38
Combined	2.63	2.60	2.63
Industrial	0.65	0.37	0.59
Demolition, Construction	0.23	0.02	0.18
Street and Alley	0.11	0.03	0.09
Miscellaneous	0.38	0.08	0.31
Totals	5.72	3.93	5.32

The average community budget is about $1.42/person-yr for disposal activities, of which about 1/6 is for capital expenditures. For communities actually operating disposal systems, about $2.17/person-yr are expended, with 1/3 for capital expenditures. For collection activities, the national average is $5.39/person-yr, with 10 percent for capital expenditures. Collection budgets for community-operated collection systems average $5.60/person-yr for once-a-week collection and $6.82/person-yr for twice per week collection.

About 79 percent of disposal sites are publicly operated, and about 63 percent are owned by the public. Of the 6,000 sites surveyed, only about 6 percent were truly sanitary landfills. The total cost for landfill (operating plus amortized capital) was $1.05/ton. Inadequately operated fills averaged 70¢/ton. About 96 percent of the 142 incinerators in the U. S. are publicly owned, as are 76 percent of the 43 transfer stations and 59 percent of the 23 conical burners. The average daily input to incinerators built after 1950 is from 230 to 400 tons. Input to transfer stations averages 375 tons/day; and to conical burners, 41 tons/day. Approximately 8 percent of the total collected U. S. solids are incinerated. About 4 percent of the collected garbage is fed to hogs. The operating costs/ton for incinerators, transfer stations, and conical burners are $4.50, $1.10, and $1.60, respectively. Capital costs are $7,100, $1,100, and $1,700, respectively.

About $560 million/yr is needed to upgrade our current collection systems, $230 million/yr to eliminate the open dumps, and $45 million/yr to provide adequate incinerator capacity.

"Integrated Solid Wastes Management Project"
Solid Wastes Management/Refuse Removal Journal, 11(11):6, November 1968

This is another article on the "Fresno Study." [See the abstracts for "The Status of Solid Wastes Management in California" as reported in Public Works, 100(5):80, May 1969 and in California Vector Views, 15(12):123, December 1968.]

The following are items not mentioned in the other two abstracts. For general collection of urban refuse, the reported total costs range from about $8 to $25/ton of refuse collected. The median range is about $10 to $16/ton. Motor transport costs are from 6¢ to 10¢/ton-mile. Rail transport costs would range from 0.008¢ to 0.01¢/ton-mile. Central incineration costs are from $4 to $10/ton of refuse burned. Portable and field-erected incinerators for decentralized, at-source burning cost about $12/lb of refuse burning capacity/hr to install, and 50¢/hr to operate.

Pneumatic collection systems currently in existence for high-rise buildings and hospitals may also be used for commercial and institutional operations. For such utilization, the relatively high initial costs can be amortized over several years on the basis of labor savings. As far as low density areas, the utilization of such systems would be basically contingent on the demand for ultimate environmental improvement, convenience, and the willingness to accept the cost.

Central refuse grinding (1/4 to 1/2-in. particle size) costs are estimated to be from 90¢ to $1.40/ton of material processed. Pulverization would cost from $2.00 to $3.50/ton. Combining grinding with salvaging would raise the cost to $5.00/ton.

On page 10 of the Journal is given a table in which are listed unit costs of recommendations. This table includes costs of collection by a wide variety of means and disposal costs by several systems.

Among the interesting developments in the Fresno area since the release of the report were the passing of an ordinance making twice-a-week collection mandatory, with few exceptions. In addition, open burning at dump sites is forbidden.

Mandatory once-a-week collection was imposed on suburban residents with lot sizes of 36,000 sq ft or less. Nine separate haulers merged to create a single large collection and disposal company to bring about greater efficiency in routing and service to community areas not served by municipal agencies.

Marburger, J. H., Jr.
"Municipalities, Suburban Groups Work with Private Operators"
Solid Wastes Management/Refuse Removal Journal, 11(12):10, December 1968

In a 2-1/2 year period, a countywide solid wastes program was developed in Prince George County, Maryland. (The county adjoins Washington, D. C.) The program is designed to serve until the year 2000. Development of the program included the acquisition of some thousand acres for three landfills and a transfer station, as well as the winning of the acceptance of people of the county and its government. A 600-acre landfill site has been put into use, and two other sites — 180 acres and 200 acres in size — have been contracted for development. A seven-acre site has been purchased for a transfer station.

The county has an area of 496 sq miles and a population of 650,000. The population is expected to expand to 1,200,000 by the year 2000. Refuse production is expected to increase from 1,000 tons/day in 1965 to 3,100 tons/day in 2000. Thus a total of 22,000,000 tons of refuse must be collected and disposed of between the years 1965 and 2000.

To make the new program possible, it was necessary for the Maryland state legislature to pass a law which would authorize the commissioners of Prince George County "to establish urban areas to provide municipal type services, such as refuse collection and disposal without petition, when they were determined to be necessary." Taxes were to be levied to cover the costs. In October, the Department of Public Works created the office of Urban Engineer to develop and implement a program for the county as a whole. After due study, a combination landfill and incineration program was concluded as being the most desirable approach when land costs and site availability were considered. The plan finally accepted was one which included an integrated approach with incineration to be introduced in the mid-1970's.

The method of implementing the study is of interest. "The term sanitary landfill had to achieve public acceptance, and the idea of a dump erased. A controlled county contract collection program had to be established so that all refuse contracts for one-, two-, and three-family homes would eventually be under the county jurisdiction." The program was begun in 1966 by way of a plan which involved printing and distributing a five-page booklet containing a description of the plan; liberal showings of the film "The Third Pollution"; giving a series of "slide-talks" on the John Sexton landfill in Chicago, and the need for careful long-range planning; showing of photographs of a golf course in Baltimore County which had originally been a landfill; making speeches to every civic group possible to contact in the county; and drafting a model ordinance and regulations for the storage, transportation, collection, and disposal of solid wastes.

Not all was smooth sailing, however. The Civic Federation, the largest and strongest citizens' group in the county, passed a resolution which in effect condemned the extent of landfill envisioned in the plan, and called for a greater emphasis on incineration and the development of adequate roads on which to transport the refuse. With help received by way of a Solid Wastes Disposal Study being prepared for the Metropolitan Washington Council of Governments by Black and Veatch, Consulting Engineers, the objections of the Civic Federation were answered and the program was preserved intact.

Rogers, P. A., D. R. Andres, J. Cornelius, L. A. Burch, and S. E. Richardson, Jr.
"The Status of Solid Wastes Management in California"
California Vector Views, 15(12):123, December 1968

"A comprehensive report published by the California Department of Public Health in October 1968, entitled 'The Status of Solid Wastes Management in California' is summarized and discussed. This report presented the findings of an intensive, statewide study and evaluation of current solid waste management practices in California. The report was intended to be a factual progress report or summary data bank on the existing system of solid waste management, and as such did not contain recommendations for actions to be taken. A second report, to be completed in late 1969, will present a comprehensive recommended program of action which will be submitted to the state legislature."

During 1967, the estimated total production of solid wastes in California amounted to 71.5 million tons, or an average of 20 lb/person-day; of the 71.5 million tons, 32 percent were municipal in origin, 34.9 percent agricultural, and 19.2 percent industrial. The division of the municipal wastes was as follows: residential wastes, 8.9 million tons/yr; commercial, 9.7 million tons; demolition, 3.0 million tons; and special, 1.3 million tons. Agricultural wastes were divided as follows: animal manure, 21.8 million tons/yr; fruit and nut crop, 2.4 million tons; field and row crop, 10.7 million tons. Industrial wastes: food processing, 2.1 million tons; lumber industry, 8.0 million tons; chemical and petroleum refining, 0.5 million tons; and manufacturing, 3.1 million tons.

Of the total of 716 general-use sites in the state, 9.4 percent are sanitary landfills, 13.4 percent are modified sanitary landfills, 4.0 percent are modified sanitary landfills with controlled burning, 18.7 percent are supervised dumps with burning, 52.7 percent are dumps without controlled burning, and 1.8 percent are unspecified. (Ed. note: The survey is the subject of an article in the Solid Wastes Management/Refuse Removal Journal, 12(4):30, December 1969. The article has no known author.)

"Jobs, People, and Land — Bay Area Simulation Study"
Center for Real Estate and Urban Economics, Institute of Urban and Regional Development, University of California, Berkeley, Special Report No. 6, 1968

The publication is concerned with the development of Bay Area Simulation Study (BASS) Model No. III to serve as an extension and modification of BASS Model No. II. The models were designed for the purpose of forecasting land utilization and related waste disposal in 13 counties of Northern California for the period 1965-2020. The BASS model required the following major modifications of BASS II, a prototype model: 1) An extension of the time horizon for employment and land-use estimates to the year 2020. 2) An extension of the geographical area from nine counties to 13 counties. 3) Substantial additional data with respect to present employment and land utilization. 4) Further analysis and experimentation with the employment techniques used in BASS Model II. 5) Addition of an industrial algorithm. 6) Revision of the BASS Residential Submodel to take into consideration the filtering process in the housing inventory. 7) Refinements in the computer program to accommodate the increases in data and in the time period covered by BASS Model III. 8) More sophisticated methods of estimating changing land-use coefficients over time.

The publication is a valuable source of information in the development of the multipliers needed in estimating waste generation.

Rogers, P. A., J. Cornelius, and L. A. Burch
"Solid Wastes and Water Quality"
Solid Wastes Engineering Division, Bureau of Vector Control, California Department of Public Health, prepared for the California State Water Resources Control Board, 1968

The report is a combination of two reports – one covering solid wastes in general, and a second, concerned with water quality in particular.

The studies discussed in the report include San Francisco, San Pablo, and Suisun bays and their watersheds, and the Sacramento-San Joaquin Delta and all channels lying therein. Also included are those areas sufficiently near the above-named areas to warrant inclusion in the study. Counties bordering the bodies of water named above are Napa, Solano, Contra Costa, Marin, San Francisco, San Mateo, Santa Clara, and Alameda. Bordering counties are Yolo, Sonoma, Santa Cruz, San Joaquin, and Sacramento. The land area of the counties being studied amounts to 10,850 sq miles. The total population of the area was 5,628,000 (1 July 1967).

Interesting facts gleaned in the solid waste portion of the study are: a) During 1967, approximately 13.8 million tons of solid waste were generated in the study area. b) On a lb/capita basis, the solid waste generation was as follows: municipal, 5.7 lb; industrial, 1.6 lb; and agricultural, 6.1 lb. c) About 4.9 lb of these wastes/capita-day (37 percent of total) were disposed of by landfill. d) The 222 disposal sites in the Bay-Delta area consist of 103 general-use disposal sites, 44 special-use sites, 69 closed sites, and 6 proposed sites. e) The 147 active sites plus a proposed site presently under development comprise a total of 13,423 acres and have a remaining capacity of approximately 219,000 acre-ft. f) Of active sites, 7 percent are sanitary landfills, 46 percent modified sanitary landfills (i.e., they do not fully meet accepted sanitary landfill requirements), 10 percent modified sanitary landfills with burning, 13 percent supervised burning dumps, 15 percent uncontrolled burning dumps, and 9 percent are unspecified.

Facts of interest concerning the water quality aspects of the study are: a) Solid waste disposal in the San Francisco Bay-Delta area has a history of unsatisfactory operation and localized surface water quality problems. The primary factor has been contact of adjacent water with the solid wastes. b) Presently, 47 solid waste disposal sites in the Bay-Delta study area have an adverse contact with the adjacent surface water. Of these, 32 affect tidal waters and only 8 of these 32 sites are considered to be sources of moderate pollutant loadings. Unless plans are altered, surface water problems could occur in the future in 72 disposal sites in the Bay-Delta area. c) The existing pollutant loading to groundwater is negligible in the Bay-Delta area except where the ground level is shallow (e.g., eastern Solano County). d) Analyses were made of water samples collected at seven disposal sites considered to have the most serious water quality-solid waste interrelationships in the Bay-Delta area. The BOD of tidal water draining out of these fills during ebb tide ranges from 1 to 78 mg/ℓ; the total sulfide content from 0 to 60 mg/ℓ; fecal coliforms (MPN/100 mℓ) from 13 to 1.3×10^6. Leachate (concentrated seepage resulting from excess rainfall, improper surface drainage, or excessive amounts of applied water) was sampled in three of the seven disposal sites. Analyses of the leachates showed a range of electrical conductivity from 11,000 micromhos to 52,500; BOD, 30 to 8,460 mg/ℓ; fecal coliforms (MPN/100 mℓ) from less than 45 to 6.2×10^6; and fecal streptococci (MPN/100 mℓ) from 62 to 1.3×10^6.

"A Study of a Metropolitan Solid Waste Program"
Public Works, 100(3):78, March 1969

The study was made by the John Carollo Engineers for Maricopa County, Arizona. The three major objectives of the study were: 1) To define the character and magnitude of the problem of disposing of solid wastes; 2) To report on the present stage of development of disposal facilities; and 3) To present a feasible solid wastes disposal plan and system for countywide reference and use to the year 2000. The initiator of the study was J. J. Weinstein, Director of Environmental Sanitation for the Maricopa County Health Department, Phoenix.

The population of the county (1960 census) is 663,510; its area, 9,238 sq miles. Five adjacent cities represent 80 percent of the county population and occupy less than 5 percent of its area. Twenty communities or agencies participated in the report. Ten percent of the county population is rural and too dispersed for collection services and facilities. Population trends indicate a growth from 1,170,000 in 1970 to 1,739,000 in 1980, and to 3 million in 2000.

Sanitary landfills, landfills, dumps, and burning dumps are used as disposal methods. Feeding of cooked garbage to swine was practiced at 67 locations. Commercial solid wastes are generally collected by municipal forces. However, in Phoenix, noncity vehicles haul almost half of all solid wastes produced in the city to the city landfills.

In Phoenix (1967, population 518,000), the per capita daily production of solid wastes was 5.1 lb. Data from private haulers serving eight communities showed 2.1 to 5.1 lb/person. Also in Phoenix, residential production averaged 2.8 lb/person-day, and commercial wastes 2.3 lb/person-day. In 1967, about 86 percent of the county population was served by sanitary landfills, 3 percent used open dumps, and the remaining 11 percent were in rural areas and used other means of disposal or were not reported.

In estimating costs of various methods of disposal, it was estimated that haul to an incinerator and disposal in it would cost about $6.89/ton for a 500-ton unit. Cost for sanitary landfill is estimated at $1.68/ton. (As determined at a Phoenix landfill, one ton of solid wastes occupies about two cu yd of fill volume.) If a transfer station is used in an operation, its costs will be $1.00/ton. In Phoenix, haul costs are estimated to be 7¢/ton-mile over freeways and 12¢/ton-mile over arterial streets.

Solid wastes disposal programs proposed for the two decades 1980-2000 naturally are quite general. At the present base of 7,000 tons of waste/acre, the land needed for fill from 1970-1980 will be 1,915 acres; and for 1980-2000, 6,228 acres. It is envisioned that regional programs, i.e., on a countywide scale, will be of value in locating new fill areas, studying the development of borrow pits for fill areas, using containers as supplemental help for rural areas, engineering planning for fill-area use, studying population growth trends, and studying and developing specialized equipment for long hauls. County participation is not recommended for collection and/or disposal services.

Rogers, P. A.
"The Status of Solid Waste Management in California"
Public Works, 100(5):80, May 1969

A summary of the study findings regarding environmental effects indicate that: a) Occupational or safety hazards prevalent at disposal sites include: injuries from fires and explosions; high embankments with no safety barrier; traffic hazards; and contact with hazardous wastes such as pesticides. b) Complete daily covering is provided at only 12 percent of the general-use disposal sites, and no covering is applied at 468 sites. c) Only 20 percent of the sites have effective control over blowing paper. d) Solid wastes are being discharged directly into surface water at 33 disposal sites. At 81 sites, the wastes are, or appear to be, in contact with groundwater, and control of surface water drainage was inadequate at 207 sites. e) Open burning is practiced at 540 disposal sites in 51 counties, and more than 250 fires requiring the use of outside fire control equipment originated from refuse disposal sites during 1967.

The areas of deficiencies in solid wastes management in California are as follows: a) Fragmented authority and lack of cooperation. b) Inadequate planning. c) Inadequate standards. d) Poorly developed technology. e) Inadequate financing.

The greater part of the article includes material covered by P. A. Rogers et al. in an earlier paper, and in an interim report released in September 1968. (See Rogers, P. A. et al., "The Status of Solid Wastes Management in California," California Vector Views, 15(12):123, December 1968; and "California Solid Waste Planning Study — Status of Solid Waste Management in California," Interim Report, September 1968.)

Haug, L. A. and S. Davidson
"99 Towns in Western States Disclose Costs and Methods"
Solid Wastes Management/Refuse Removal Journal, 12(6):28, June 1969

This is the first of two installment articles in which are given figures on municipal and private handling combinations. As was the case with the article on the survey made in Ohio (see abstract for "Ohio Municipal League Measures Hauler Costs"), the feature of the present paper is the chart giving a detailed breakdown of collection practices. In this instance, the figures apply to 99 towns in ten western states. The primary intent was to obtain information on residential refuse collection and disposal services.

Of the 99 respondents to the questionnaire sent out by Western City magazine, 53 communities use private contractors and 46 have municipal collection. Of the 53 private haulers, 28 work on a private contract basis, and the other 25 contract with the city. Some cities use a combination of private or contract and municipal service. In California, 281 cities using private collectors require them to obtain a permit other than a mere routine business license. This takes the form of a contract or franchise in 256 communities. Seventy-five of the municipalities have once-a-week collection, and 15 have it twice weekly.

In a survey made 11 years ago, 66 percent of the cities had combined collection; in the present survey, the number has increased to 90 percent of the total. Separate collection is had in Davis, Duarte, El Segundo, Huntington Park, Modesto, Salinas, Santa Clara, Twin Falls, Watsonville, and Woodland — all in California.

ECONOMICS

Pender, M. R. and W. L. Hyland
"Town of Hempstead Faces Refuse Disposal Problems"
Public Works, 99(11):62, November 1968

The town of Hempstead, Long Island, New York, is the most heavily populated township in the United States. It is subdivided into 8 special districts for solid wastes management. The collection costs of the various refuse subdivisions average $8.65/capita-yr. Collection costs/acre-yr range from $77.20 to $168.50; mean cost, $102.00/acre.

A critical problem is the rapidly diminishing capacity of the town's sanitary landfill areas. Incinerators serve the entire town and currently burn 7,800 tons of refuse/week (63 percent of the total refuse generated), or 2.8 lb/capita-day. The major portion (6,000 tons/week) are processed through the town's two large incinerators, while four smaller village and district plants burn approximately 1,800 tons/week. The average cost of disposal is $3.80/capita-yr. Currently, the per capita production of refuse approximates 4.5 lb/capita-day. To achieve the goal of burning all of its combustible refuse, the town will have to modify its present disposal practices in two ways: 1) Install a shredder and separator in existing refuse disposal plants to increase the volumes of combustible material which can be processed and 2) Install compaction equipment so as to reduce solid wastes volume by a ratio of 7:1 or greater. By burning more and more of the combustible refuse, the percentage going to the landfill can be decreased from the prevailing 37 percent to a low of 7 percent. The concept of combining a grinder with an incinerator presently is receiving consideration by many municipalities. The estimated cost for a shredding and separating plant for a 1,300 ton/day incinerator would be $600,000. Operation, including interest and amortization, would come to about $2.00/ton.

"Solid Waste Management. 6. Financing"
National Association of Counties Research Foundation, prepared for the Bureau of Solid Waste Management of the U. S. Public Health Service, no date (distributed, 1969)

"Financing" constitutes the sixth in a series of publications of guidelines intended for use by local governing boards in plans for solid wastes management. In Publication 6 are discussed financial planning, revenue sources, purchasing techniques, and areawide financing. Three field reports are given.

Solid wastes management is a necessary public service which must be adequately financed. Two basic financial decisions must be made: 1) How to finance capital requirements; and 2) How to meet operating costs. Since the system must be financed within the constraints of state laws and local charters, these should be thoroughly examined during the planning process. Local governments can pay for the system through taxes, bond issues, loans, service charges or fees, and leases.

A table gives a summary of alternative methods of financing capital requirements. The alternatives are pay-as-you-go, leasing, subsidies/grants, and borrowed funds. Generally, the pay-as-you-go is the best method and should be used as extensively as possible with consideration given to total budgetary requirements and financial resources, to total construction needs, and to the benefit of the facilities/equipment to future residents, and to the availability of subsidies. The method should be used for minor needs or for additions, improvements, and modifications to existing structures and equipment. Short-term renting is recommended only when needs are well defined and the renting is on a temporary basis until plans and financing arrangements can be developed for permanent facilities and equipment. Three- to five-year leases should be considered whenever major uncertainties exist concerning the need for space — either in terms of scope, timing, or location. Attempts should be made to obtain subsidies on approved projects so as to reduce the local property tax burden and service charges. Any financing plan which anticipates subsidies should be flexible enough to allow for some undercollection. Long-term debt financing should be used when a pay-as-you-go method would place too great a burden on current sources, and when borrowing would not create equally severe future financing problems. The borrowing method should be evaluated in relation to the type of facility or equipment to be acquired. Resorting to financing segments of capital development programs with local bank loans can be very expensive because of high interest rates.

In another table, a comparison is made between methods of long-term debt financing for capital requirements. Such methods are revenue bonds, general obligation bonds, lease/lease-back, and lease purchase. Whenever possible, the use of revenue bonds should be considered for any revenue-producing activity. General obligation bonds generally should be considered for major projects of long-term benefits to the total community. They should also be considered for revenue-producing activities because of lower interest rates. However, a secondary method of financing also should be developed in the event the bond issue fails. Lease/lease-back should be considered only if a bond issue appears to be unfeasible, or if an urgent and unanticipated need develops. The same recommendations apply to lease purchase. The employees' retirement fund should be given preference over private investors if this method is used.

"Solid Waste Management. 7. Technical and Financial Assistance"
National Association of Counties Research Foundation, prepared for the Bureau of Solid Waste Management of the U. S. Public Health Service, no date (distributed, 1969)

This publication, the seventh in a series of publications of guidelines for local governing bodies, deals with the federal solid wastes program, other federal programs, state assistance, and it supplies other sources of information. Three field reports pertinent to these subjects are given.

Technical assistance from federal, state, and private sources is available to local officials to develop or expand their solid wastes management systems. On the federal level, the primary source of financial and technical assistance is the Bureau of Solid Wastes Management. Although the Bureau of Mines provides limited technical assistance, its main emphasis is on research. Imaginative use of assistance from other federal agencies may provide help for solid wastes management. Many states are beginning to provide technical assistance, particularly in the planning field. At present, almost no financial assistance is available.

As an appendix, a list is given of the addresses of main and regional offices of federal departments offering assistance in solid wastes management.

LEGAL

"Open Dumping and Burning are Outlawed by Ohio Code"
Solid Wastes Management/Refuse Removal Journal, 12(1):10, January 1969

The ban on open dumping and burning will become effective 30 June 1969. Regulations presently in force have to do with control of water pollution and the operation of sanitary landfills. Terminology is carefully defined in the code and penalties are named. Anyone planning to convert an open dump operation to a sanitary landfill is required to submit his plan of operation to the State Department of Health for approval at least 60 days before the initiation of the proposed operation.

Among the regulations in the code are the following: a) The operator shall not permit access to the sanitary landfill site except when operating personnel are on hand, and he shall permit no loitering. b) Unloading of solid wastes shall be confined to the smallest practical area and shall be made under the supervision of competent operating personnel. c) The operational portion of the fill shall be policed regularly to prevent the accumulation of scattered litter. d) Equipment commensurate with size and needs of the operation must be on hand at all times. e) Cover material shall be of earth or of other material acceptable to the Health Commissioner and shall be applied at the end of each day's operation or more frequently when necessary, unless otherwise provided in the plan approved by the Director. It should be compacted and sufficiently deep to prevent insect and rodent attraction, etc. f) Sewage solids and other hazardous material may be deposited with the regular refuse only to the extent that it does not interfere with the proper operation of the fill. However, a separate section of the site may be set aside for such materials. g) Salvaging shall not be done except with the written approval of the State Director of Public Health. h) No live animals shall be permitted on the operating area of the site. i) The operator must maintain a daily log of information pertinent to the operation of the fill. A copy of the log, plans, specifications, etc., shall be on file and available to the Director and the Health Commissioner upon request.

With respect to incineration, incinerators must be operated so that the incineration residue is substantially free of organic and putrescible material, and so that air pollution does not exceed the air quality standards set up for that region by the air pollution control board.

After January 1969, no person shall operate or maintain a disposal site or facility without a license issued by the board of health of the district in which the site or facility will be located. The license may be transferred to another person upon the sale or disposition of the site, providing the Director of Public Health acquiesces. The annual fee shall not exceed $500 and shall be paid at the time application is made for the license. State and political subdivisions of the state may be exempted from payment of the fee.

Suspension or revocation of the license of a poorly operated site may be imposed by the state after the operator has been given a written notice specifically listing the violation or violations. Unless the violation is of an immediate and seriously dangerous type, the operator may be given a reasonable length of time to correct it.

A loophole in the enforcement of the regulations is the following: "After considering the evidence, the board of health may grant the political subdivision a conditional license to operate a waste disposal site or facility, <u>without</u> full compliance with the regulations adopted by the public health council and establish a reasonable time for full compliance <u>by said political subdivision</u>, which time may be <u>extended</u> by the board of health from <u>time to time</u> for good cause." (Underlines added by the editor of this report.)

"Disposal Laws Changed by Rhode Island Assembly Act"
<u>Solid Wastes Management/Refuse Removal Journal</u>, <u>12</u>(3):24, March 1969

Recently, the state of Rhode Island has enacted several important pieces of legislation relating to refuse disposal. Thus, a regulation was passed whereby each city and town is made to see to it that all refuse generated within its boundaries be disposed of in a safe and sanitary manner. This includes refuse from commercial and industrial sources. The disposal facilities used to meet this responsibility may be located within or without the muncipality, may be publicly or privately owned, and may include facilities used only by the owner. Each city and town must adopt rules and regulations concerning the collection and disposal of refuse which are consistent with state board of health standards. Necessary long-range plans consistent with those of the state must be drawn up.

Of great significance is the fact that the legislation empowers cities and towns to make arrangements with other like entities to plan for waste management on a regional scale. In fact, the law provides that should a town or municipality find that it cannot dispose of its refuse within its own boundaries, and neighboring municipalities refuse to enter into an arrangement with it, it can have recourse to the state board of health. The state board of health will make a study of the situation to determine whether or not the problem could indeed be solved by combining two or more municipalities into a refuse disposal district. If it so concludes, the department would then use its office to bring about an amicable arrangement. Failing this, the department would recommend to the governor that the general assembly create a refuse disposal district comprising the two or more municipalities. "The district may be created by (1) requiring the municipalities involved to form a refuse disposal district to undertake refuse disposal on a joint basis; (2) creating an agency with powers to plan, acquire, construct, operate, and finance refuse disposal facilities in and for the district, or (3) other suitable procedures. The department of health may make the studies, findings, and recommendations described above without a request from any municipality if it deems desirable."

Another interesting feature of the legislation is the provision for grants-in-aid. An appropriation of 40¢/capita is made for providing the funds needed to carry out the purposes of the act. Of the total, 62-1/2 percent (25¢/capita) shall be apportioned to each community of the state, 80 percent on the basis of the ratio of the population of each community to the total population of the state, and 20 percent on the basis of the ratio of the number of employees located in each community to the total number employed in the state.

"Pennsylvania Gets New Solid Wastes Management Act"
Solid Wastes Management/Refuse Removal Journal, 12(4):14, April 1969

The following quote from the journal sums up the main points of the act, which is given in full in the journal: "An Act (241) providing for the planning and regulation of solid waste storage, collection, transportation, processing, and disposal systems; requiring municipalities to submit plans for solid waste management systems in their jurisdiction; authorizing grants to municipalities; authorizing the Department of Health to adopt rules, regulations, standards, and procedures; creating an advisory committee; providing remedies, prescribing penalties, and making an appropriation."

The comments by the editor of the journal are worth noting: "The Pennsylvania Solid Waste Management Act is a forward-looking and far-reaching document in its outlook and strongly endorses 'utilization of the capabilities of private enterprise in accomplishing the objectives of an effective program.'"

"Unfortunately, the 22-member Advisory Committee, appointed by the Governor, under the Act, does not include a municipal sanitation executive or a refuse contractor."

"Solid Waste Management. 2. Legal Authority"
National Association of Counties Research Foundation, prepared for the Bureau of Solid Waste Management of the U. S. Public Health Service, no date (distributed, 1969)

This is the second of a series of guidelines written for local governing boards. In this publication are given not only guidelines for copying with the legal problems of establishing a waste management program, but also a number of case histories and a suggested outline of a solid wastes management ordinance.

State legislation to permit establishment of solid wastes management systems must permit state and local action. Statewide standards and regulations must be drawn up and enforced by a responsible state agency.

The legal basis for local governments to control solid wastes is a state-enabling law. It is by way of such a law that local governments have the authority to acquire land, develop facilities, and spend public funds to regulate and control solid wastes. Legislation should allow political subdivisions to manage wastes in coordination with other environmental protection programs.

Local officials should enact a comprehensive ordinance governing the management of solid wastes. Ordinances should not be encumbered with technical details likely to be out-of-date in a short time. Ordinances should be conceptual in scope, flexible in method, positive in direction, and prohibitive of any type of air, water, or land pollution. The ordinance should designate a local agency or agencies to adopt and enforce standards, rules, and regulations, to plan, and, if necessary, to operate a system.

Local governments should be allowed to: a) plan and zone for wastes processing sites and acquisition of sites through purchase, eminent domain, or leasing of private property; and b) to regulate private solid wastes operators through the issuance of permits and licenses, and the use of franchises or contracts. In any system, there should be a clear statement of liability protection and "guarantee of performance" clause in all design and construction contracts.

A selected bibliography consisting of seven publications is given.

MISCELLANEOUS

Black, R. J.
"Solid Wastes Handling in Hospitals"
U. S. Department of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, Public Health Service Publication No. 930-C-16, Cincinnati, Ohio, 1968

The principal types of solid wastes in a hospital are: a) garbage; b) paper, trash, and other combustibles; c) treatment room wastes; d) surgery wastes; e) autopsy wastes; f) noncombustibles such as cans and bottles. The average weight and volume of solid wastes/patient/day is from 7 to 8.5 lb, and occupies about 0.7 cu ft/patient-day. Single-service plastic waste receptacle liners or moisture-proof paper bags are preferable to unlined metal containers or cloth bags. Trash chutes should discharge trash to a receiving room separate from the incinerator charging areas, and the receiving room should have exhaust ventilation.

Incineration is the common method of disposal. Equipment for wet grinding or pulping of refuse, followed by dewatering of the pulp, has been introduced recently. This type of equipment has an advantage in that both garbage and rubbish can be handled together. Its disadvantage is that the pulp is suited best to landfill.

There are two types of hospital incinerators — natural draft and heavy-duty, high-temperature. The use of the natural draft type because of the limits on upper temperatures leads to some uncertainty of complete destruction of pathological materials. The high temperature (1200° to 1800°F) unit is the one to be preferred.

Housemen performing collection and storage work should be carefully trained in protective techniques necessary for the proper handling of pathogenic wastes.

Routine procedures to prolong incinerator life are: clean grates and ash pits daily; keep all draft passages clean; operate damper weekly; keep cans, bottles, and noncombustibles out of the incinerators; ventilate furnace well before lighting; don't overload the furnace; keep materials stirred and loose; give a smoking fire more air; don't strike brickwork with bars or rakes; and learn what type and amounts of wastes may safely be burned without overheating the brickwork.

Vaughn, R. D.
"Management of Solid Wastes from Hospitals: Problems and Technology"
Paper presented at the meeting of the National Sanitation Foundation Steering Committee for the Conference on the Use and Disposal of Single-Use Items in Health Care Facilities, Ann Arbor, Michigan, 4-5 December 1968 (distributed by the U. S. Department of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, Cincinnati, Ohio)

Problems besetting the management of hospital wastes are essentially akin to those characteristics of the community as a whole, viz., large and growing solid waste volumes, and hazards posed to man and his environment. Thus, recent studies indicate that at present the wastes generated/patient amounts to 19 lb/day, whereas in 1955 it was 3.89 lb/day. A major factor in the increase is the switch to disposable single-use articles. For example, in a 1964 survey it was found that 24 throw-away items were found in a typical surgical/obstetrical wing; 26 in the hospital laboratory; 26 in nursing services; 29 in the dietary department; and 13 in the housekeeping staff. An idea of the effect on increase in volume of wastes may be obtained from the following example: In one hospital, it was found that a storage volume of 20 cu ft was sufficient to maintain a six-month supply of reusable 2-cc syringes, while 100 cu ft was required to stock disposable syringes (10 deliveries/yr).

Ideally, all hospital wastes should be packaged when disposed. Such a procedure eliminates continuous direct handling and consequently reduces danger to hospital employees. It also eliminates or controls the generation of aerosols. The gravity chute is preferable to the cart in the collection and transport of the wastes. A pneumatic refuse collection system is an excellent method. Wet pulping is satisfactory if collection costs are a function of volume. It becomes expensive when the costs are a function of weight.

Incineration is the common method for disposing of hospital wastes; and it is the recommended method for infectious wastes. Disposal of radioactive wastes is a growing problem. Disposable items made of plastic constitute a problem in incineration because of the high temperatures required to burn them and the dangerous gases released when they are burned. The problem of phosphorus deposits from the burning of bones is one peculiar to hospital incinerators. From 7 to 10 percent of the hospital wastes are not incinerable. Ultimate disposal for these is by sanitary landfill.

Hart, S. A.
"Solid Wastes Management in Germany"
U. S. Department of Health, Education, and Welfare, Public Health Service, National Center for Urban and Industrial Health, Solid Wastes Program, Public Health Service Publication No. 1812, Cincinnati, Ohio, 1968

The pamphlet is a report of the U. S. Solid Wastes Study Team visit which took place from 25 June to 8 July 1967. The trip was designed to evaluate the possibilities of applying German technology to U. S. needs and to encourage a mutual information exchange between the two countries.

A summary of observations made by the team is as follows: a) German domestic refuse is quite similar to U. S. domestic refuse, although its ash content is slightly higher, and its can, bottle, and paper content is somewhat less. b) The principal storage container for domestic refuse has been a 110-liter refuse can. However, larger containers — 1.1-, 4-, and 6-cu m — are becoming more popular. c) Domestic refuse collection generally is handled by the municipal government. Collection is from curbside, and the containers are dumped into the collection vehicle by a mechanized lifting device. d) Landfills generally have the same ill repute as U. S. landfills; no sanitary landfills were observed. e) Composting is practiced in nine locations in West Germany, but it is not a major refuse disposal system.

f) Refuse incineration that produces steam or electricity is common in Germany. Refuse is not a "free" fuel, inasmuch as it costs more to produce steam or electricity from refuse than from conventional fuels. The additional cost is charged to refuse disposal.

Special attention was paid to the German practice of steam and electricity production using refuse as a fuel. The Study Team concluded that consideration of the significant economic, political, and philosophical difference between the situation in Germany and that in the U. S. was paramount in evaluating application of this system to any given U. S. community.

Also of note is the relative freedom of public works departments and officials in West Germany to determine operating considerations such as disposal fees. Stack emission, metal salvage, incinerator grates, ash sintering, and other subjects are discussed.

Black, R. J.
"Private Contractor Opportunities in the Solid Wastes Program"
Paper presented at the National Refuse Equipment Show and Congress, San Francisco, California, 2-4 June 1967 (U. S. Department of Health, Education, and Welfare, Public Health Service)

For the present, the principal concern of the private contractor is with the safe and sanitary disposal of the increasing amounts of wastes being generated. Before very long, he will have to be concerned by the fact that the amount of potentially dangerous wastes to be disposed of is steadily growing.

Every major activity in the Solid Wastes Program will result in some benefit to the private contractor. Everyone gains whenever technical competence in solid wastes management is strengthened. Opportunities for tangible benefits include: a) statewide surveys of solid wastes disposal needs and the development of state plans to meet those needs; b) projects for the conduct of research; and c) projects to demonstrate new and improved solid wastes technology and to design new areawide waste management systems.

With respect to demonstration grants, it should be kept in mind that federal regulations a) require detailed records to be kept by demonstration grantees; and b) provide that interested persons may review progress on projects during normal business hours.

"State Solid Waste Planning Agencies"
Circular issued by the U. S. Department of Health, Education, and Welfare, Public Health Service, Systems and Operations Planning, Solid Wastes Program, 222 E. Central Parkway, Cincinnati, Ohio 45202, March 1968

The circular provides a listing of the names and addresses of solid waste planning agencies for all states, territories, and the District of Columbia. The address noted is the contact for that jurisdiction's solid waste planning activities.

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Stern, H.
"Optimal Service Policies for Solid Wastes Treatment Facilities"
Operations Research Center Report No. 69-3, Operations Research Center and Sanitary Engineering Research Laboratory, University of California, Berkeley, January 1969

The investigated system consists of a stochastic periodic treatment of raw waste, a processing operation with controllable terministic service rate, and adequate storage capacity. Superimposed on this system is a cost structure composed of processing and holding costs. A service rate rule that minimizes the infinite horizon discounted expected total cost is found. The problem of finding such a rule is formulated as a stochastic Markovian decision process with continuous state space, continuous decision space, and finite transition times. Existence and uniqueness of long-term optimal costs and policy functions are shown. Since the optimal policy cannot be expressed explicitly, an approximate solution was found. An error bound on the optimal cost associated with this solution is exhibited.

Stevens, R. P.
"Role of the Private Contractor in Handling Industrial Waste"
Paper presented in the Solid Wastes Seminar held under the auspices of Environmental Systems Division, Eidal International Corporation, 245 Woodward Road, S.E. Albuquerque, New Mexico, 16-17 April 1969 (Richard P. Stevens is President of Universal By-Products, Inc., Sun Valley, California)

Approximately 60 percent of all refuse collection in the United States today is handled by private contractors. In many instances, the private contractor specializes in collection of industrial wastes, thereby enhancing his revenues through salvage procedures. Salvage includes such materials as corrugated cardboard, scrap metal, and even apricot pits. Ultimate disposal at a site, however, usually is handled in municipal facilities, with about 79 percent of land disposal sites and some 96 percent of incinerators being publicly owned. It was noted that collection and hauling of solid wastes to the ultimate disposal site represented an excess of 65 percent of the total disposal costs.

COLLECTION AND TRANSPORT

CONTAINERS AND STORAGE

"A Thud Instead of a Reverberating Clang"
The American City, 83(7):67, July 1968

By scientifically pinpointing areas of vibration and placing sound-absorbing materials to dampen the vibrations, it was possible to "sound-deaden" garbage cans to the extent that noise ceases to be a problem in handling them. Six rubber feet are attached to the bottom rim of the barrel. The bottom is coated with a mastic, and a resilient material is placed under the handles to keep them from banging against the sides of the can. Strategic positioning of strips of asphalted felt on the walls of the container lessens noises from that source. The can is sold under the name of the "Silencer." (Dover Stamping Company, Fall River, Massachusetts.)

"Containers Get Into The Act"
Public Cleansing, 58(12):624, December 1968

Despite free collection service, the town of Bury had been troubed with a great deal of illicit dumping. One of the factors was that the town dump had an exceedingly difficult-to-travel access road. To help solve the problem, a vehicle fitted with container-handling equipment was purchased, together with 12 containers. Ten disposal sites were then set up throughout the district. The containers each have a capacity of 10 cu yd. After the installation, over 80 percent of the illicit dumping in the district was voluntarily discontinued within the first months of operation. The facilities are available 24 hr/day, 7 days/week. No restriction is placed on types of material to be placed in the containers.

"Collection of Future? It May Be in the Bag"
Refuse News (Gardena, California), p. 3, 5 May 1969

In this news item are presented the results of a survey made by the editor of the paper to determine the effectiveness of the use of paper bags in refuse collection. (Plastic bags also were included in the study.) The problem in making a switchover to the use of paper or plastic bags from the conventional metal or plastic container is not only one of practicality but also of the homeowners' acceptance, especially in view of the somewhat higher cost of the bags. The author of the article states that although no definite answer can be given regarding the homeowners' attitude toward the higher cost, it can be stated positively that in general they are enthusiastic about the concept itself. During the survey, three types of bag systems were tested: the St. Regis Sack System, the International Garbax Disposal System, and the Mobile Chemical Castaway Refuse Sack System. The St. Regis system is available in stand and wall-mounted units or with an optional free-standing animal guard. The International Garbax system is available in metal wall mount, stand, and completely enclosed animal guard units. The Mobile system is available in a wall and stand model only. Each of the three systems has a tight-fitting lid which can be easily opened with an elbow. The Mobile unit tested by the author had a lid which would not remain open unsupported; this proved to be an inconvenience. None of the stand models seemed to have much stability. The wall mount may prove to be a bit unstable if attached to unsupported plasterboard, since it would be supporting weights as heavy as 50 to 60 lb.

Loading the International Garbax unit proved to be a complex operation, especially with respect to fitting it in the supporting frame. Care must be taken not to overload the bag, lest it turn out to be an impossible task to close it. The author points out the need for developing some type of a permanent closure for the bag. Of all the units, the International's stand had the most stability. The sewn bottom of the International sack made it difficult to keep the sack in an upright position at the curbside on collection day.

While the St. Regis system was quite easy to load and unload, the stand was very unstable and had a decided tendency to fall over. The system shares the bag closure problems with the International. Without a closure or fastening device, "it is entirely too easy for animals to get into the bags, or for the trash to spill if they are knocked over." The bags are waterproof and quite sturdy. The St. Regis bag has a pasted bottom, and hence can be left upright without any difficulty.

The Mobile unit also is easy to knock over; but not being as damage prone, this handicap is not the problem it is with the St. Regis unit. The plastic bags lack the sturdiness of paper ones. The sacks contain an animal repellent which, although having a rather overpowering aroma, does keep the animals away. The Mobile treated bags do prevent the development of objectionable odors, even of putrescible material allowed to remain in the bag for a two-week period. The overload problem has been met with the use of twister-ties.

Providing storage for the paper bags is a space-consuming problem. Space required for storage of the plastic bags is less voluminous.

Despite the criticisms, the author feels that the advantages in the use of the sack system outweigh the disadvantages. They are convenient and clean. The customers are enthusiastic about them. Savings of as much as one-third are possible in pickup time.

Collectors like the bags, but with some reservations. One reservation is that the collectors would be faced with the need to sell the system to their customers. The bags themselves cost 10¢/bag in bulk or 85¢ for five by package sale. Another problem is that of delivering the bags to the customers. However, these problems will be compensated by the savings in time, improvement in cleanliness, increase in safety for the collection crew.

EQUIPMENT

"The New Fleet — Bigger and Quieter"
The American City, 83(5):48, May 1968

The interesting feature of this item is the listing of the specifications of the new collection vehicles acquired by the city of New York. They illustrate the trend in refuse collection equipment.

The specifications are: a) Capacities of 20 cu yd and 7 tons. (Present units: 16 cu yd and 3.2 tons.) b) Compacting equipment which can crush bulky items such as sofas, bureaus, etc. c) Automatic transmissions and power steering. d) Noise abatement features. e) Engines designed to emit a minimum of air pollutants. f) Comfortable cabs.

"Four Stationary Packers Save $320 a Week"
The American City, 83(8):50, August 1968

The superintendent of sanitation in Tyler, Texas, converted four used packer bodies into stationary packing containers. By replacing supermarket "trash houses" with converted packers, he saves up to $80/week/installation on labor and truck costs. He converted four Hobbs Hyd-Pak-60-Series packer bodies to stationary use. Formerly truck mounted, the containers now remain at commercial sites until packed full. A Hobbs Hyd-Pak Sp-25 electric power unit is used with each one. This drives the self-contained packer plate to clear the loading hopper and compress refuse into the main storage compartment. The power unit is detached easily and is left at the site when the container is brought to the disposal area for dumping. The four containers are serviced with a Hobbs Pack-Saddle system truck. The conversion is possible only on side loaders.

"A Big 40-Yard Refuse Truck"
The American City, 83(11):101, November 1968

The city, Garfield Heights (part of the Cleveland, Ohio) metropolitan complex, invested in a 40-yard refuse collection truck. Despite its capacity, the truck has a shorter wheelbase (191-1/2 in.) than that of conventional-size trucks. It handles almost as easily as a passenger car. Its front-wheel drive permits it to go almost anywhere in the fill area.

Because of the three-yard capacity of the receiving hopper, the compacting cycle need not be activated as frequently as is normally the case. Because of the 40-yard capacity, a crew can work all day on one route and make only one trip to the disposal site. The increased capacity of the truck without expanding the wheelbase was possible because of the absence of a drive shaft (front-wheel drive). The body was enlarged by dropping it between the front and back wheels. A typical load is 14 tons, or 700 lb/cu yd.

Garfield Heights has a population of 46,000 and a land area of only 7-1/2 sq miles.

Hurst, W. D.
"One-Man Side Loading Refuse Packers"
The American City, 83(12):50, December 1968

In 1966, three side-loading refuse collection vehicles were placed in operation in Winnipeg, Manitoba, Canada. The vehicles consist of a side-loading packer body mounted on a modified school bus chassis (International Model 1800). The chassis is equipped with a stand-up drive on the right-hand side as well as a conventional left-side drive. The loading opening is immediately behind the cab and is relatively low. The units were operated experimentally with both one and two-man operation. No appreciable economic advantage could be detected of one type over the other. The reason was that "if only one man was employed, it was necessary to pass through the lane twice in order to collect from both sides. Two men would make it possible for both sides to be cleaned simultaneously."

On comparable work in back lane collecting, the direct cost with conventional equipment is $10.67/ton, whereas it is $9.40/ton with the side-loading packers. Offsetting difficulties are the longer wheel base and consequently longer turning radius of the side loader, their lesser degree of mechanical reliability, and consequently more frequent downtimes.

FREQUENCY AND PROGRAMMING

Truitt, M. M., J. C. Liebman, and C. W. Kruse
"An Investigation of Solid Waste Collection Policies"
Department of Environmental Health, The Johns Hopkins University, Baltimore, Maryland, Volumes 1 and 2, Terminal Report, August 1968

In Volume 1 are discussed in detail three simulation models prepared in FORTRAN IV language on an IBM 7094 computer for use on digital computers. It includes data from observations of urban collection activity. It presents the results of model usage in predicting results of proposed system changes in the existing Baltimore system.

A User's Guide for future operation of the final model and the program coding of the model is given in Volume 2.

Model 1 simulates many trucks collecting in an urban neighborhood which has household densities per acre defined within certain limits. Model response of major interest is the number of household units which can be serviced by a collection truck in an 8-hour day. Runs were made for different combinations of haul distances, neighborhood densities, collection frequencies, and seasons.

Model 2 is similar to Model 1, with one major policy difference, namely, a definite number of households is assigned to each truck as the day's task, rather than working an 8-hour day. Response of major interest keeps unit cost of the operation for combinations of different collection frequencies, neighborhood types, and haul distances. Sensitivity of response is noted for changes in size of daily task assignment.

A more complex and realistic system is simulated in Model 3. It involves an assigned task policy in a large urban area of many residential subareas, each definable in one of four classifications. The number of daily routes in each subarea is calculated as a function of subarea neighborhood type, collection frequency, and haul distance. Trucks are then assigned by number to subareas by days of the week.

Collection for a 6-day week in the entire area is then simulated and a resumé of the week's activities is printed. The model is structured for semi or triweekly collection frequencies, and can simulate a system with or without a transfer station. Different locations for final disposal sites or transfer stations can be cost investigated and so compared. Many runs were made in the study with the northwest quadrant of Baltimore as the area for which the collection activity was simulated. The response of major interest always was unit cost in dollars per ton for the many combinations of policies and affecting variables.

Runs with the model indicated: a) An increase in collection frequency from semiweekly to triweekly in the northwest quadrant of Baltimore would increase costs approximately $1.00/ton. b) In this northwest area, eight miles is the critical haul distance above which a transfer station is warranted.

Stone, R. and R. Stearns
"For More Efficient Refuse Collection"
The American City, 84(5):98, May 1969

In the article a model is developed which includes as variables: average quantity of refuse per collection stop; average number and type of containers at the collection stop; average time at each collection stop, including travel time to the next stop; average driving time between route and disposal site; average disposal time per load at the disposal site; and total nonproductive time.

The total time in minutes (X_1) to complete one trip and dispose of one full load is: $X_1 = Vtd/Q + B + K + D$ where B = one-way average driving time between route and disposal site (min); D = average disposal time (min/load); K = total nonproductive time and includes dispatch, lunch and relief, yard-to-route time, and disposal site-to-yard time; Q = average quantity of refuse per collection stop (lb); V = vehicle volumetric capacity (cu yd); t = average time per collection stop plus travel time to the next stop; and d= average density of refuse in the vehicle (lb/cu yd).

If $X_1 + 2B + D \geqq 510$, there may be only one trip for the day. (The normal workday is 480 min, with a maximum allowable overtime of 30 min.) If $X_1 > 510$, the following calculation is made: $510 = a\ Vtd/Q + B + K + D$, solving the value of (a) gives the fraction of the truck capacity used or the partial load size. If $X_1 + 2B + D < 510$, the truck may be sent for a second or more load(s) as time permits.

Generally, the total number of trips (n) is $Xn = (n + a-1)\ Vtd/Q + (2n-1)\ B + K \div nD$, provided $Xn \leqq 510 < Xn_1$ and a is $\geqq 1/8$. If $a < 1/8$, only (n-1) trips are made. The daily number of loads per truck (N) is: $N = (n + a-1)$. The total tons of refuse collected per truck (T) is: $T = NVd/2000$. The total services (SC) collected per truck is $SC = NVd/Q$. The total man-minutes of labor time expressed as straight time (Lt) is $Lt = 480\ (CS)$ if $Xn \leqq 480$, or $Lt = CS\ [1.5\ (Xn - 480) + 480)]$ if $Xn > 480$. CS is the crew size and includes the driver. Paid man-minutes per ton (M_H) = Lt/T. Labor cost (Lc) per ton is: $Lc = M_H\ (\$0.08)$, assuming that labor is available at 8¢/man-minute or \$4.80/hour.

The vehicle cost (Vc) is found by multiplying the respective times spent during collection, haul, and relief by the appropriate cost value shown in the following table:

COSTS OF VEHICLE TIME
(Equipment Cost Only)

Truck Size (cu yd)	Collection Time ($/hr)	Haul Time ($/hr)	Relief Time ($/hr)
12	3.75	4.00	2.00
16	3.90	4.35	2.18
20	4.12	4.60	2.30
25	4.20	5.10	2.55
32	4.73	5.74	2.87
40	5.10	6.20	3.10

Vehicle cost/ton (V_T) is $V_T = Vc/T$.

Total cost/ton (C) is $C = Lc + Vc$.

The model assumes that the crews collect refuse for as long as time permits.

In operations having a fixed number of services to be collected each day or within a given time period, the average cost per ton varied less than 10 percent from the values predicted by the model in small systems involving less than 5,000 services. The difference decreased to 3 percent as the number of services increased to 100,000.

One of the conclusions reached by the authors was as follows: "The ability of the two- and three-man crews to collect a greater number of services per day reduces the total equipment requirements for the refuse collection operation, thereby reducing the total equipment costs. But increased labor cost of the multi-man crews more than offset the reduced equipment costs."

HAUL AND TRANSFER STATIONS

Transfer Stations

Vondrak, G. H.
"Transfer Station Shrinks the Dead Haul"
The American City, 83(2):100, February 1968

The population (114,000) of Dearborn, Michigan, generates 250,000 cu yd of refuse/yr. The disposal sites are 26 miles from the collection routes. Inasmuch as studies indicated a decade or more of use with the disposal sites, the decision was made to build a transfer station. The station is equipped with three hoppers and an opening for a fourth. Each hopper is independently operated by a stationary Hobbs Hyd-Pak power unit. Sixty-yard compaction trailers are parked under each hopper. The collection trucks discharge the refuse into the hoppers at the upper level of the station.

Through the use of a stationary control panel near each hopper, the operator can control the discharge from the 20-yd capacity hoppers to the trailer rig and also activate the compaction cycle in the trailer rig. The packing plate exerts 111,000 lb of pressure, compacting refuse to upwards of 700 lb/cu yd.

Evans, H., Jr.
"Transfer Stations Solve Dump Problems"
Public Works, 99(5):84, May 1968

The Department of Sanitary Operations in King County, Washington, is responsible for ensuring proper solid wastes management in the city of Seattle, and in a dozen smaller communities as well. To provide a more effective operation, a system of transfer stations was set up. An example of a transfer station is the one at Houghton. The station is built on two levels — the upper for access by vehicles to be dumped, and the lower for trailer trucks to receive the refuse. The upper floor is of concrete slab construction supported by steel columns, and is 90 by 40 ft. Each of the two dumping pits is 10 ft x 40 ft x 15 ft deep.

"Kills Odors at Transfer Stations"
The American City, 83(7):67, July 1968

Odor problems which arose at Detroit's two transfer stations were minimized by daily spraying with Cairox potassium permanganate. A 400-gal high-pressure sprayer is employed. The areas to be sprayed are about 1-1/2 acres apiece. A total of 35 lb of the dark permanganate crystals are added to each 400-gal water (1 percent solution).

Lausch, J.
"How to Transfer Refuse — Elegantly"
The American City, 83(10):85, October 1968

A new transfer station serves the 150,000 residents and industries of Lancaster, Pennsylvania. The refuse is transferred to 65-cu yd transport trailers for the 17-mile trip to the landfill. Several ideas and devices were incorporated into the design: a) Location: An 800-ft driveway connects the station to an arterial street in an industrial zone, and a state highway is less than a mile away. b) Loading: Push-out heads and 10-ft wide pits insure adequate storage capacity. c) A sprinkling and deodorizing system. d) Scales (30-ton Toledo scale which prints weight and truck number).

The transfer takes place in a 100 x 40 ft structure equipped with four dumping stalls on either side of a small control room. Refuse haulers can continue dumping while the stationary compaction cycle occurs. The station handles about 300 tons daily from 275 vehicles.

The station is operated by the Lancaster Refuse Authority (Lancaster and six surrounding townships). When the nearby sites were exhausted, incineration was investigated as an alternative to hauling the refuse to a landfill site 17 miles away with the use of a transfer station to breakup the haul. Costs ruled out the incinerator.

The transfer station cost $385,000. It includes two acres of land, grading, paving, fencing, five Dempster transport trailers, the station and its equipment, scale and scalehouse, and a 20 x 30 ft office structure. The office is air-conditioned.

"Transfer Plant Operation for Combined Refuse Pretreating with the Heil-Tollemache Pulverizer and Baling the Milled Refuse"
Heil Company, 3000 W. Montana Street, Milwaukee, Wisconsin 53201, 1968

According to the brochure, the experience of the company with this type of operation has been limited to experiments with a baler manufacturer using milled refuse only. The brochure includes a layout showing a landfill or transfer station incorporating a baler following a pulverizer. Initial density of combined refuse as dumped from a packer averages 300 to 400 lb/cu yd; milled material initially averages 275 to 375 lb. The baler brings the density to 1,566 lb/cu yd.

No cost figures are given because of the limited experience. The equipment cost would be about $40,000 for the following specifications: a) high-speed horizontal single-ram baler with 100 hp motor, starters, and switches; b) baler complete with motor, controls, and supports; c) no input and output conveyors or strapping equipment included; d) capacity: 165 tons/day, two 8-hour shifts; e) 400 PSD on ram face compressed to 58 lb/cu ft – 1,566 lb/cu yd; f) size of bale: 3 ft x 3 ft x 5 ft (can be adjusted).

"Transfer Stations Assist Refuse Disposal"
Public Works, 100(1):74, January 1969

The transfer stations are located in Orange County, California. Three such stations are now being operated, each located about 20 miles from the ultimate disposal point. During the period July 1967 to June 1968, a total of 481,000 tons of wastes were transferred. At one of the stations the cost of transfer, transport to the landfill, and unloading, amounted to $2.24/ton. These costs include all related costs such as manpower, maintenance, depreciation of equipment, fuel, etc. The landfill placing costs $0.32/ton. At present, homeowners in the service area pay an average of $1.20/mo for once-a-week pickup. Without the transfer stations, this cost would rise to $3.00/mo.

Time studies show that load transfer is accomplished in 30 sec when all of the load goes into a single trailer and in about 50 sec when the load must be divided between two trailers. Desired payload, viz., the upper limit permitted by state law, is 10-1/2 tons for the front and rear trailers, i.e., a total of 21 tons. Thus, each trailer can take care of four to five packer truckloads.

A drawback is the tendency of refuse to lose its compaction as a result of the transfer operation. As a consequence, it is impossible to load to the maximum weight limit within the legal height limit, viz., 13 ft 6 in. Recompaction on the trailer body is accomplished by a Drott Cruz-Airs machine. This machine, which has a specially modified clamshell bucket mounted on a boom, exerts 8,000 lb of down pressure on the refuse in the trailer body. Voids disappear and the refuse is compressed so that its level is below that of the trailer top rail. With such compaction, it is usually possible to reach the legal load limit. The compaction operation takes about 10 min/double-trailer.

Because of the good compaction, the trailers can be unloaded neatly and efficiently at the disposal site by the cable pull-out method.

Transfer Station No. II sends out an average of 22 loads/day, and can on occasion reach a top of 42 loads/day. The station has a crew of 17 men. This crew includes eight tandem trailer drivers, a scale man, two Cruz-Air operators, a sweeper operator, three laborers, a vacation-sick leave man, and the foreman. Equipment includes the Cruz-Air, a Wayne sweeper, seven diesel tractors, and eleven two-unit trailer trains.

Rail Haul

Bugher, R. D. and Dr. Karl Wolf
"Rail-Haul Refuse Disposal"
The American City, 83(8):79, August 1968

The American Public Works Association Research Foundation is currently engaged in a $486,000 research effort to explore the potential use of rail haul. Transport by rail can be made an integral part of many different waste disposal systems. It can be used to move raw wastes or incinerator residue. If technically and economically feasible, large incinerator complexes could be designed to operate in the countryside where the environmental requirements would not be as stringent as in urban areas.

Preliminary findings of the study indicate compression and/or baling as the most effective and economical way for handling wastes in a rail haul system. Test results to date indicate that an expanded production-scale refuse-compaction program should be conducted immediately. The Foundation is preparing designs for transfer stations with capacities for 50, 100, 250, 500, and 1,000 tons/8-hr shift.

Economics: Costs developed suggest that a 500-ton/8-hr shift installation may cost about $1.0 to $1.5 million; and a 1,500-ton/8-hr day, about $2.0 to $3.0 million.

Railroad Cars: For the rail haul, the standard cars include gondolas, hoppers, flat cars, and box cars. Capital costs for all are about the same, viz., $12,000 to $20,000/car. Net loads of 100 tons/car are feasible. (The same cars hold about 100 cu yd of conventional freight.)

Train Types: Four kinds: 1) In type one, one or more carloads of refuse are handled as a part of a regularly scheduled freight. 2) In the second type, a special train is dedicated entirely to wastes hauling. The special train travels only between two points, makes no stops en route, and often pulls 100 or more cars. A special refuse train can run economically with fewer cars and with stops along the route. 3) The third type involves the use of the empty haul of an existing train unit. Unfortunately, this type is not universally applicable. 4) The fourth type is the rent-a-train. This concept was introduced last year for agricultural commodities by the Illinois Central Railroad. According to this plan, a shipper can rent eighty-six 100-ton cars plus motive power on short notice whenever requested for an annual charge of $1.0 million plus 1.5 mills/ton-mile of load. Waste rail haul of less than 100 miles suggests that a rate of about $2.00/ton or less is achievable.

To forestall difficulties imposed by shortsighted local officials, the Foundation considers it desirable that legislation be enacted authorizing an appropriate agency of a state government to develop plans and acquire sites for solid waste disposal facilities which could serve the needs for various communities within the state.

"In terms of economics, present estimates show that large-scale landfill operations made possible through rail-haul can be conducted at less than $1 per ton."

"Rail-Haul Station Operation for Combined Refuse Using the Heil-Tollemache Pulverizer"
Heil Company, 3000 W. Montana Street, Milwaukee, Wisconsin 53201, 1968

This brochure states that by pulverizing the refuse, its bulk is reduced by 50 percent. Milled refuse can be readily handled into covered gondolas or box cars, and air-transported from them to final landfill. Material rejected from the machine could be handled separately. Experience at Madison, Wisconsin, indicates that reject material amounts to 1.5 percent with a 150 mm grate size. The brochure includes a diagrammatic sketch of a building in which refuse is transferred from truck to railroad car.

Costs of grinding for a railroad haul operation are as follows (December 1968): a) 172 tons/day (1 grinder, two 8-hr shifts): labor, $1.2465/ton; equipment, $0.4054/ton; operating charges, $0.6837/ton; total, $2.3356/ton. b) 344 tons/day (2 grinders, two 8-hr shifts): labor, $0.7628/ton; equipment, $0.3456/ton; operating charges, $0.6312/ton; total, $1.7396/ton. c) 516 tons/day (3 grinders, two 8-hr shifts): labor, $0.5706/ton; equipment, $0.3230/ton; operating charges, \$0.6136/ton; total, \$1.5071/ton. d) 774 tons/day (3 grinders, three 8-hr shifts): labor, \$0.5705/ton; equipment, \$0.2213/ton; operating charges, \$0.6116/ton; total \$1.4034/ton.

"\$4.61 A Ton Asked to Railhaul Denver's Pickup Out-of-Town"
Solid Wastes Management/Refuse Removal Journal, 12(3):48, March 1969

Negotiations continue to be made between the city of Denver and the Denver and Rio Grande Western Railroad for the hauling of the city's household wastes. Cost estimates indicate that should the city continue to handle the entire household refuse operation, the annual cost by 1980 would be \$7,372,000, whereas the railroad maintains it could do the same for \$7,226,000 annually. In 1967, the railroad company offered to take the city's refuse at a cost to the latter of \$4.50/ton on the basis of a guaranteed daily minimum of 875 tons household refuse/day (90 percent of the city's total). The service would be provided on a 5-day/week basis. (The price asked for in the company's latest bid is \$4.61/ton.) According to the company's calculations, a total of 1,208 truck-miles/week would be saved with the use of its truck-rail system. In terms of travel time, this would amount to 81 hr/week.

"Milwaukee Picks Railhaul Instead of Incineration"
Solid Wastes Management/Refuse Removal Journal, 12(4):10, April 1969

The board of supervisors for Milwaukee County has accepted a joint bid from the St. Paul and Pacific Railroad and the Acme Disposal Corporation of Brookfield (suburb of the city of Milwaukee) to carry out a large-scale railroad refuse disposal program for the city of Milwaukee and other municipalities in the county. According to the terms of a 20-yr contract, the two companies would haul and dispose of the county's refuse in Acme-owned landfill. At a guaranteed minimum of 360,000 tons/yr, the charges would be \$6.23/ton. At 960,000 tons/yr, the charges would be dropped to \$5.45/ton.

The city of Milwaukee generates 330,000 tons of refuse/yr. Total production in the county will be about 475,000 tons/yr in 1970, 570,000 tons/yr in 1975, 680,000 tons/yr in 1985, and 920,000 tons/yr in 1990.

The final signing of the contract depends on two items: 1) the ability of the Acme Company to acquire and obtain approval from local officials to use a 760-acre site in Kenosha, Wisconsin, as a landfill; and 2) persuading a sufficient number of communities to join the program so that the minimum required tonnage can be supplied, viz., 360,000 tons/yr.

In the plan as tentatively approved, the county would bill all charges to the local governments and add its own costs of 21 to 52¢/ton, depending on volume, for amortization of capital expenditures. This would bring the per-ton cost for the individual communities using the service to a total of \$6.75 or \$5.66/ton, again depending on the volume involved. According to estimates, these costs would be \$2/ton less than would be the case were incineration used as the means of disposal.

To provide an incentive for those communities presently using incineration, the county plans to purchase these incinerators and then raze them. The reasoning behind this plan is that a community already possessing a usable incinerator may be reluctant to abandon it in favor of the rail haul systems. (Ed. note: Raising the air pollution standards could accomplish the same purpose!)

According to the plan as presently approved, a given load of refuse becomes the contractor's responsibility when the truck carrying it arrives at the scalehouse of one of the three transfer stations to be built. The load weight of the vehicle is automatically flashed to a central point inside the transfer station. The driver is then directed to the unloading hopper in which to discharge the load of refuse. The refuse is removed from the hopper and fed into a Model P-70 Anchorpac, which is capable of compacting 10 cu yd of refuse/min at the conversion ratio of 500 lb/cu yd. This and other arriving refuse is compressed within an enclosed 107-cu yd steel container with a 30-ton capacity. When the container is full, it is detached from the Anchorpac unit and with the use of cable is rolled to the transfer dock. Two such containers are mechanically placed on a single railcar.

Each evening, a train will pickup 16 railcars at each of the three 1,000-ton/day transfer stations and haul them to Acme's landfill. At the landfill, each container is picked up by a large carrier which hauls the container to the disposal trench, unloads it, and returns it to the rail-siding. There, the container is washed, cleaned, and replaced on the railcar for return to the transfer station.

Dye, R. L.
"Rail Haul of Solid Waste"
Paper presented in the Solid Waste Seminar held at Albuquerque, New Mexico under the auspices of the Eidal International Corporation, 245 Woodward Road, S.E., Albuquerque, New Mexico, 16-17 April 1969 (The author of the paper is Project Engineer of Metcalf and Eddy, Boston, Massachusetts)

The following is a direct quote of Mr. Dye's resumé of his paper:

Briefly, the so-called rail haul method of solid waste disposal is a system which involves three basic operations: 1) processing at a central station to reduce volume and produce easily handled units; 2) haulage by rail to a point of disposal; and 3) final disposal by landfill. If it develops satisfactorily, and there are still questions to be answered, it appears that there will be situations where this disposal method will be competitive with incineration both as to cost and to final fill volume.

Currently, rail haul is emerging from the talking stage. Eastern Land Reclamation Company of Philadelphia has a contract with that city for disposal of part of its refuse by rail haul. Construction of the compaction-transfer station is now underway. Also underway at this time in the Boston area is the design of a compaction station to be built in Cambridge, Massachusetts. In the news are proposals for other cities such as San Francisco and Denver for disposal of their solid wastes. The proposed San Francisco operation involves hauling of refuse some 375 miles to a desert disposal area.

Westchester County is located just north of New York City and has a population of about 900,000 people. Approximately 26 of the 44 cities, towns, and villages now dispose of their refuse at a county-owned and operated sanitary landfill facility. Both land area and cover material at this sanitary landfill are running out very rapidly.

"Western Pacific, Golden Gate, Sunset Companies Solid Waste Disposal Plan for the City of San Francisco"
Western Pacific Railroad Company, San Francisco, California, 1969

The plan was developed as a result of a study in which the Western Pacific Company commissioned Kaiser Engineers to study San Francisco's wastes problem and to come up with a plan that would be reliable, low in cost, and aesthetically acceptable. The system would have to accommodate eight to ten thousand tons per week. The wastes would be hauled to the Lassen County disposal site (350 sq miles of desert land). A 66-mile strip of land along the railroad right-of-way would provide wastes disposal sites for the present population of the Bay Area for a period of approximately 600 years, and with a fill depth of only eight feet.

A transfer terminal will be built in San Francisco. An automatic scale will weigh all loaded trucks and furnish weights for billing purposes. To control dust and odor, water will be sprayed upon the material as it is removed from the collection vehicles. Refuse will be discharged from the collection trucks directly into containers on flat cars, and the refuse will be compacted by back hoe tampers. This operation will accommodate at least 100 trucks/hr. In turn, the container lids will be closed, sealing the refuse in a watertight container for shipping. Automated equipment will have the capability to move a car loaded with full containers and replace it with cars loaded with empty containers every three minutes. Flat cars with containers will leave San Francisco five days each week, Monday through Friday. (Ed. note: As of 1 August 1969, the plan has fallen through.)

Pipe Transport

Clift, M. A.
"Experience with Pressure Sewerage"
Journal, Sanitary Engineering Division, American Society of Civil Engineers, Paper 6150, 94(SA5):849, October 1968

The transport of sewage and waste liquids by means of a closed-to-atmosphere pressure sewer system offers a substantial reduction in sewer construction costs in locations, or under conditions adverse to gravity sewerage. Experience with pressure sewerage over a three-year period at Radcliff, Kentucky, is described in the article. A discussion is included of the factors influencing the use of pressurized sewerage, design considerations, economies obtained, and operational and maintenance procedures developed. Information is included on the availability and performance characteristics of individual pumping units. Estimates are given on the costs of two proposed projects involving pressure sewerage.

As an example of the savings in the situation described in the article, the following may be quoted: Financing gravity sewers would have required $3,170 per connection. Based on 4.625 percent interest, the interest on financing would have been $146.61/year. Pressure sewerage involved financing of $1,346/installation. Interest is $62.25/year.

In the three-year operational period, operational difficulties have been largely electrical in origin. Failure of timers, relays, and condensers have been frequent. The biggest factor in these failures has been corrosion.

The Radcliff system is primarily of the conventional gravity type, with conventional sewage lift stations. However, certain areas could not be economically provided with sewers by these means. In these areas pressure sewerage was used. This section constitutes about 2 percent of all the residences. The number of residences served by pressurized sewerage is 42.

"Down to the Sea in Pipes"
Industrial Research, 11(1):28, January 1969

During the past four months, the technique of collecting and disposing of concentrated wastes via pipeline to the ocean has been studied by Dr. R. A. Erb of the Franklin Institute Research Laboratories, Philadelphia, Pennsylvania. The system would be regional, gathering wastes from plants along its route to the sea. Disposal would be beyond the continental shelf in the deep ocean. Preliminary estimates indicate that costs would be only 25 to 30 percent those of barging wastes to sea beyond the continental shelf. Wastes would be discharged at a depth of 370 m or more. Dilution would be extensive. It is estimated that if 150,000 m^3/day of wastes were emptied in the ocean for 1,000 years, the effluent would have been diluted with five million times its volume of seawater.

Waller, D. H.
"An Examination of the Benefits and Disadvantages of the Project Scheme with Respect to the Disposal of Solid Wastes"
American Society of Civil Engineers Combined Sewer Separation Project, Technical Memorandum No. 10, American Society of Civil Engineers, 345 E. 47th Street, New York, New York 10017, 1 February 1969

The purpose of the memorandum is to examine considerations that are important to an evaluation of the feasibility and benefits of adapting to the transport of solid wastes new systems of pressure sanitary sewers installed as a method of diverting sanitary sewage from existing combined sewers. Considerations common to both open channel and pressure sanitary sewers are discussed first, followed by an examination of the considerations peculiar to the adaptation of the new systems to the transport of solid wastes.

Little work has been done to determine the velocities required for transporting solid wastes other than garbage. In Los Angeles County studies, ground refuse (glass and metals removed) was transported 13 miles through sewers in which the average velocity was just under 4 fps. Zandi has transported ground solid wastes (particle sizes up to 1 in.) at concentrations of 2 to 12 percent in pressure pipelines. He noted that head losses for concentrations up to 4 percent were no greater than with water alone. A colloidal matrix capable of holding solids in suspension was formed at concentrations less than 2 percent.

It is recommended that if ground solids are dumped for transport into sewers in which the sewage flow is not great enough to move the solids, the flow should be augmented periodically to prevent any objectionable accumulations. If not enough sewage is available for this purpose, then supplementary water would be needed. If segregation is a prerequisite to introduction of the wastes into the sewer, this might constitute a significant objection to the use of sewers as carriers. Although equipment may be available for grinding the refuse, at present there is no pulper or grinder pump suited to handling refuse.

Solid Wastes in Sewage Treatment Plants: To avoid costly handling at the treatment plant, items such as cans, bottles, crockery, ashes, etc., must not be discharged into the sewer. In laboratory experiments, about 93 percent of the total solids in ground refuse (freed of glass, cans, etc.) were removed as primary sludge. In a municipal operation at Jasper, Indiana, about 75 percent were removed. On the basis of present refuse production estimates, sludge production would be about 25 times that of normal sludge accumulation if refuse were transported with sewage. Loading on secondary treatment facilities would be increased by 50 percent to 75 percent.

Cost Benefit Considerations: Potential benefits include increased convenience to householders, reduced odor, fly, and rodent problems, reduction or elimination of spillage, noise, traffic congestion, and unsightliness, and reduced property devaluation. It is too early to make firm or even fairly firm cost estimates. (Ed. note: The "true believers" are convinced that the cost of handling garbage with sewage would be about one-quarter that of surface transport.) Zandi, basing his estimates on the use of present technology, concludes that pipe transport would be competitive with surface transport when the haul distance reaches 50 miles or longer.

If refuse is transported in pressure sewer systems, the self-cleansing requirements would be more stringent than those of open-channel systems, since the amount of deposition at minimum flows is greater in the former than in the latter. The Liljendahl Vacuum Sewerage System would involve the use of less water to transport the solids than pressure systems would need, and it would provide much greater velocities than open-channel or pressure systems. This system has been used to transport boiler ashes. Pipe sizes are such that grinding would have to precede the introduction of solid wastes materials into the system.

"Vacuuming Trash"
Industrial Research, 11(2):29, February 1969

A two-year trial is being given for the vacuum method of transporting trash in the Los Angeles County Martin Luther King Memorial Hospital in the Watts section. The vacuum is 25 torrs (1/15 normal atmospheric pressure), and is able to move basketball-sized rocks as rapidly as 55 mph as far as 8 km and up 30-degree slopes. The purpose of the system in the Watts hospital is to move trash horizontally and thus eliminate the pushcarts needed in hospitals.

The system is based on the AB Centralsug system developed in Sweden. (The U. S. rights to the system are owned by Aerojet-General Corporation, El Monte, California.)

A dual system will be installed in the Watts hospital — one pneumatic network to carry refuse and another for linens. An inward flow of air in vertical chutes throughout the hospital complex is maintained by means of a battery of turbo-extractors.

When upward movement is needed to get around an obstacle, a spiral configuration inclined at 30° is used. All of the pipes are 0.5 meter in diameter. Straight-line horizontal runs of 2.8 km have been achieved. It is estimated that 8-km straight-line runs would be feasible before booster pumps would be needed. In a typical hospital, vacuum would be applied about 15 percent of the time during peak hours and 5 percent during off hours.

ECONOMICS

Arora, S. R. and W. R. Bunker
"Examining Costs in Solid Waste Disposal"
Public Works, 98(10):134, October 1967

The article presents a simple model for quantifying the cost of collection and hauling. The time required for collecting a route, T, may be divided into three components: $T = T_1 + T_2 + T_3 \ldots (1)$ in which T_1 = average time required for travel between the collection points of each route, T_2 = average time for loading at each point, and T_3 = average time required for the roundtrip between the central point of the collection route and the disposal site. The shortest haul distance required to visit n points distributed randomly in a Euclidean space of two dimensions of area A is asymptotically given by $B\sqrt{2An}$ for large n, where B is a constant approximating 0.5. For small values of n, B is a random variable. According to simulation studies, B approaches zero quite rapidly as n is increased. On this basis, the expected interstation distance required to visit n collection points will be taken as $DB\sqrt{2An}$, in which D is a constant greater than 1. On the basis of an empirical study, D is taken as equal to 1.2.

Mathematical Description: Let a = average time required to collect at one collection point (hr/collection point); L = distance between disposal site and central point of the route (miles); S' = average speed of travel on rountrip between disposal site and collection area (mph). Equation (1) becomes: $T = BD\sqrt{2An}/S' + an + 2L/S''$ ... (2) in which the three components on the right-hand side represent T_1, T_2, and T_3, respectively. Let C denote total truck capacity for collection and transport, and b denote average waste collected at one point, and assuming the units of C and b are the same, then: $m = C/b$ ... (3), in which m denotes the average number of collection points per full truckload of wastes. The number of collection points which can be serviced at one trip are limited either by the capacity of the truck or the length of the working day. Therefore, this condition limits n, the number of points constituting a route.

System Evaluation: Two systems are evaluated. In System 1, each route is serviced by one truck with one driver and two helpers. All three men make the roundtrip to the disposal site. Several trips may be made per day. In System 2, the "Continuous Flow Refuse Collection System" is followed (see Althouse, G. F., "Continuous Flow Refuse Collection," The American City, 81, December 1966). In this system, front-loading trucks are used in conjunction with three "trains" (tow car pulling three trailers). Two men operate each of the trains, and only the driver is required in each of the two trucks.

System 1: Assuming a collection truck capacity of 18 cu yd, and the refuse at each point is 0.09 cu yd, then m = C/b = 18 cu yd/0.09 cu yd per collection point = 200 collection points per truckload. Assuming the following hypothetical parameters: A_1 = 5 sq miles/route; n_1 = 200 collection points/route; a_1 = 0.02 hr/collection point; S' = 10 mph; S" = 15 mph; L = 10 miles, D = 1.2; and B = 0.5, and substituting these values into the basic equation, the result is: $T = (1.2)(0.5)\sqrt{(2)(5)(200)}/10 + (0.02)(200) + (2)(10)/15 = 2.68 + 4.00 + 1.33 = 8.01$ hours. This value indicates that one truck per day is required for 200 collection points.

System 2: The assumption is made that the total capacity of each train is 9 cu yd. Refuse collected at each point is 0.09 cu yd. Then m = C/b = 9 cu yd/0.09 cu yd per collection point = 100 collection points per train. The following parameters are assumed: A_2 = 2.5 miles/route; n_2 = 100 collection points/route; S' = 10 mph; D = 1.2; B = 0.5. The total time per train is modified according to the following components: a) time for the train to travel between collection points; b) time to load a train; c) time to transfer load to the truck; and d) time for the train to rendezvous with the truck. Component of time (a) is: $DB\sqrt{2A_2n_2}/S = (1.2)(0.5)\sqrt{(2)(2.5)(100)}/10 = 1.34$ hours. The component for time (b) is: $an_2 = (0.02)(100) = 2$ hours. The component for time (c) is: $an_2/12 = (0.0017)(100) = 0.17$ hours. A value of 30 min (0.5 hr) is assumed for component (d). The total time required to service each route comprised of 100 collection points is the sum of the four components: $T + 1.34 + 2 + 0.17 + 0.5 = 4.01$ hours. In one day, therefore, each train can service two routes, or a total of 200 collection points. In making evaluations such as the two above, appropriate values for the various parameters must be conscientiously determined for a given system. The model can be used for analyzing categorically the costs incurred in a given system, predict future requirements and costs, and evaluate differences between alternative systems.

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"Conversion to Municipal Refuse Collection Results in Multiple Benefits"
Public Works, 99(2):78, February 1968

The town of Saline (population 4,200), Michigan, was faced with a problem when its refuse contractor was not interested in renewing his contract and the town was due for rapid expansion because of substantial industrial plant growth. The town had no refuse equipment of its own. The town decided it had no alternative but to go into refuse collection on a permanent basis. Wisely, the council decided to invest in new, up-to-date refuse handling equipment and the personnel to operate it. Accordingly, a 25-yd packer ($18,000) was procured on a lease-purchase arrangement. The pickup schedule involves collecting in the north half of the city on Tuesday, in the south half on Thursday, and on Monday, Wednesday, and Friday service is provided to the schools and commercial stops. In adding the cost of operation, maintenance, salaries, depreciation, and other expenses, an annual net cost of $21,000 is predicted. Under the unsatisfactory service of the private contractor, the annual cost to the city and its citizens had been $33,000.

"Ohio Municipal League Measures Hauler Costs"
Solid Wastes Management/Refuse Removal Journal, 11(12):20, December 1968

This is an excellent article, the principal features of which are charts showing rates and charges for rear alley, curb, houseline front and rear service by contract. The survey was made by the Ohio Municipal League to determine current refuse collection practices. A total of 405 municipalities responded to the comprehensive questionnaire sent to every city and village in the state.

In Ohio, three types of collection service are in general use: private haulers, municipal collection, and collection by contract (with private haulers). Of the 405 respondents, 218 use private haulers; 140, municipal collection; and 66 contract for the service. Some of these use more than one type of service.

PERSONNEL

Mendoza, E.
"Larger Trucks Permit Reduction in Collection Crew Size"
Public Works, 99(4):106, April 1968

An increase in collection efficiency and reduction in operating costs accompanied the reduction of refuse collection crews from three to two in San Diego, California. Collection frequency is once per week at the public right-of-way. Funding is by property tax.

When the three-man crew was in effect, the average daily workload per man was 14.35 tons refuse. A 20-cu yd packer averaged 42 total travel-miles/day. With the new system, the trucks are 25-cu yd rear-load packers. Driving and swamping duties are divided equally between the two men of the two-man crew. The crew of two pickup an average of 14.25 tons/day (the same as did the three-man crew). The reason is the larger capacity of the truck. The old truck could carry only five tons refuse, the new truck, eight tons, thereby reducing the daily trips to the disposal site from three to two. The larger truck travels about 30 miles/day. The second reason for the increase in efficiency was the increase in pay to the new men.

COST ANALYSIS OF ALTERNATIVE PROCEDURES

2-Man Crew, 25-yd Packer		3-Man Crew, 20-yd Packer	
Labor		Labor	
S.C. III ($647 x 12)	$ 7,764	S.C. II ($616 x 12)	$ 7,392
S.C. II ($616 x 12)	7,392	S.C. I ($532 x 12 x 2)	12,768
Equipment		Equipment	
30 miles x 260 days at $1.02/mile[a]	7,956	42 miles x 260 days at $0.81/mile[a]	8,845
	$23,112		$29,005
Tons		Tons	
14.25 x 260	3,705	14.25 x 260	3,705
Cost/ton	$ 6.24	Cost/ton	$ 7.83

[a]Includes depreciation, fuel, oil, and maintenance.

Farnum, W. F.
"Municipality Finds Plan Cuts Operating Costs, Speeds Work"
Solid Wastes Management/Refuse Removal Journal, 12(1):6, January 1969

In a system in operation in Inglewood, California, involving one man/refuse truck, it was found that with this setup one man picks up as much refuse as two men did previously. The equipment used by the one-man crew is designed to reduce work effort in that it has a dual steering wheel and side-loading facilities. Containers too heavy for one man to lift are left for a return trip by two men. Continued public education has reduced such incidents to negligible proportions.

A great deal of adverse feeling was generated when the changeover from a two-man crew to a one-man crew was proposed, especially since this was the first time such a changeover was proposed by a municipally-operated system. Despite this fact, it was adopted because studies showed that a one-man crew system would prove less costly than preserving the former multiman crew system accompanied by a transfer station complex.

The transition from the two-man crew to the one-man crew system took about eight years. During the eight-year period, despite a 42 percent population increase and a more than 50 percent rise in the amount of collected refuse, the number of truck trips to the landfill site decreased by 24 percent. The one-man trucks have 35-cu yd capacity as compared to the 20-cu yd capacity of the old trucks. Man hours per ton decreased by 50 percent. The typical daily collection of each man includes 902 containers, 240 boxes and bags, 65 bundles, a chair, two hot water heaters, 250 stops, three collection miles, and 9.25 tons of refuse.

The transition was slow because of the gradual acquisition of the 35-cu yd trucks and employee attrition. Factors making the one-man system successful are: a) There are no old men in the department. (The average age is 27, the minimum 19, and the maximum, 45.) b) Length of service is short. Refuse collection is not a career. The average length of service, exclusive of supervisory personnel, is three years. Only high school graduates wishing to train for future jobs requiring technical skills are hired. c) Salaries are high. d) Training is essential. Each man takes an eight-week course entitled "Truck Driver Training" and must obtain a Class II chauffeur's license.

Accidents, both vehicular and personal injury, have been reduced by more than 65 percent over that with the two-man operation.

The following table as given in the article lists some changeover data.

	1/1/60	1/1/68	% Increase or Decrease
Population	66,598	99,940	+ 42.5
Dwelling Units	25,330	37,097	+ 46.5
Annual Tons of Refuse	24,265	36,051	+ 50.5
Total Truck Loads (or trips to landfill site)	5,855	4,431	- 24.3
Annual Man-Hours	52,167	39,742	- 24
Man-Hours/Ton	2.19	1.08	- 50.6

"Injury Record Tops all Others in the Country"
Solid Wastes Management/Refuse Removal Journal, 12(1):10, January 1969

The survey was made by the National Safety Council. The Council pointed out that while certain hazards are inherent in the nature and conditions of the work itself, there are many others which could be mitigated with the application of suitable measures.

Hazards peculiar to the operations of refuse haulers are narrow streets and alleys; inadequate, old, or poorly maintained equipment; faulty design; and variation in requirements for size, weight, and contents of refuse bins and bundles. A table, too lengthy to reproduce here, is given in the article to show the number and types of injuries occurring in a typical operation during a one-year period. Personnel may be required to walk as much as 12.5 miles/day and handle from one to 15 tons of refuse a day for a crew of three. Most injuries in refuse collection originate as a result of slips and falls. These lead to strains, sprains, back injuries, cuts, amputations, bruises, lacerations, fractures, and eye injuries.

It is generally conceded that human errors far outweigh mechanical failures as causes of the accidents. An analysis of the general causes relating to the human element led to three conclusions: 1) Improper lifting during the performance of repetitive tasks or overexertion produces strain on the back. 2) Improper acts of collectors during truck movement and frequent in-and-out of vehicles produce many accidents. 3) Analysis suggests a need for training in lifting techniques and in truck discipline.

A table is presented which shows an accident record of a typical refuse operation, and another which lists the frequency-severity of accidents in refuse collection in major U. S. cities. They are too lengthy to reproduce in this presentation.

Brigman, V. L.
"Time and Motion Studies Aid Solid Waste Collection"
Public Works, 100(2):84, February 1969

Areal organization of the refuse collection system of the city of Atlanta, Georgia, is based on the use of four stations or substations, including special services and night garbage collection and street-cleaning units. For its refuse servicing, the city has 146 garbage trucks, 66 rubbish trucks, 20 mechanical brooms, and 44 "scouts" or "scooters" utilized on mobile collection routes.

The use of time and motion studies has been an important factor in obtaining an efficient operation. Operations include: studies of residential and commercial garbage; refuse and street-cleaning routes; pushcart ("white wings") routes; emergency procedures concerning personnel and vehicles; citizen contact on collection problems; and holiday procedures.

In operation, the time and motion supervisor and his assistants attend the roll call of the district inspector they are in the process of surveying. The manner in which the roll call is made is observed, as are the crews as they prepare for the day's work. One assistant time and motion inspector is assigned to each of the two trucks. They ride to the first pickup point on the route; times of departure and arrival are recorded. Manner of the crew in servicing its route as well as of the driver in his handling of the truck are observed. As the route is covered on Mondays and Tuesdays, maps are drawn of all of the streets the route covers. Unnecessary deadheads are eliminated, and the coverage of new streets is adjusted in routing. The survey man checks on the condition of the "garbage" cans at the residential sites.

The big problem is to keep the crews moving at their usual pace and not at an accelerated one because of the observation crew. Routes covered on Monday and Tuesday are again surveyed on Thursday and Friday. Each service stop is recorded on a counter to show how many units are serviced by the trucks and crews during the course of the four-day survey. When the survey of the Hill station (one of the four substations) shall have been completed, each district inspector will be given a map and information sheet of each of the eight routes. The map and information sheet are of great value to inspectors in locating their trucks at a specific time, and to new drivers in familiarizing them with their routes.

"Sets up Community Operation for Full Service in 5 Months"
Solid Wastes Management/Refuse Removal Journal, 12(2):10, February 1969

Within a five-month period, the Sanitation Department of the city of Oakland Park, Florida, has been able to set up a refuse collection and disposal operation to meet the needs of its 15,000 citizens. The daily production of refuse is 20 tons. Eleven full-time men are on the payroll. The number of residential accounts amounts to 4,000. In addition, 300 spots for containers are committed. This number soon will be increased to 500. Four collections are made weekly for the residential accounts, once each weekday for the commercial and industrial accounts. Tuesdays and Thursdays are reserved for picking up household wastes, and Mondays and Fridays for yard trash and green cuttings from the residential accounts.

To provide this service, the following equipment had to be purchased: Four Evos, two LoDals, three container trains, one jeep, and two Commander pickup trucks. The LoDals are 32 cu yd transfer trucks, one for wet putrescible waste, the other for trash. The city is divided into four areas for the pickups, with two areas and two routes assigned to each truck. Four trucks each having a crew of two serve each area. Both men in the crew serve as driver and loader; the last man back to the truck is the one who drives to the next stop. When the container is full, the vehicle is driven back to the lot, where the container contents are compacted. The container is removed from the truck and replaced by an empty one. The operation takes about three minutes. About six containers are filled per week.

Six men are used in the train operation, in which curbside refuse is collected. The collected wastes are transported by a LoDal either to an incinerator nine miles away or to a landfill.

All equipment is installed with a two-way radio system.

Applicants for sanitation collection must have a driver's license. After being shown how to operate the equipment, he is "trained" by "doing," i.e., he is taken along as a third man on a vehicle always operated by two experienced workers. He "graduates" when the latter deem him suitably trained. The new man's pay is $96.40/week at the start. At the end of a four-month probationary period, his pay goes up to $101/week for a 40-hour work week. Overtime is paid for work in excess of 40 hr/week. If allotted work is finished in less than 40 hr/week, the man receives full pay for 40 hours.

A budget of $250,000 yearly is allotted the solid waste collection and removal operation. Customer revenue about meets this budget.

"Honolulu Works Crewmen on a Twenty-Hour Week"
Solid Wastes Management/Refuse Removal Journal, 12(2):38, February 1969

The number of employees in the Honolulu city-county refuse department is about 300. They work an average of four hours a day, five days a week, with alternate days off. About half of the workers hold second jobs, as well they must, since the pay scale is only from $458 to $508 monthly, not including overtime. Salaries for drivers and workers in other categories are higher. Despite the short hours, the work is as demanding as any full-time job, since the amount done is compressed into a shorter period of time. It takes three men only approximately five minutes to pull lids off waiting refuse cans, shake out the contents of approximately 50 containers, and return the cans to the sidewalk in front of a high-rise apartment building. A typical crew collects about 20 cu yd of rubbish in an hour. It is this speedup system which makes it possible for a crew to complete its scheduled work in so short a time.

A major penalty accompanying the speedup is the high injury rate. Because of the type of work, the percentage of mishaps and men who call in sick is higher than that of any other city division, as well as the highest accident rate for employees in the county and state.

Stone, R.
"Fatigue Study Reveals One-Man Crew Doesn't Tire any Faster than Larger Number"
Solid Wastes Management/Refuse Removal Journal, 12(5):14, May 1969

This is another article based upon an evaluation of one-man collection crews as compared to 2- to 3-man crews. (See abstract for "Municipality Finds Plan Cuts Operating Costs, Speeds Work," by W. F. Farnum.)

The byline for the article indicates the major conclusion, namely, that weight handled, not amount of bins, seems to be the answer. The objective of the study was to explore origins of fatigue in a collection crew and to determine what effect, if any, size of crew and weight lifted have on the degree of fatigue. Data obtained from a field survey of three municipalities were used in making the evaluation. The results indicate that a one-man crew does not become more fatigued than do his counterparts on two and three-man teams. One-man crews consistently loaded eight or more tons/day from curbside collections.

A second area of study was the fatigue created by lifting many containers at a single stop. In this phase, resort was had to experimentation in which was assessed the rate of performance deterioration resulting from both loading height and container plus contents weight. Loading heights were 30, 42, and 48 in.; weights were 45, 60, and 75 lb. Subjects serving as the "test" crew members ranged in weight from 160 to 200 lb and had no experience in loading refuse.

Analysis of the data obtained in the experimentation showed that the total weight of the filled container is a positive factor in the determination of performance, and that the addition of each 10-lb increment to the container weight between 45 and 75 lb resulted in an additional 0.7 sec loading time/can. The increase was relatively constant whether the cumulative loading was 1,000, 3,000, or 5,000 lb. The effect of loading height on performance was not significant.

"Municipal Strikes are Costly Affairs"
Refuse News (Gardena, California), p. 3, 5 May 1969

The article, published in a monthly publication (newspaper format) serving the refuse industry in California is excerpted here to provide information by way of a case history on the cost of strikes. In the summer of 1968, the sanitation crews of Santa Monica went on strike. The cost to the city for the strike and the subsequent legal proceedings by dismissed trash men suing for reinstatement in their jobs was $73,005. Of the total, $58,710 was spent directly on the strike, $14,295 on legal battles which ranged over four months of hearings. Included in the city's direct strike costs was a total of $12,137 paid to a private contractor to haul away a portion of the 1,173 tons of trash that accumulated uncollected during the strike.

MISCELLANEOUS

Andrews, J. B.
"Operation Junklift — A Community Public Works Program"
Public Works, 99(4):96, April 1968

A survey made of abandoned automobiles in Portland, Maine, showed that there were "nearly 1,000 junks within the city limits and over 200 in the fire-block Bayside area alone." The elimination of the junks was regarded as a three-step process: 1) Location and legal release of the vehicles; 2) Removal of the hulks to a central staging area; and 3) Final disposition of the scrap metal.

The cleanup operation was made a community-participation affair. In the collection phase, the city's only contribution consisted of two dump trucks and one small crane. Donations of flatbed trucks and additional cranes came through the activity of local societies and organizations. Disposition of the collected automobiles was done by giving them to a local dealer who sold them to a company for prolerization. A portable crusher was used to compress the junked cars for transport. The crusher is mainly composed of 2-ft deep, steel I-beams mounted on a low-bed trailer. It is powered by a 1962 Ford, 352 cu in. V-8 engine which generates crushing power through a system of four 20,000 psi hydraulic valves. (The operation is also described in The American City, 83(2):33, February 1968.)

"Hauling System as Late as 1947 was a Horse-Drawn Operation"
Solid Wastes Management/Refuse Removal Journal, 11(7):10, July 1968

The title is somewhat misleading, in that the greater part of the article is concerned with modern waste management in the cities Tel Aviv and Jaffa, Israel. The density of the refuse in the two cities has decreased from 540 to 510 lb/cu yd in the 1940's and 50's to 420 to 400 lb/cu yd at the present time. The per capita volume of production has increased to the extent that the 12-gal cans formerly used for storing household wastes are being replaced by 18 to 30-gal containers. The city supplies the bins to the householders, although the latter refund the city by way of $2.00/yr charge for six years. The municipality is responsible for the periodical washing of the bins.

Collection men pickup the bins from inside yards or backyards. The collection team consists of one driver and six men. Two take the bins to the street, two dump them, and two return them to the yard. A fleet of 80 trucks (including 60 French made, 12-yd Semats) is operated by the city. The collection schedule for residential and commercial areas includes three to six pickups/week. The dustless method of collection has been introduced and found to be successful.

"A Successful Attack on Automobile Blight"
The American City, 83(2):33, February 1968

"By trying a new approach to an old problem, Portland, Maine, collected and disposed of approximately 400 junked cars." The actual collection required only four days and cost about $3.19/car. The "disposal" was accomplished in three stages: 1) locate the automobiles, 2) remove them to a central staging area, and 3) final disposition. The location and transport stages were accomplished mainly by donated labor of members of local organizations. The job of removing the collected automobiles was awarded to a contractor from a nearby city on the basis of no cost to Portland. The contractor crushed the cars by means of a crusher machine of his own design. He sold the junked cars to the Prolerized New England Company of Everett, Massachusetts.

DISPOSAL

SANITARY LANDFILL

Design and Operation

Smith, C. D.
"A Sanitary Fill Inside the City"
The American City, 83(4):90, April 1968

The city of Cedar Rapids, Iowa, has a sanitary landfill inside the city limits and close to good residential areas, and yet it arouses no wrath in the citizenry residing near the operation. Two key factors account for the success of the operation: 1) meticulous attention is given to details to ensure the fill being operated as truly a sanitary landfill; and 2) the fill will eventually eliminate what had been a public eyesore, namely, an abandoned quarry occupying 94 acres within the city. The landfill serves about 36,000 homes plus Cedar Rapids' large industrial community.

Waste disposal is a function of the city's health department. The reason is that in the city refuse disposal is regarded as a health concern — an essential in protecting the environment. A total pickup service is supplied. (Exception: No rubbish items larger than two feet in diameter, four feet in height, or more than 80 lb is picked up.)

Operation of collection and disposal is financed by a millage levy. In 1966, $45,880 was spent on the landfill exclusive of capital improvements. The cost covered payroll, parts, fuel, etc. Collection costs totaled $293,118. (In 1956, the combined cost — landfill and collection — was $143,000.)

The article also gives details of operation and lists the equipment used at the facility.

Davis, K.
"Planned Landfills Cut Costs and Complaints"
The American City, 83(12):102, December 1968

Fort Worth's (Texas) two poorly functioning incinerators were shutdown and various improperly operated dumps were discontinued. In their place has been substituted a system of disposal consisting of sanitary landfill in the true sense of the term. The sanitary landfill method of disposal was selected over the incineration and composting methods because it is lowest in cost. Over the period through 1980, disposal by landfill should average at $1.13/ton; whereas incineration would cost $5.25/ton; and composting, $3.50/ton. The city now operates five model sanitary landfills which service all refuse disposal needs. Their total acreage is 350 acres. All incoming refuse is weighed and accurate tonnage records are kept. Charges to private individuals range from 25¢/passenger car to $3.25/packer truck or three-axle hauling unit.

The landfills present an attractive street appearance. "Redwood gates and small chalet houses decorate the entrances. High wire fences (15 to 20 ft) keep paper from being blown from the grounds."

It was found that the city's existing Cat 977H crawlers cost $1.29/hr to operate as contrasted with $2.56/hr for other crawlers. Its four new D-8's cost $1.46/hr to operate. The D-8's employ special V-shaped landfill blades.

Ground water contamination and drainage are prevented by never digging down to the water table and by contouring the fill.

Stone, R. and E. T. Conrad
"Landfill Compaction Equipment Efficiency"
Public Works, 100(5):111, May 1969

The article describes work and reports results obtained in a project to study and demonstrate improved sanitary landfill compaction. The location of the activities was a landfill owned by the city of Santa Clara, California. The fill operation is a normal cut-and-cover operation, varying in depth from 10 to 20 ft. In the studies the authors a) measured and evaluated the inplace density of refuse, using alternative rubber tire, steel wheel, and crawler type of equipment; and b) analyzed multipurpose equipment capability for other normal landfill tasks in order to compare the overall suitability of the alternative crawler and wheel type equipment.

Formulas for density calculations were as follows: a) Refuse density prior to soil covering = weight of refuse/net volume of refuse. b) Refuse density after soil cover = weight of refuse plus soil cover/total volume of soil cover plus refuse.

Conclusions are as follows: 1) The wet and dry densities achieved with the use of the Cat D-9 and the rubber-tired FWD Wagner were not significantly different. 2) The wet weight density of refuse spread and compacted by the steel-wheeled FWD Wagner was about 20 percent greater than that by the Cat D-9. 3) Placement of the soil cover caused the underlying refuse to settle approximately one-half of the soil cover thickness.

Generally, the Cat D-9 was more flexible in performing all tasks on the landfill than were either the rubber-tired or the steel-wheeled FWD Wagner. The steel-wheeled FWD Wagner was far superior to the rubber-tired unit with respect to refuse compaction, maneuverability, traction, maintenance, and human factors. "Adverse effects of installing the steel wheels were: 1) More power was required to drive the equipment, and 2) the operating speed was reduced." The FWD Wagner was seldom used for earthwork because it did not perform that function as efficiently as did the track machine.

The mean rate of the crawler tractor was 64 tons/hr; of the rubber-tired compactor, 63; and of the steel-wheeled compactor, 71. The mean peak rates of the three types were, respectively, 109, 97, and 95 tons/hr. A comparison of the major items of cost are as follows: a) Maintenance, fuel, and repairs — crawler tractor, $12,835; rubber-tired compactor, $3,480; and steel-wheeled compactor, $1,603. b) Labor ($5.40/hr including 23 percent fringe benefits, 40-hr week) — crawler tractor (7/67 to 9/68), $14,040; rubber-tired compactor (7/67 to 1/69), $6,552; and steel-wheeled compactor (2/68 to 9/68), $7,488. c) Total costs (including depreciation and capital costs) — crawler tractor, $38,314; rubber-tired compactor, $13,995; and steel-wheeled compactor, $13,620. d) Operating costs in dollars/hr — crawler tractor, $26.53; rubber-tired compactor, $24.68; and steel-wheeled compactor, $14.95. e) Average rate for spreading and compacting refuse in tons/hr — crawler tractor, 35; rubber-tired compactor, 30; and steel-wheeled compactor, 35. f) Unit costs in dollars/ton — crawler tractor, $0.76/ton; rubber-tired compactor, $0.82/ton; and steel-wheeled compactor, $0.43/ton.

Cowman, H.
"Town Turns Landfill Over to Private Contractor"
Solid Wastes Management/Refuse Removal Journal, 11(8):14, August 1969
(Ed. note: The interest potential of this article is not so much the relative virtues of private and public ownership and operation, but rather its excellent description of an efficient landfill operation.)

Faced with the need for making a sizable expenditure in the new equipment and the hiring and training of a crew to operate a landfill in accordance with the new regulations recently coming into force in Illinois, the city of Rock Island, Illinois, decided to contract out its waste disposal operation. Rite-Way Disposal Company, the successful bidder, took over the disposal operation from the city and undertook to conduct the landfill such that the disposal site ultimately could be converted to a park.

On the average, 1,600 cu yd of mixed refuse is received daily. About 40 percent comes in city-operated packers. The remaining 60 percent comes from private contractors and neighboring industries. An important feature in ensuring the conduct of an efficient operation is the regularity with which the city-carried trash arrives at the disposal site. During peak arrival periods in late morning, a five-truck face is worked to minimize truck backups. As activity slackens in the afternoon, the face area is reduced to a three-truck face; and, finally, to a one-truck dump area before the 6:00 p.m. closing hour. "With this kind of planning, we are able to speedup packer cycles, practically eliminate truck waiting time, and minimize excessive overtime penalties. When the landfill closes, our day's work is all but completed."

To handle the heavy industrial refuse, a steel-wheeled compactor, the Michigan Trash-Pak, was purchased. It exerts a force of 1,061 lb/lineal inch on its cleated wheels. A Michigan-Hancock 14-yd elevating scraper was purchased for cutting and hauling the needed cover material. Only one operator is needed to carry out the daily quota of operations of the two units. To achieve concentrated dumping, the complete haul area was compacted. As a result, arriving trucks roll the full 1,100 ft or so directly to the dumping face where the compactor is working, and hence the dumping activity can be closely controlled. When the refuse is spread and compacted in eight to ten-foot cells, the operator simply switches over to the elevating scraper. Distance from "borrow" to fill is about 1,100 ft. The scraper, cycling in five minutes, can cut a load of sand in 35 seconds and run back to the dumping face at speeds up to 25 mph.

The benefit of the on-site borrow pit is that it allows a speeding up of the operation and keeps the spread-haul costs low. The pit is 4 ft deep, 250 ft wide, and 900 ft long. The compacted refuse is covered each day with an 18-in. layer of sandy dirt. An average of 160 cu yd of dirt (11 scraper loads) are needed each day. A final 6-in. cover is spread to finish the job.

Equipment

Staff
"City of Santa Clara/USPHS Demonstration Landfill Compaction Studies"
Ralph Stone and Company, Inc., Los Angeles, California, prepared for the U. S. Department of Health, Education, and Welfare, U. S. Public Health Service, Solid Wastes Program, First Annual Report, 1 June 1967 to 31 May 1968

Results to date show an average density of 1,126 lb/cu yd wet weight of refuse (683 lb/cu yd dry weight) compacted by a Caterpillar D-9. A rubber-tired FWD Wagner SF-17 worked in parallel imparted a density of 1,087 lb/cu yd (662 lb/cu yd dry weight). Using steel wheels on the Wagner imparted a density about 20 percent higher than that by the Cat D-9. Of the two machines, the Cat D-9 has greater flexibility to do all the tasks required on a landfill, i.e., excavation, road maintenance, spreading, compaction, etc. The rubber-tired FWD Wagner was the faster machine, but has less flexibility for performing landfill tasks. Installation of steel wheels improved the usefulness and effectiveness of the Wagner, but reduced its speed and power. The Cat D-9 spread and compacted refuse about 10 percent faster than either the rubber-tired or steel-wheeled FWD Wagner. The steel-wheeled compactor may have a definite place on large, shallow landfills (less than 40 ft deep) where it can be used almost exclusively for spreading and compacting.

Optimum moisture-density relationships (laboratory studies) are: for clay cove soil — 23 percent moisture at a density of 92 lb/cu ft; for augured refuse — 47 percent moisture at a density of 58.5 lb/cu ft; for green grass — 86 percent moisture at a density of 15.5 lb/cu ft; and for stacked newspaper — 8 percent moisture at a density of 35 lb/cu ft.

"Geophysical Instruments Help Locate Landfill Sites"
The American City, 83(5):48, May 1968

In a geological survey for appropriate landfill sites made by the geologist of the National Disposal Service, two Soiltest, Inc., instruments — an R-150 Terra Scout portable refraction seismograph and an R-30 Michinko electric earth sensitivity meter — were used. The instruments are of value in determining the amount of available cover material and locating the water table. The Terra Scout unit can be used to check for proper compaction.

Culham, W. B.
"Equipment Needed for a Sanitary Fill"
The American City, 84(1):100, January 1969

A list of equipment and the modifications needed to make them more suited to sanitary landfill operations have been compiled by the Solid Waste Program of the Oregon State Board of Health. A summary of the listing is as follows:

Crawler Tractor: 1) Full extra-heavy-duty belly guard which is smooth and without obstructions. 2) Combination forward-flow or reverse-flow radiator fan with auxiliary radiator to prevent objects from entering radiator core. 3) Extra-heavy-duty radiator guard which will offer a minimum obstruction to air flow. 4) Full hood side panels to protect motor. 5) All-hydraulic hoses, fittings, and drain plugs protected with guards or shields. 6) Completely sealed hydraulic system.

Bucket (4-1 or standard design): 1) Equipped with a spill plate. 2) Have bolt-on replaceable bucket teeth. 3) Width of bucket exceeds width of tractor.

Dozer Blade (one or more of following): 1) Meshed wire spill plate extension on top of blade. 2) Blade equipped with angle extension on either side. 3) Standard "U" dozer blade.

Tracks: 1) Tracks protected with heavy-duty track roller guards. 2) Tracks designed to be overlapping or closed when they go around front idler or rear sprocket. 3) Full grouser tracks. 4) Full extra-wide track pads (shoes). 5) Extra-heavy-duty front idler. 6) If refuse begins to buildup between track links, holes can be provided in track shoe to allow refuse to squeeze out.

Equipment Extras: 1) Medford canopy or equivalent. 2) Power winch. 3) Front pull hook. 4) Cap locks for diesel fuel tank and starting engine fuel tank. 5) Lock for battery compartment. 6) Fire extinguisher in operator's compartment.

Compaction Equipment (other than tractor): 1) Protector guards over oil and water fill plugs. 2) Auxiliary belly pads.

Costs

Cannella, A. A.
"The Refuse Disposal Problem"
Public Works, 99(2):116, February 1968

Four methods of refuse disposal generally are practiced in the U. S.: open-pit dumping (30 percent of the cities); sanitary landfill; incineration; and composting. From purely health and sanitary aspects, open-pit dumping is unacceptable. Landfill is a desirable method if land is available within a practical distance of the wastes source. The full value and implications of refuse disposal by composting are as yet unknown.

REFUSE DISPOSAL COSTS IN U. S. CITIES (1962)

	Refuse Collection[a] Cost	Sanitary Landfill Operations Costs
Cost Range, dollars/ton	4 to 25	0.50 to 2.00
Median, dollars/ton	16.00	1.50
Per Capita, dollars/ton	5.00	3.00

[a]Includes all costs except amortization of equipment.

Coppa, R. B.
"How to Start a Sanitary Landfill"
The American City, 83(3):85, March 1968

The article opens with a description of the difficulties encountered in establishing a satisfactory sanitary landfill by the people of the town of Glastonbur, Connecticut (population, 19,500). The opening of the new site was made in July of 1967. The site comprises a total of 55 acres, of which 25 will be used for landfill. The town contributes from 40 to 50 tons/day. Equipment consists of a caterpillar crawler tractor with a 2-1/2 yd bucket loader to compact and cover the refuse, and a Wayne model 1000-16 chipper which will accept logs up to six inches in diameter.

COST STATISTICS

1. Purchase price (total) — $90,000 — $35,000 open space not used for landfill; $55,000 used for landfill.

2. Development costs:

a.	Survey and study	=	$ 1,200
b.	Materials (pipe, etc.)	=	6,637
c.	Paving	=	10,901
d.	Total out of pocket (a + b + c)	=	$18,738
e.	Labor (highway department)	=	15,000
f.	Total development costs (d + e)	=	$33,738

3. Operating costs — annual:

a.	Payroll	=	$21,000
b.	Equipment maintenance	=	1,000
c.	Supplies	=	800
d.	a + b + c	=	$22,800

4. Cost per capita: $1.14 not including equipment depreciation.
$1.27 including equipment depreciation.

McKinnon, J. J.
"Landfill Replaces Controversial Dump"
Public Works, 99(10):121, October 1968

In Clinton, Massachusetts (population, 13,600), the use of an overloaded dump led to the development of enough public pressure to force the city fathers to begin a sanitary landfill. A private operator was hired at first. His inadequate operations (e.g., he covered refuse with sandy gravel) led to the assumption of the responsibility of operating the fill by the Department of Public Works. The Department was unsuccessful, largely because of the lack of adequate equipment. Finally, the Department got the needed equipment and adopted a modified progressive trench method.

Present cost of the operation is about $0.85/ton. All types of wastes are handled. Of the 48 industrial users served, one-third to one-half use plastics in their operations. Immediate burial of these products reduces the hazards resulting from their flammability.

"Landfill Operation for Combined Refuse Pretreating with the Heil-Tollemache Pulverizer"
Heil Company, 3000 W. Montana Street, Milwaukee, Wisconsin 53201, 1968

Among the advantages listed in the brochure for milling prior to landfill are: 1) Cover is needed only for final grade. 2) Dozing and compacting requirements are minimal. 3) Fires, blowing paper, rodent and fly attraction, and odor, are eliminated. 4) Less final settlement.

Costs for grinding for disposition in a landfill are: 1) 172 tons/day (1 grinder, two 8-hr shifts): Labor, $1.619/ton; Equipment, $0.548/ton; Operating charges, $0.6837/ton; Total, $2.9507/ton. 2) 344 tons/day (2 grinders, two 8-hr shifts): Labor, $0.949/ton; Equipment, $0.398/ton; Operating charges, $0.6312/ton; Total, $2.0682/ton. 3) 516 tons/day (3 grinders, two 8-hr shifts): Labor, $0.971/ton; Equipment, $0.342/ton; Operating charges, $0.6048/ton; Total, $2.0018/ton.

Figures are based on Madison, Wisconsin, operation expanded to multiple machine, two- and three-shift operation.

Use of Compacted Fill

Klein, S.
"New Building Constructed on Sanitary Landfill"
Public Works, 99(10):125, October 1968

This article is of interest because of a description of sinking piling through a refuse fill. The site of the operation was Wenatchee, Washington (population, 18,500). The building in question is a Public Works building. The location of the new building was entirely on sanitary landfill placed only two years prior to the construction of the building. The depth of the fill varied from 20 to 30 ft. The expected settling of the fill dictated the need for placing the building on piling. Inasmuch as the fill contained tree trunks, boulders, car bodies, in addition to the usual refuse, conventional pile-driving could not be done because of the possibility of the piles hitting solid objects. Auguring the hole was unfeasible because augurs would become clogged. The only method left was to have the holes dug by a well driller. Consequently, a contract was made with a well driller on an hourly basis to sink pipes to the underlying gravel stratum. Reinforcement was placed in the casing and the casing filled with concrete, after which the well driller pulled the casing, leaving a cast-in-place pile. A total of 17 piles were constructed, with depths varying from 22 to 32 feet. The cost of drilling was $3.50/ft.

The steel building is an Armco LS-3 type, 60 by 120 ft, and a maximum wall height of 16 ft, with door openings being 16 by 14 ft.

Hopson, R. S.
"From Landfill to Heliport"
The American City, 83(10):42, October 1968

In Richmond, Virginia, a deep gully was transformed into a heliport by way of sanitary landfill. The first step consisted of raising the level nearly to grade. A bulldozer and a rubber-tired loader were used for compacting the refuse. Then a cover of four feet of compacted earth fill was applied. As well as elevating the site to proper grade, the final fill accelerated compression and strengthened the bearing capacity enough to accommodate the helicopters.

Research (Leaching, Gas Production, etc.)

"Giant Refuse 'Container' Used to Study Effects of Landfill on Water Table"
Solid Wastes Management/Refuse Removal Journal, 11(7):6, July 1968

A popularized description is given of work being done at the Drexel Institute of Technology on possible groundwater contamination by way of percolation through a landfill. (Dr. Remson, one of the investigators mentioned in the article, is now with Stanford University, Palo Alto, California.) The researchers are using as a test vehicle a rectangular prism (lysimeter) 6 ft by 6 ft by 13 ft high with a capacity of 7,000 lb of refuse. All climatic conditions encountered under practical situations are simulated in the study, i.e., temperature, humidity, and rainfall. In conjunction with the laboratory phase, a field study will be made at a nearby location in Kennett Square, Pennsylvania.

Merz, R. C. and R. Stone
"Quantitative Study of the Gas Produced by Decomposing Refuse"
Public Works, 99(11):86, November 1968

The article describes results obtained in a study in which approximately 15 tons of refuse were encapsulated in a 10,000-gal underground storage tank. In the filling process, a 6-in. layer of sand was placed in the bottom of the tank, then refuse was added and gas-sampling piping installed. The refuse consisted of paper (42 percent), grass and garden clippings (38 percent), plastic (3 percent), glass (5 percent), metal (7 percent), and dirt (5 percent). Water was added to bring the moisture content to 69.9 percent (dry weight basis). The in-place density of the refuse was 634 lb/cu yd. After filling, the top of the tank was sealed. About 39.3 cu ft of gas were produced during the first three days after sealing. However, gas production was negligible by the end of 60 days and continued so until about the 230th day. Thereafter production was resumed and a total of 2,025 cu ft of gas were produced during the period 230-530 days after initiation. Production again dropped after the 550th day. Its production during the 550-750-day period was about 27.5 cu ft gas/cu yd refuse. The temperature ranged from 78° to 100°F during the first 300 days, and from 105° to 120°F during the period 350 to 475 days. The deep level (14-ft) temperature probes failed during the later stages of the study, and hence no firm figures are available for that period.

Stone, R., E. T. Conrad, and C. Melville
"Land Conservation by Aerobic Landfill Stabilization"
Public Works, 99(12):95, December 1968

The paper is a report on results obtained in a demonstration project, the main purpose of which was to demonstrate acceleration of the stabilization in a process in which compacted refuse is aerobically decomposed before final disposal. In the study, a large cell or pit (200 ft long x 50 ft wide x 17 ft deep) was used. It was underlaid with a series of gravel-covered perforated pipes through which air was forced by means of a 1,200 cfm (under 10 in. of water) blower. After the refuse had been aerated for a specific length of time, the "relatively stable" residue was transferred from the aeration pit to a final residue cell where it was compacted again and covered with soil, as is done in conventional sanitary landfill operations. Here anaerobic decomposition took place.

The test material consisted of domestic rubbish and garbage. The aforesaid refuse was about 45 percent (by wet weight) paper or paper in origin, about 45 percent tree and garden trimmings, and about 10 percent garbage. The organic content was about 85 percent, and moisture content ranged from 35 percent in the fall to 80 percent in the spring.

Filling of the first test cell began in June 1967. The filled cell contained 2,940 tons of compacted refuse (overall density, 1,253 lb/cu yd wet weight). No soil cover was used in the first test; however, one was used in the subsequent tests. The blower cycle during loading (2 months) was 55 minutes on, 35 minutes off; and thereafter (1-1/2 months), 70 minutes on, 20 minutes off. Rate of aeration ranged from 225 to 310 cu ft/cu yd refuse/day.

Temperatures rose to as high as 190°F in the test cell. During the aeration period, the composition of gas samples taken from the cell varied as follows: CO_2 from 3 percent to 19 percent; O_2 from 7 percent to 17 percent; N_2 from 67 percent to 80 percent; and CH_4 from zero to a trace. During the aeration stage in the first run, a fire occurred in the cell contents. Whether or not the fire had an internal or external origin could not be determined. To exclude future external origins, the cell was covered with soil. No fires occurred after the soil cover was used.

At the end of six months, the aeration was discontinued and the material was allowed to revert to the anaerobic state. During the subsequent three-month period, the CO_2 percentage rose to 57 percent to 85 percent; O_2 dropped to 0 percent; N_2 declined to 1 percent to 12 percent; and CH_4 rose to a level of 2 percent to 42 percent. Excluding that lost by way of the fire, the volume reduction during the ten-month aeration-nonaeration period was approximately 1,100 cu yd; i.e., slightly less than 1/4 of the original volume.

Miscellaneous

"Disposal Near Water Banned by Ohio Law"
Solid Wastes Management/Refuse Removal Journal, 11(7):42, July 1968

The new law prohibits the placing of refuse in any ditch, stream, river, or other watercourse, or upon the banks thereof, where it would be washed into the water by ordinary flows or by floods. The law does not apply to waters which do not combine or effect a junction with natural surface or underground waters. Penalties for violating the law are fines not less than \$25 nor more than \$500 or imprisonment of not more than 30 days.

Gershowitz, H.
"Model Landfill Contract Recommends Very Stringent Performance Bond"
Solid Wastes Management/Refuse Removal Journal, 11(7):16, July 1968

A stringent and uniform performance bond provision is recommended in the model contract submitted by the National Solid Wastes Management Association to the federal government for review. (The model is discussed in the May 1968 issue of the Solid Wastes Management/Refuse Removal Journal.) The bond provision states that "the Contractor shall furnish a performance bond for the faithful performance of this Agreement, said bond to be executed by a responsible surety company acceptable to the City, and to be in a penal sum equal to one-half of the estimated annual price payable by the City to the Contractor for the first year of this Agreement up to \$100,000.00, and for each year thereafter to be in the penal sum of one-half of the total compensation paid by the City to the Contractor for each year of the Agreement or any extension thereof, and shall guarantee performance of the Agreement by the Contractor, and shall indemnify the City against any loss resulting from any failure or performance by the Contractor, not exceeding, however, the penal sum of the bond."

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In case of a poorly operated landfill, the model contract provides for the city to take over any equipment of the contractor needed to operate the fill in a proper manner. This action would take place after a five-day grace period following an official warning, and would apply only to those occurrences within the control of the contractor.

Provision is made for adjusting cost figures in the contract upon mutual agreement between the city and the contractor in those situations in which the site of the fill has been changed following mutual agreement, and, in consequence, costs have gone up. The same recourse applied to situations leading to an upgrading of the contracted method of disposal. The ravages of inflation in long-term contracts are prevented by allowing for upward or downward revisions based on fluctuations in the consumer price index published by the U. S. Department of Labor, Bureau of Labor Statistics.

The article includes a verbatim reproduction of the model contract. It is too lengthy for inclusion in this except for major headings covered, which are: Bid Bond and Landfill Operation Agreement. Subjects under Landfill Operation Agreement are: Disposal Site, Materials to be Disposed Of, Inspection, Operation of Disposal Site, Vector Control, Insurance, Compensation to Contractor, Term, Performance Bond, and Standard of Performance.

Sorg, T. J. and H. L. Hickman
"Sanitary Landfill Facts"
U. S. Department of Health, Education, and Welfare, National Center for Urban and Industrial Health, Solid Wastes Program, SW-4ts, Cincinnati, Ohio, 1968

"Sanitary Landfill Facts" presents general information on the state-of-the-art of sanitary landfill. In the publication are examined the planning, design, operation, and public health aspects of sanitary landfills. The information is intended as an aid to those involved with planning and development in solid waste disposal management.

Subjects covered in the publication are: a) planning a sanitary landfill; b) selecting a site; c) designing a sanitary landfill; d) operating a sanitary landfill; e) public health and nuisance aspects; f) equipment, facilities; g) costs; h) completed sanitary landfill; i) advantages; j) disadvantages; k) public health service sanitary landfill projects; l) references; m) bibliography.

Steiner, R. L. and R. Kantz
"Sanitary Landfill; A Bibliography"
U. S. Government Printing Office, Washington, D. C., U. S. Public Health Service Publication No. 1819, 1968

The publication is a comprehensive bibliography of articles related to sanitary landfills selected from a wide variety of American and British periodicals. Entries are arranged chronologically, ranging from 1925 through 1968.

The search to obtain this information was supported by a Public Health Service research grant from the Solid Wastes Program to the Drexel Institute of Technology. The publication represents a revised edition of a 1967 bibliography published by Drexel Institute (Series I, Number 2). An extensive list of references used in the search is also included.

Articles reflect a wide range of topics related to sanitary landfills; numerous city or state landfill reports; economic feasibility studies; disease and pollution aspects; manpower and equipment factors; and future potential and restrictions for the sanitary landfill.

"Portable Fences Improve Landfill Housekeeping"
The American City, 84(2):125, February 1969

The fences were developed by the National Disposal Service primarily to keep papers from being blown on sanitary landfill sites. One type of fence is made up of five sections, each 20 ft long by 9-3/4 ft high and jointed by five-ft strips of wire. Each section rests on a wood skid measuring 10 ft x 20 ft. The fence can be positioned in the shape of an arc around the working face when desired.

Another design features a fence constructed completely of metal. It consists of three sections, each having a face 21 ft long by 14 ft high.

Hughes, G. M., R. A. London, and R. N. Farvolden
"Hydrogeologic Data from Four Landfills in Northeastern Illinois"
Illinois State Geological Survey, Urbana, Illinois 61801, Environmental Geology Notes No. 26, March 1969

The report describes methods of drilling, sampling, and analysis used in an investigation of four landfills in northeastern Illinois, and presents the geologic and geochemical data thus obtained. One of the landfills is located in Du Page County in poorly-drained lowland. A second is located at Winnetka in a flat area adjacent to the Skokie River. The third site is at Elgin and is adjacent to the Fox River. The fourth fill is located at Woodstock and occupies a swampy lowland.

According to the authors, considerable variations were apparent in the results of the quality analysis that seemed to be unrelated to the distance of the leachate from the landfill or to the age of the landfill. Samples taken from adjacent borings, with depth variations as little as four feet and not separated by any apparent permeability barrier, were consistently different. The shallower boring had as much as 50 percent fewer total dissolved solids than did the deeper boring. Moreover, samples taken on successive weeks from the same boring differed. "The variability, combined with the errors inherent in the sampling and analytical procedures, made it impossible to calculate the amount of dissolved solids adsorbed during travel through specific types of materials. The data were, however, adequate for definition of the envelope of dissolved solids around each fill."

INCINERATION

Design

"Industry Teams up to Build Joint Waste-Disposal Plant"
The American City, 83(1):101, January 1968

Although the disposal plant setup described in the article is as yet largely in the "paper stage," the information in the article is of value in that it points out one approach to the management of industrial wastes. Industries in Houston, Texas, are collaborating in establishing a joint disposal agency which will be named Consolidated Oxidation Process Enterprises, Inc. (COPE). The plan is for COPE to build a central plant designed to handle all types of industrial wastes — liquid, solid, or semisolid. The plant is to be located on a 20-acre site adjacent to the ship canal, thus permitting the delivery of industrial wastes by barge and truck. The capacity would be 10,000 tons/month; and the cost, about 5 million dollars. Plans call for the construction to begin in June 1968.

Oxidation units will be of three types: rotary kiln, multiple hearth, and moving hearth. Sludges will be burned in a Nichols Herreshoff multiple-hearth furnace; bulky items, in a high-temperature Foster Wheeler water-wall furnace; and plastics and other similar materials in a rotary kiln similar to that used in cement mills. Decomposition will take place in two stages. In Stage 1, supplemental natural gas firing will be used to ensure destruction of volatiles; and in Stage 2, complete combustion will be provided at temperatures over 1800°F. It is expected to produce over 100,000 lb of steam/hr for sale to nearby industries. Air pollution control will be provided by an electrostatic precipitator. About 30 employees will be required.

The following cost requirements are proposed: 1) Costs must be lower than the cost users would incur if disposing of their own wastes, i.e., individually, in a nuisance-free manner. 2) The central facility should be located to keep transportation costs at a minimum. 3) The central facility must make a profit; this entails waste heat recovery for a useful purpose. 4) Service charges should be a function of difficulty of handling and disposing rather than of quantity alone, so that all users may benefit from advantages of plant size.

Peters, E.
"Non-Clogging Pump Solves Fly-Ash Removal Problem"
The American City, 83(5):135, May 1968

Difficulty was encountered in removing fly ash from the quenching water at the Skokie, Illinois, incinerator. The difficulty originated in the fact that the scraper or flight-type conveyor would not carry the sludge, and as a result the sludge would buildup in the residue pit. The problem was solved with the use of a Mid-Whirl clogless pump (Midland Products Company, Midland Park, New Jersey) and a steel tank with a capacity of 18 cu yd mounted about 15 ft above the ground. The pump moves the fly ash laden water into the overhead tank. The ash settles to the bottom, and the water flows over a vertical baffle at one end of the tank and returns to the quench water tank by gravity. When the overhead tank is filled with sludge, it is emptied into the residue tank.

Pearl, D. R.
"What the Future Holds for Incinerators"
The American City, 83(10):121, October 1968

The article was taken from "A Review of the State of Art of Modern Municipal Incineration System Equipment," a detailed report by Mr. Pearl for the Public Health Service.

Mr. Pearl begins this article with the somewhat debatable statement that incineration seems the only practical answer to the mounting refuse disposal problems in the heavily industrialized regions of the U. S. He predicts: a) Improvements in air pollution control will be the most significant immediate change; b) A renewed interest will develop in salvaging waste heat; c) Refractory-lined furnaces and water-wall furnaces, both equipped with conventional flow-through stoker systems will become common; d) The trend will be toward air-cooled walls in refractory-lined furnaces, and silicon-carbide or high alumina facings will be used in the slagging and abrasion zones. Cooled walls resist penetration by heavy glassy slags. e) The tendency will be away from heavily insulated furnace walls, since with thinner, more conductive air-cooled walls some excess heat can be directly dissipated through the furnace walls; f) More plastic and castable refractories will be employed for walls and arches; g) Increasing use will be made of water-wall furnaces to provide a cooling surface to shrink gas volume, to facilitate cleaning the flue gases, and to serve as heat-absorption surfaces in steam generating plants. Refractory coating tubing will be used for corrosion resistance in critical areas.

Present Novel Experiments: Suspension burning, melting with auxiliary fuel, pyrolysis, fluid-bed combustion, and pressurized burning. Suspension burning: Finely divided fuel is blown in a vortex pattern into the furnace. The material burns while suspended in the turbulent air stream. The idea behind the melting approach is to produce a melted residue which includes all metals and minerals, and which is passed into a water bath where it solidifies into coarse crystals. These are the ultimate in cleanliness, compactness, and durability. Pyrolysis is decomposition by the application of high heat in the absence of oxygen. In fluid-bed combustion, combustion takes place in a bed of granular mineral (sand) heated in a refractory vessel on a perforated plate. The mixture is "fluidized" by blowing air through it from below the bed at a controlled rate. The problem is to separate the residue from the bed material. In pressurized burning, combustion takes place in a smaller-than-normal furnace by introducing the combustion air under high pressure. The additional power required to compress the air is a drawback. However, the existence of hot pressurized flue gas offers the thermodynamic possibility of directly operating a gas-turbine engine to generate power.

Dissipation of Heat: 1) Interest in developing in the use of gas-to-air heat exchangers of tubular construction to cool and shrink flue gases. The heated ambient air can be discharged directly to the atmosphere. 2) Dissipation of heat absorbed in water walls will be done by air-cooled condensers to avoid the cloud of visible steam otherwise visible in cold weather. 3) The prospects of an economic return is likely to lead to the conversion of waste heat into steam for: a) heat and power required in the plant itself; b) heat, power, and steam for nearby industry, institutions, or municipal installations; and c) power for commercial electric utility networks.

Air Pollution: To comply with today's codes, an incinerator might require an overall 94 percent collection efficiency with a fractional efficiency of about 75 percent by weight collected of all particles of 5 microns or less. Present standards can be met by cyclones, wet scrubbers, and filter-bag collectors with fan-powered induced-draft systems. However, electrostatic precipitators and high-performance wet scrubbers will gain greatly. Bag filters can do a near-perfect job of dust collection, but they require considerable power and maintenance.

Miscellaneous: 1) Fully automatic or computer-controlled incinerators will not be adopted for some time, because cities will continue to look to refuse disposal as a source of employment for the unskilled and semiskilled. However, automatic controls will be provided for certain critical parameters, such as furnace temperature and CO_2 in the flue gas. 2) Capital investment will be reduced by resorting to functional structures instead of those emphasizing traditional architecture (i.e., to resemble city hall or a school). 3) Increasing use will be made of breakers, crushers, and shredders to reduce awkward combustibles to workable sizes.

"Britain's First Automatic Grate"
Public Cleansing, 58(12):612, December 1968

The grate was installed in a new incinerator plant at Middleton. Refuse is received in one of six separately-enclosed bays. A crane with a clamshell type grab transfers the refuse from the bays to the incinerator. The incinerator is of the roller-drum type, operating in what is known as the "Dusseldorf System." The incinerator is of the continuous-operating, moving-grate type, specifically designed for burning refuse. The grate consists of six rollers five ft in diameter. The rollers are stepped at a 30 degree angle and arranged to produce the turbulence needed for maximum burning. Forced draft for combustion is supplied from a forward-curved centrifugal fan which also controls the dust at the feed hopper by directing air by way of a hood to the suction side of the fan.

Exhaust gases are conveyed to a 150 ft brick chimney by two aerofoil-bladed, induced-draft fans operating in tandem. Flue gas is collected by a multicell mechanical collector. Waste heat from the flue gas is recovered for heating the incinerator and ancillary buildings by means of a grilled tube economizer located between the fan discharge and the chimney.

Low, D. K.
"Direct Incineration — Aesthetic Design of Plant"
Public Cleansing, 58(12):647, December 1968

Because wastes production is increasing so rapidly, refuse disposal buildings can no longer be tucked away in hidden corners. Instead, they are becoming the dominant building in corporation properties. Since transportation costs demand a centralized locale for the disposal facility, the structures involved should be designed with an eye for the aesthetics. In the last few years, a limited number of plants have been built in such a manner as not to be aesthetically objectionable. The number has been small, because, among other reasons, there is little that the designer of a refuse disposal plant can turn to for inspiration or guidance. The author, while advocating aesthetic design, sees no merit in trying to camouflage the incinerator plant. He proposes the functional design as defined by J. M. Richards "that style of design which, though dominated by functional considerations, is remarkable for the wide range and subtlety of its aesthetic effects."

Two principal factors affect the external appearance of the buildings — method of approach and arrangements for tipping. Ideally, the refuse should be tipped as closely to the feed hopper as is possible. With respect to tipping arrangements, the traditional one for a ramp approach is the tipping hall. This results in a greater building enclosure than for an arrangement involving individual tipping bays.

The reception building is one of the larger structures in an incinerator complex. The relationship between a long, narrow reception pit at a low level and a feed hopper which could easily be some 60 ft higher (and higher when the room for the crane is included) results in a tremendous volume of building above the reception pit. For greater economy, it is desirable to create the maximum enclosure with a minimum perimeter, but the needs of the reception building are contrary to this requirement. The incinerator house is the second largest building in the complex. Its height would be about 20 ft less than that of the reception building.

The chimney more than any other section of the plant is the one which could prove most difficult to accept in the visual scene without injuring the amenities of a residential or town center. The height may need to be as high as 350 ft.

"The Martin Stoker"
Public Cleansing, 59(2):56, February 1969

This is the second in a series of articles on automatic grates. The description is geared to the uninitiated in incineration, and hence is an excellent article for those interested in incineration.

The Martin Stoker was developed in Germany about 40 years ago to burn low-grade fuels such as industrial wastes and slurries. The stoker consists of only one grate, and the grate, in turn, of a number of individual grate bars approximately 2 ft long and 5 in. square. Alternate bars down the grate are fixed to a common stationary reciprocating beam. The remaining bars are attached to a common supporting structure.

The reciprocation beam is actuated by a hydraulically-operated piston, and moves alternate bars over the fixed bars in a direction up and down the inclined grate surface. Combustion air is supplied by a forced draft fan which forces air up through the grate bar air apertures (2 percent of the total grate area) by way of separate combustion air chambers situated underneath the grate. Approximately 80 percent of the combustion air is supplied in this manner. The remaining 20 percent is delivered into the combustion chamber which is situated over the grate.

Mixing of refuse, i.e., a degree of homogenization, is accomplished by the use of the counterflow principle. By use of this principle, each particle flowing down the grate comes into contact with each particle coming up the grate. The reverse action, which is a part of a counterflow operation, levels the heat output over the grate as well as the fuel bed itself. The usual practice, to insure the ignition of overly-moist refuse, is to use two or more grates – one to serve as drying and ignition zones, and another as the burning zone. To simplify the process, drying, igniting, and burning take place simultaneously on the single Martin Stoker. "The red-hot layer of refuse is pushed up from the lower end of the grate, underneath the oncoming cold refuse at the front of the stoker. Furious burning takes place, therefore, at the front of the stoker, so that the full area of the single grate is utilized." Complete burnout usually is achieved two-thirds of the way down the grate.

The grate bars on the Martin Stoker are made from high chromium alloy cast steel. Because of this construction, a burning rate of as much as 80 lb refuse/sq ft grate area/hr at temperatures as high as 1700°F can be achieved.

Because of the reverse action feature of the stoker, the speed of the reciprocating grate bars can be adjusted until optimum burning conditions are met without any effect on throughput. The depth of the always-level bed is determined by the speed of the clinker discharge roll. Discharge of clinkers (ash) is accomplished such that the clinkers are quenches and air-dried to relative coolness before the point of collection.

Sutin, G. L.
"Solid Waste Reduction Unit Promises to be a Better Mousetrap"
Public Works, 100(2):72, February 1969

As a result of a 1967 study on the extent of its refuse management problem, the city of Hamilton, Canada, learned of several interesting facts. Among these were: 1) Per capita generation of combustible solid wastes were 23.9 lb/capita/week. 2) Due to the city's urban renewal activities, disposal facilities were required for 150 tons/day of demolition lumber. 3) The existing sanitary landfill will be exhausted by 1975. To meet the problem, the construction of a 600-ton/day incinerator was recommended.

Not being satisfied with existing incinerator design information, a design team was formed to come up with a suitable design. As a result of its investigation, the team came to the conclusion that: 1) Incinerators of the fixed grate type (monohearths), although having a relatively low capital cost, would be very high in operational costs because of the high manpower requirements. 2) Best air pollution control can be obtained by way of complete combustion and removal of fly ash by electrostatic precipitators. 3) Due to depth of the burning bed of refuse, proper combustion and complete burnout are difficult to achieve in conventional incinerators without constant manual supervision. 4) Overhead cranes should not be used for charging. 5) Although steam generation is excellent as a concept, in practice it is not always desirable because of high maintenance costs. A change in name for the plant from "incinerator" to "solid waste reduction plant" was recommended for reasons too obvious to list here.

A fundamentally simple system was designed. In the proposed design, mixed refuse is passed through shredding machinery in which ferrous materials are removed magnetically from the refuse stream. The shredded refuse is blown into the boiler. About 50 percent of the combustion takes place in suspension and the balance on a short, slow-moving grate with a bed of shredded refuse about 2-1/2 in. thick. Residue exits from the unit at a temperature of 200°F, "thus eliminating the need for quenching." Ash is removed by means of steam-activated suction lines to a silo and thence to the ultimate disposal site. Steam generated is used for running high-horsepower equipment and other inhouse use. The balance is condensed for recirculation.

A capital cost of $8,337/ton is expected with the design, and operating costs without amortization as low as $1.68/ton for large plants of this type. The low operating costs would be due to four key items: 1) low power requirements; 2) low maintenance costs; 3) minimum water consumption; and 4) low labor requirements. A typical shift would consist of a plant operator and his assistant and two floor men. During the day shift, added manpower would be a plant manager and his assistant, a clerk, a bookkeeper, electrical maintenance men, one relief operator and mechanic, one extra floor attendant, and two truck drivers. Water would be required only for boiler makeup — about $5,000/yr. A summary of costs is shown in the following table (reproduced from the article):

SUMMARY OF COSTS

Solid Waste Reduction Unit Capacity (tons/day)	Total Capital Investment ($$10^6$)	Capital Cost/ton ($)	Annual Operating Cost ($$10^6$)	Operating Cost/ton ($)	Annual Amort. Costs ($$10^6$)	Amort. Cost/ton ($)	Plus Oper. Amort. Cost/yr ($$10^6$)	Plus Oper. Amort. Cost/ton ($)
1,500	12.506	8,337	1.224	2.24	1.272	2.32	2.497	4.56
900	7.748	8,600	0.550	1.68	0.790	2.42	1.340	4.10
600	6.248	10,410	0.525	2.40	0.639	2.92	1.165	5.32
300	4.685	15,620	0.519	4.74	0.439	4.01	0.959	8.75

Staff
"Combustion Power Unit — 400"
A Technical Abstract prepared by the Staff of Combustion Power Company, Inc., Palo Alto, California, for the Bureau of Solid Waste Management, U. S. Department of Health, Education, and Welfare, Public Health Service, Rockville, Maryland, 1969

The concept behind the unit, as yet to be built, is an outgrowth of aerospace technology. The Combustion Power Unit 400 (CPU-400) is designed as a turboelectric generator plant that will use solid wastes as fuel. The baseline configuration is a modular unit designed to utilize 400 tons of refuse/day. The 400 tons are expected to produce 15,000 kw of electric power. Currently, the CPU-400 unit is in the early development phase. Experimental tests are being conducted on subscale hardware. A working model (1/10th-scale) of the system is scheduled for testing early in 1970, and a full-scale prototype is planned for operation in 1972.

In the system, solid wastes are burned in a high-pressure combustor to produce hot gases to power a gas turbine. In turn, the turbine drives a 15,000 kw electric generator.

Unsorted solid wastes would be passed through a shredder and dried in the hot gases discharged from the combustor. The shredded, dried, and mixed solid wastes will be injected into the combustor, which will be supplied 100 psia, 584°F air from a compressor. A fluid-bed combustor reactor is planned for the CPU-400. In this reactor, the inert material is suspended or "fluidized" by the air from the compressor passing through the chamber. Removal of the particulate matter from the combustion gases is accomplished upstream from the turbine by an electrostatic precipitator. The gas leaving the particle collectors is expanded through the gas turbine, which drives the compressor and the electric generator. Exhaust gas leaving the turbine will be near atmospheric pressure at a temperature of 930°F.

Operation

Michaels, A.
"What Good Incineration Means. Part II — Design Parameters"
The American City, 83(6):88, June 1968

Essentially, incineration without waste heat utilization consists of two main functions, combustion and materials handling. Materials handling falls into four categories: 1) refuse receiving and storage, 2) furnace charging, 3) conveyance through the furnace, and 4) residue removal.

Refuse receiving: There are three methods, viz., storage bins, floors, and conveyors. Storage bins vary in size equivalent to 12 to 36 hours of plant burning capacity. In some operations, all refuse is collected and incinerated together. In others, garbage is separated from rubbish and either is burned. Density in the bin ranges from 300 to 400 lb/cu yd.

Conveyance: Usually the overhead crane is used to transport refuse from the bin to the furnace.

Grates: Three types are popular, viz., chain or bar and key traveling grate, the rocker arm grate, and the reciprocating grate.

Residue removal is accomplished by: 1) direct discharge into a dump truck or container; and 2) discharge into a water trough equipped with a chain flight or pan-type conveyor, and discharge into a sluicing trough.

Operating conditions: The furnace should be operated at temperatures between 1300° and 2000°F with an average of 1750° to 1850°F. At temperatures higher than 2000°F, refractories deteriorate rapidly.

Design: The two major design elements are the grate areas and combustion volumes. For optimum burning, grate loads are based on a heat release from the burning material at the rate of 300,000 Btu/hr/sq ft. Combustion space is based on a heat release at the rate of 20,000 Btu/hr/sq ft. Because of variations in the nature of refuse, however, engineers have found that a heat release of 12,500 Btu/hr/cu ft is a more reliable measure of combustion space needs.

Combustion space is generally divided into the furnace chamber (primary) and the combustion (secondary) chamber. More recently, some designs combine the two chambers into one by shaping the chamber such that ignition takes place in the charging section and combustion in another section.

Air usage: The theoretical air usage is 6.5 lb/lb waste. In practice, an average of 250 percent excess air is applied in American furnaces. Because of the demands of air pollution control, means are now being sought for reducing the amount of air applied in a furnace.

Pollution: For each 1,000 lb refuse, 20-25 lb of fly ash are produced. Most air pollution control regulations permit an emission of only 5 to 10 lb fly ash/1,000 lb refuse. Popular types of control equipment are the wet baffle impingement and dry mechanical cyclone systems. An electrostatic precipitator would be needed to meet the standards of the future, viz., 0.2 percent emission instead of the present 40 percent.

Waste heat recovery: A design for the proposed East Central Incinerator (Philadelphia, Pennsylvania) would make possible the generation of about 327.6 million lb steam/yr with the burning of 600 tons/day of municipal refuse. The total cost of the steam-generating facilities would be $791,000; operating expenses $83,164/yr; and fixed charges (3-1/2 percent interest, 10-yr amortization), $95,195. The cost/1,000 lb steam would be from $0.43 to $0.55, depending on the amortization period. (Power companies indicate a willingness to pay as high as $0.60/1,000 lb steam delivered to the power plant.)

"Steel Deposits on Incinerator Grates"
The American City, 83(9):39, September 1968

Although generally incinerator temperatures are much too low to melt pieces of steel introduced into the furnaces, J. B. Caine found and tested some chunks of steel which had apparently melted and subsequently hardened on the grate keys. Examination proved that welding had occurred rather than mechanical adherence. One adhering lump had 0.15 percent carbon. Its large silicate inclusions indicated that the steel was deposited at a temperature higher than 2900°F — certainly far higher than temperatures normally occurring. According to Mr. Caine, the only possible way this steel could have become molten and then deposited on the keys was by the thermite process. When iron oxide and aluminum are in contact and heated to about 1600°F they will react to form molten steel and generate temperatures exceeding 3000°F. Plenty of iron oxide from "tin" cans is available in refuse, as is also true with aluminum. Although aluminum oxidizes quickly, in the case cited some remained unoxidized until it contacted the iron oxide.

"The unexpectedly high combustion temperatures responsible for the deposition of the steel," reports Mr. Caine, "may be the reason for unexplained failures of some cast iron keys in incinerator service. Cast iron melts at about 2100°F, 700°F less than low carbon steel, and at least 800°F under the temperature that must have prevailed locally in this incinerator."

"Special Studies for Incinerators for the Government of the District of Columbia Department of Sanitary Engineering"
Day and Zimmerman, Engineers and Architects, prepared for the U. S. Department of Health, Education, and Welfare, U. S. Public Health Service, Consumer Protection and Environmental Health Service, Solid Wastes Program, Cincinnati, Ohio, 1968

The scope of the study includes an estimation of the chemical constituents of municipal incinerator effluent gases; the potential air pollution hazard of such chemicals; and the evaluation of various air pollution abatement devices was made. The effluent stream was found to contain inorganic and organic materials in the form of gases and particulates. Some of the materials were both toxic and corrosive. Electrostatic precipitators and high energy scrubbers are two types of pollution control equipment applicable to this plant. While the use of high energy scrubbers may be acceptable from a performance standpoint, it is ruled out because of aesthetic objections to the vapor plume and possible thermal pollution of the water source.

Inorganic gases from incinerators are primarily ammonia and oxides of sulfur and nitrogen. The inorganic particulates consist primarily of oxides of Al, Si, K, Ca, Fe, Ti, Zn, Na, and Mg. The organic gases and particulate matter consist of fatty acids, esters, aldehydes, hydrocarbons, and oxides of carbon. Corrosion problems can be caused by the oxides of S, N, and C. Oxides of Na, K, Fe, and Zn may contribute to corrosion because of either the strong acidic or basic characteristics exhibited when such oxides are hydrolyzed.

Venturi and flooded plate scrubbers exhibit relatively high efficiency of particulate removal and can absorb some of the gaseous contaminants. They have the disadvantage of high water consumption, high power costs, presence of a plume of steam, and the problem of treating the water for pH control and removal of fly ash. Construction materials must be carefully selected for corrosion protection. Estimated costs for the two basic systems for an installation at the proposed incinerator (800 tons/day) are: 1) Electrostatic precipitator with mechanical collector — capital — $2,409,200; annual operating — $512,500. 2) High energy scrubber — capital — $1,838,600; annual operating — $400,000.

The report contains a number of interesting tables on refuse composition too lengthy to be reproduced in this publication. A partial listing of titles will give some idea of the data offered. Refuse Analysis: Dirt and Vacuum Cleaner Catch; Refuse Analysis: Glass and Ceramics; Refuse Analysis: Metals; Refuse Analysis: Wood, Paper Products, Plant and Wood Wastes; Refuse Analysis: Plastics; Refuse Analysis: Rags; Refuse Analysis: Paints and Oils; Refuse Analysis: Leather; Refuse Analysis: Rubber; Refuse Analysis: Miscellaneous; Data on Fatty Acids; Analysis of Incinerator Slags; Analysis of Incinerator Effluents; Analysis of Fly Ash; Sources of Ammonia in Effluent Gases; Toxic and Corrosive Characteristics of Organic Substances; Toxic and Corrosive Characteristics of Polynuclear Hydrocarbons; Solubility of Gaseous Pollution in Water.

The report contains itemized lists of instrumentation and laboratory equipment and their estimated installed costs. The equipment was selected to permit normal monitoring of plant operation and to aid in the performance of tests for development of incinerator design and operating techniques. References to existing test procedures are given. Estimated costs of indicating and recording equipment for incinerator operation is $158,000; of the physical laboratory, $11,900; of the physical laboratory space, $22,500; of the chemical control room for monitoring equipment, $106,320; of the master control room for monitoring equipment, $25,000.

The report discusses methods for municipal disposal of bulky objects. The use of compression presses to reduce the volume of these objects is acceptable under certain conditions. The amount of metal to be handled in the District of Columbia is not sufficient to achieve a good economy of operation. The alternate use of outside contractors or metal shredding is a potentially more economical solution. The capital investment cost of a press would be $235,000. Operating costs would be $11/ton.

For the proposed Washington, D. C. plant, the report reviews the application of a boiler plant capable of burning 800 tons of refuse/day with four incinerator furnaces. The economics of the proposed plant do not justify the installation of heat recovery equipment. Among the difficulties in designing for heat recovery under U. S. conditions are: a) High percentage of materials which when burned results in the production of corrosive materials; b) the operation of furnaces at high excess air levels (150 percent or more as contrasted to European practice of 50 percent); and c) the generation of steam in a municipal refuse incinerator plant cannot be reasonably varied to meet seasonal load conditions unless the plant is provided with boiler bypass flues or steam condensing equipment. The installation of water-cooled furnaces or steam boilers was not recommended because: a) The anticipated operating expense of water-cooled furnaces is higher than that of the refractory furnace type. b) The trend of refuse composition toward additional plastics, freons, etc., will probably increase the existing critical metallic tube maintenance with insufficient assurance that present technology can deliver a boiler design which will be satisfactory for the present trends of refuse composition. c) Reductions in operating economies, capital costs, etc., resulting from the lower gas velocities potentially available with lower excess air operation are not sufficiently assured to warrant consideration of water-cooled furnaces without an employable market for the sale of the steam produced. d) Successful operation at the lower excess air levels recommended for water-cooled furnaces has not been proven.

"Incinerator Operation — Pretreating Combined Refuse with the Heil-Tollemache Pulverizer"
Heil Company, 3000 W. Montana Street, Milwaukee, Wisconsin 53201, 1968

Addition of a pulverizer to a refuse incinerator system permits automatic handling of refuse from tip floor to pulverizer to hopper at the furnace feed point. Milled refuse movement to grates can be by gravity from hopper, ram jet, or air transport. Doing this would eliminate the handling expenses involved in the normal operation of an incinerator; i.e., expenses involved in deep pit construction, crane installation, maintenance, and operation. (Of course, in place of these expenses would be those involved in the purchase, installation, and operation of the hammermill.)

Grinder costs (December 1968) when used in an incinerator operation are: a) <u>86 tons/day</u> (1 grinder, one 8-hr shift): Labor, $0.744/ton; Equipment (includes 5 percent interest), $0.444/ton; Operating charges, $1.8899/ton. b) <u>172 tons/day</u> (1 grinder, two 8-hr shifts): Labor, $0.744/ton; Equipment, $0.222/ton; Operating charges, $1.6498/ton. c) <u>258 tons/day</u> (1 grinder, three 8-hr shifts): Labor, $0.744/ton; Equipment, $0.148/ton; Operating charges, $1.5697/ton. d) <u>516 tons/day</u> (2 grinders, three 8-hr shifts): Labor, $0.465/ton; Equipment, $0.136/ton; Operating charges, $1.2292/ton. e) <u>1032 tons/day</u> (4 grinders, three 8-hr shifts): Labor, $0.435/ton; Equipment, $0.124/ton; Operating charges, $1.1624/ton. The figures are based on the Madison (Wisconsin) operation expanded to a multiple-machine, two and three-shift operation.

Pit Incineration

Pagan, A. R.
"A Sequel – Solving the Problems of a Pit Incinerator"
Public Works, 99(2):84, February 1968

The pit incinerator in question has a nominal capacity of 25,000 tons/yr and is used primarily for wood demolition materials. It was constructed of cinderbrick lined with firebrick, holding about 800 cu ft. Air is supplied by an engine-driven blower through a 21-nozzle manifold. The location is in Bergen County, New Jersey. During the past year of use, the integrity of the incinerator was greatly impaired as a result of the pounding received when heavy timbers were thrown into the pit. Removing the residue after combustion constituted another problem. A clamshell bucket was used in the removal operation. The difficulty was in the fact that despite careful manipulation, the bucket would be banged against the pit walls. Another problem was that of charging the pit at a rate great enough to keep it working at maximum capacity. Push-feeding failed to work.

To solve these problems, the decision was made to rebuild the walls by installing an 11-in. thick reinforced concrete wall, utilizing No. 6 and No. 8 reinforcing bars. Two layers of firebrick were utilized instead of one to protect the wall from the heat. A one-half in. thick asbestos cement board was placed between the bricks and the concrete. The refurbishing was done at a cost of $10,794. (The original cost of the pit was $37,000.)

A highly successful feature of the installation has been the relative absence of smoke. The amount of air forced downward into the pit has been great enough to prevent the emergence of unburned gases.

In designing such a structure, the direction of the prevailing wind should be taken into account. The charging area should be on the upwind side of the pit.

"New Driftwood Incinerator for New York Harbor"
Public Works, 99(9):99, September 1968

A special incinerator for burning refuse is being built for the New York District Corps of Engineers for use in New York Harbor. Approximately 600,000 cu ft of driftwood are collected annually from the harbor waters. At present, disposal is by open burning on two large incinerator barges anchored in the Upper Bay.

The overfire air technique was selected for the design of the new incinerator. It is hoped that with the new incinerator it will be possible to meet federal, state, and city air pollution regulations.

The furnace proper is to be a box-shaped structure, 25 x 20 x 17 ft deep. A 2-ft bottom layer of sand will serve as a buffer. The capacity should be about 10 tons/hr. With the furnace loaded to 2/3 of its volumetric capacity, and the refuse bulk density at 25 lb/cu ft, the furnace's charge capacity will be 62.5 tons. Furnace walls will be composite sectionally supported units composed of an insulated firebrick base and a monolithic face.

Combustion air will be supplied at three levels via manifolds of inlet nozzles on all four sides. Air control will be provided by using a separate blower for each individual run along a wall at each level. Three retractable gas burners will constitute the ignition system. Gas will be supplied from refillable propane tanks.

In constructing the plant, provision is to be made for allowing the future conversion of the plant from an open-pit type to a conventional enclosed incinerator.

Air pollution control will be obtained by way of manual control of the overfire and sidewall air and a water spray curtain over the fire.

Cost of the facility is estimated at $2,000,000.

Heat Recovery

Engdahl, R. B. and J. D. Hummell
"Power from Refuse"
The American City, 83(9):119, September 1968

The theme of the article is expressed in the opening sentences: "We can generate power by burning refuse, and do so economically. But to put it into practice, the utilities will have to be aggressive and government at all levels must provide a favorable political and legal climate for expansion of utilities into this new phase of public service." Problems to be solved are those concerned with the legal aspects of utilities engaging in refuse disposal; management problems involved in utilities working with private and public haulers; acquiring the concepts and skills required for the operation of refuse burning boilers; and modification of present laws governing utilities to permit them to make a reasonable profit while serving the waste disposal needs of a community.

Incineration as an energy source now has more promise than it did years ago because the nature of refuse has changed. Formerly additional fuels had to be added to ensure continuous burning; now the material is highly combustible, having a heating value as high as 5,000 Btu/lb or more. With incineration equipment developed in recent years, firing can be continuous. Shredding and pulverizing the material make it into a fuel of more uniform quality.

In the U. S., one new incinerator has been placed in operation almost every month since World War II.

In most communities, the market for steam as a source of heat is limited and fluctuates widely. On the other hand, there is a continuous demand for power. Whether the local power-generating plant be publicly or privately owned, the electric utility can help in better waste management by participating in a point incinerator power-generation plant program.

The decision to use refuse as a fuel for power generation depends on: a) The dollar value of refuse as fuel; b) the cost to utilize the refuse as fuel; c) the cost of disposing of the refuse by some other means.

COST COMPARISON OF FOSSIL FUELS AND REFUSE

Conventional Fossil Fuel $/million Btu	Value of Refuse as Fuel $/ton
0.20	1.60
0.30	2.40
0.40	3.20

As a fuel, 1/8 ton of refuse is the equivalent of 1.0 million Btu. Items of cost which would make the capital costs for a generating plant burning refuse higher than those for one using fossil fuel are: a) access roads for trucks, truck scales, storage pit and cranes; b) building over pit and for cranes; c) refuse firing grates, residue conveyors, and associated equipment; d) multiple boilers rather than a single large one; e) labor and maintenance costs would be considerably higher for the power-incinerator; f) more men would be needed to handle the refuse and operate the plant.

Two tables are given to demonstrate the potential savings in the use of power-incinerators.

(SUMMARY OF TABLE II)

Cost of Conventional Fuel (cost/million Btu)	Yearly Saving by Burning Refuse	
	Dollars	% of Capital Costs
$0.22	$ 0.0	0.0
0.30	230,000	8.5
0.40	520,000	19.0

Plant: 1,000 ton/day refuse. Privately owned utility.
Population, 500,000.

(SUMMARY OF TABLE III)

Net cost considering value of power generated:

80% Plant Factor Value of Power (¢/kw-hr)	$ Net Cost/ton Refuse Burned (at 450 kw-hr/ton Refuse)
0.5	4.10
0.6	3.65
0.7	3.20
0.8	2.85

Air Pollution Control

Setteducato, N. M.
"Demonstration Incinerator To Have Electrostatic Precipitator"
Public Works, 99(3):99, March 1968

A multipurpose facility costing $1,000,000 is being built in Stamford, Connecticut. The new facility will provide for the "incineration" of all types of wastes, including junked automobiles, oversized bulky objects, spoiled merchandise, tree stumps, and flammable liquid wastes from industrial processes. The configuration of the incinerator is that of a horizontal elongated cross. The upper portion of the cross consists of three ignition chambers with separate charging aprons. Each chamber is equipped with two electrically operated guillotine doors and forced-draft fans for under-and-over fire air. One chamber at the top of the cross (6,600 cu ft) will be equipped with two sets of rails to accommodate the charging of dewheeled automobiles stacked two deep on flanged wheel "dollies." It will handle 50 automobiles/day — burning off paint, plastic, and other contaminants and making the junked cars suitable as scrap steel. The two remaining chambers will be used for other bulky wastes. Gases from the three chambers will enter an adjacent central combustion chamber. Flammable wastes will be introduced into this chamber by sprays. After being cooled, the gases will be passed through an electric precipitator. The chimney will be a steel double-wall stack 165 ft high and 9.5 ft inside diameter.

"Install Precipitation Units in New York City Incinerators"
Solid Wastes Management/Refuse Removal Journal, 11(7):42, July 1968

The city of New York has let out contracts for the installation of electrostatic precipitators for its municipally-owned incinerators. The initial installation will be in the city's Southwest Brooklyn incinerator which handles up to 1,000 tons of refuse/day. A complete turnkey arrangement, the precipitator is designed to clean 170,000 cu ft of dirty gas/minute to the extent of removing 95 percent of the dust in the gas. With its original gas cleaning installation — separation chamber and water spray — only about 50 percent of the dust was removed. Up to the time of the installation of the precipitator, the plant discharged into the atmosphere as much as 250 lb of dust/hr/stack. The precipitators will bring the discharge down to 12.5 lb/stack.

The unit includes an evaporation cooling tower to lower the gas temperature to 575° or 600°F from its temperature of 1800°F in the furnace. The unit is 23 ft wide by 34 ft long and 60 ft high. A typical installation costs from $400,000 to $500,000. The key elements in the system are the discharge electrodes and positively charged 9-round electrodes used as collecting surfaces. The negative charge is from 20,000 to 60,000 volts. The precipitators' collecting surfaces are pocketed to prevent paper ash from escaping to the atmosphere. The precipitators are of the Wheelabrator-Turgi design.

Residue

Kenahan, C. B. and P. M. Sullivan
"Let's Not Overlook Salvage"
American Public Works Association Reporter, p. 5, March 1967

Conclusions reported in the article are: 1) Sampling of incinerator residues can be accomplished on a relatively small scale (600 lb or more) with good results. 2) Glass constitutes the major fraction (44 percent by weight) in all of the samples. 3) Relatively large amounts (as much as 12 percent) of unburned paper were found in some residues. 4) Salvage of all metallic values in the residues (averaging nearly 30 percent by weight) could provide a source of revenue for municipalities. 5) Salvage would also reduce the volume of landfill required for disposal of residues by as much as 50 percent.

The tin content (dry weight basis) of the various samples of residues (i.e., from different furnaces) ranged from 16.3 percent to 18.6 percent; mill scale and small iron, 5.0 percent to 8.4 percent; iron wire, 0.3 percent to 1.3 percent; massive iron, 1.2 percent to 5.7 percent; nonferrous metals, 0.6 percent to 3.7 percent; stones and bricks, 0.8 percent to 1.9 percent; ceramics, 0.6 percent to

1.5 percent; unburned paper and charcoal, 3.9 percent to 12.3 percent; partially burned organics, 0.1 percent to 1.3 percent; ash, 12.1 percent to 17.6 percent; and glass, 37.7 percent to 50.2 percent.

Kenahan, C. B., P. M. Sullivan, J. H. Ruppert, and E. F. Spano
"Composition and Characteristics of Municipal Incinerator Residues"
Bureau of Mines, U. S. Department of the Interior, Pittsburgh, Pennsylvania, Publication No. RI-7204, December 1968

The Bureau of Mines is developing methods for retaining the metal and mineral values contained in municipal incinerator residues. The first phase of the research is described in the report. It describes the establishment of reliable methods for sampling and analyzing municipal residues. The composition and characteristics of the residues were determined. Samples were obtained from a number of grate-type furnaces and also from a rotary kiln furnace. The samples were processed on a batch basis and separated into their natural categories by a variety of methods, including screening magnetic separation, air separation techniques, and hand picking. The main components were metal, metal oxides, glass, and ash.

Miscellaneous

"A New Code for Incinerators"
Power Engineering, p. 62, August 1968

New Jersey is promulgating a new air pollution code which is applicable to all incinerators (municipal, industrial, commercial, large apartment houses). Two years after the effective date of the code, no one will be allowed to use an existing incinerator unless it is of the multiple-chamber type, or a type approved by the State Department of Health. Starting 15 August, all new incinerators must be of this type, and the construction, installation, and use of flue-fed incinerators are banned. With regard to emission, small incinerators must emit not more than 0.2 grains of particles/cu ft dry gas. Large incinerators are limited to 0.1 grains. Smoke darker than No. 1 Ringelmann will not be permitted except during the building of a new fire.

DeBoer, J. G.
"Incineration Should be Allied with Landfill to Prolong the Use of Disposal Sites"
Solid Wastes Management/Refuse Removal Journal, 11(8):16, August 1968

Despite the implication given by the title, the major thrust of the article is on the financing and operation of an incinerator owned and operated by Incinerator, Inc. (in the Chicago metroplitan area). It was incorporated in 1954, at which time two Voland-type 250-ton/day rotary kiln unit incinerators were installed. The second phase in establishing the company's activities proved to be quite difficult, viz., site location and financing. (The difficulty in finding a satisfactory site confirmed the company's original conviction that in a large municipality one large incinerator shared by many operators is far more feasible than a greater number of small incinerators shared by fewer operators.) A site finally was procured in the village of Stickney. It was situated between a two-story high smoking dump on one side and a manure processing plant on the other!

Financing was done by securing a 15-yr loan in the amount of $900,000 and at an interest rate of 5-3/4 percent. The loan was in the form of first mortgage serial bonds secured by a lien on all fixed assets. The bonds were to be retired quarterly in equal installments over a 15-yr period. An important feature was one in which the stockholders signed use contracts with the corporation, according to which they would dispose of a given amount of combustible refuse and pay sufficient unloading fees to cover operating costs. Since an objective of Incinerator, Inc. was to provide a perpetual disposal facility for its shareholders at a reasonable cost, it was decided to keep dumping fees at a level just sufficient to cover operating costs and provide for the retirement of the bonds and for required capital expenditures. To obtain adequate funds for the retirement of the bonds, operating costs were to include depreciation computed on the double declining balance method. Stockholders were given pro rata disposal rights based on the number of shares purchased by them.

In 1964, a contract was made with a salvage company to handle all of the "tin" cans in the refuse on a fixed per-ton basis. The cans are now sold to the copper industry in Arizona. "Each ton of refuse burned now produces about 40 percent of income from this source."

In 1962, facilities were installed for producing steam from the heat generated in incineration. In a 9-month period ending on 30 April 1963, 201,000,000 lb of steam were produced. Average yearly production during the 5-yr period ending 30 April 1968 was 278,570,000 lb. Because of the intermittent nature of an incinerator operation, an auxiliary fuel oil gas-fed boiler had to be installed to keep steam production at the uniform level required by the customer for the steam. For a while, costs from corrosion and consequent maintenance and other difficulties made the steam production phase a losing proposition. However, with the imposition of tighter controls, the operation is beginning to show a profit. However, the author states: "Considering the problems attendant with operating the two systems, incinerator and steam, simultaneously, and the fact that any change or required shutdown of one necessarily affects the other, I seriously doubt – after 5 years of experience with and 5 years without the steam facility – that we would include steam in any future operation."

An advantage of this incinerator operation is that it is available 365 days/yr, 24-hr each day to the shareholders for the disposal of their refuse. They are not restricted to the 6:00 a.m. to 4:00 p.m. hours imposed by most landfills now in use.

Golueke, C. G. and P. H. McGauhey
"Future Alternatives to Incineration and Their Air Pollution Potential"
In Proceedings: The Third National Conference on Air Pollution, Washington, D. C., 12-14 December 1966, U. S. Department of Health, Education, and Welfare, Public Health Service, Public Health Service Publication No. 1669, pp. 296-308, 1966

The alternatives to incineration are almost entirely limited to landfill, composting, anaerobic digestion, ocean disposal, wet oxidation, and pyrolyzation. All of these require essentially the same handling methods as are associated with preparing refuse for incineration. Offense to the aesthetic senses rather than danger to the health of man and animals, or damage to vegetation, might be considered a micro-air pollution potential common to all methods. The alternative processes themselves, if properly operated, make little further contribution to air pollution. Even with poor management, their pollution potential is confined to odors, dust, and some vapors, with the possible exception of pyrolysis, which could rival incineration if poorly managed.

An evaluation of alternatives to incineration rests lightly on their air pollution potential. A consideration in relation to this potential is extremely important, however, since it represents the first step in a concern for man's environment and may lead the way to a broader examination in that environmental context.

"Futuristic Incinerator Planned for Hamilton"
Solid Wastes Management/Refuse Removal Journal, 12(3):14, March 1969

A description is given of an incinerator to be built in Hamilton, Ontario, and expected to be in operation on a 600-ton/day basis by 1971. Interestingly, the name "incinerator" is being carefully avoided, and the plant will be designated as the "East End Solid Wastes Reduction Unit." The reasoning is that characteristic of modern practice, viz., if an objectionable entity is given an innocuous name it will cease to be objectionable. Standard material handling methods usually used in incinerator operations will not be followed in the proposed one.

Hamilton is an important manufacturing center with a rapidly expanding population, currently more than 286,000. At present it is beset by unusual amounts of wood wastes resulting from the demolition involved in carrying out urban renewal projects. Approximately 150 tons of wood are burned each day at the city's landfill site. This high output of wood wastes was considered in a study made in 1968 to determine the most practical way of utilizing incineration. The resulting recommendation was that refuse and wood be mixed such that they be consumed simultaneously. The design resulting from the study encompasses a process in which waste disposal components are integrated into an automated system.

Trucks will discharge refuse directly into a pit from which the material will be automatically conveyed. The material will be passed through shredders or pulverizers to obtain a homogenous mixture having a particle size of a maximum of 2 in. and suitable for easy handling. To reduce the capacity requirements of both boilers and inert fill sites, ferrous metals will be removed by magnetic separation directly after the incoming material is shredded. (Presently about 30 tons of metal are found each day in the city's refuse.)

Water consumption involved in quenching will be minimized by the use of a burning-in-suspension operation. This method of burning produces an ash at a 200°F temperature. Electrostatic precipitators will be used for the removal of fly ash and particulate matter. Discharge gases will be cooled to the required 650°F maximum by the employment of water-walled boilers; which, in turn, will result in the production of steam. The steam will be used to run high-horsepower equipment such as shredders and necessary fans. According to test results, about 50 percent of the combustion will take place in suspension. The balance will be accomplished on slow-moving grates. Automatic monitoring will be done throughout the process. The capacity of the boilers will each be 300 tons/day. They will utilize 165-ft high chimneys.

Total costs for a 600-ton/day unit are expected to amount to about $6,250,000. An increase in capacity to 900 tons/day could be accomplished by raising the capital investment 25 percent. Operation costs are estimated to be under $2.25/ton for the 600-ton/day plant.

(This plant was also described in an article in Public Works. See abstract for "Solid Wastes Reduction Unit Promises to be a Better Mousetrap" — Sutin, G. L.)

Fink, M.
"Incineration of Solid Wastes"
Paper presented in the Solid Wastes Seminar sponsored by the Environmental Systems Division, Eidal International Corporation, 245 Woodward Road, S.E. Albuquerque, New Mexico, 16-17 April 1969 (Mr. Fink is Project Engineer for the firm of Black and Veatch, Kansas City, Missouri)

It is logical to assume that the primary disposal of refuse will be by landfill in the next few years, and, in fact, this practice will probably continue through the foreseeable future. As the amount of refuse grows and available local landfill sites are filled to capacity, the disposal areas will be located farther and farther from the densely populated refuse generation centers, and the increasing transportation costs will dictate the economic need for volumetric reduction processing prior to hauling to the landfills. Incineration is the predominant volume reduction method in today's refuse disposal operations and it will probably continue to be for an indefinite period. It should be noted that incineration is not considered a disposal method, but rather a means of reducing the volume of material to be buried. Thus, incineration is an intermediate step in the disposal operation, and generally is not practiced if suitable and adequate close-in landfill sites are available.

The future of refuse incineration depends almost completely on the economics of incineration as compared to other processing methods and disposal schemes. Cities cannot be expected to construct and operate incinerator plants unless these plants can be used in a refuse disposal plan which costs no more than any other proven satisfactory disposal plan. Development of adequate revenue from the sale of waste heat could have a marked effect on the cost of implementing disposal plans calling for the use of incineration in some areas in the coming years. It is probable that in the coming years the continued urbanization in the United States will cause a steady increase in the refuse disposal problem, which in turn will result in increased use of incineration in refuse disposal operations throughout the country.

"I think it is safe to say that installation of incineration systems in the future will require large amounts of capital investment which lead to the basic secondary goal of cost control. This should include operating and maintenance cost as well as initial cost of the facility. The plant cost most frequently publicized is the plant construction cost and the total actual plant cost is seldom available." When all costs are considered, a modern, fully-equipped, multiunit plant with unit sizes of 250 to 300 tons/day will cost from $7,000 to $11,000/ton of daily capacity at 1969 price levels.

The field of refuse incineration is not static, and new ideas and concepts are being developed continuously. The industry is currently taking a hard look at the economics and the problems of replacing the refractory walls of conventional incinerator units with waterwalls such as are used in fossil-fuel fired boilers. Most studies to date indicate this is economically feasible only when a suitable market exists for a large percentage of the total steam generated.

Possibly the most significant of the current studies of new concepts is the development of new firing techniques similar to those used in pulverized coal-fired furnaces. This concept involves grinding and possibly drying of the refuse prior to incineration. The ground material can be blown into the furnace and burned in suspension. There is little doubt that presizing of the refuse will result in more complete burn-out; but of possibly even greater significance is the potential change in refuse handling and residue removal operations it would permit.

COMPOSTING

Design, Methods, and Operation

"Composting Operation Handles Refuse and Sludge"
Public Works, 99(3):84, March 1968

Lone Star Organics has a 20-yr contract with the city of Houston to dispose of approximately 400 tons/day of municipal refuse and 120,000 gal of waste-activated sludge. The process used is that of the Metropolitan Waste Conversion Corporation (the parent company). About 250 tons of marketable compost are produced/day. A 24 by 60-in. Bird centrifuge is used to thicken the sludge, which is added to the refuse to supply nitrogen and moisture.

In the Houston operation, domestic refuse is delivered to the plant at the rate of 40 to 50 tons/hr by private contractors. Cardboard, paper, rags, glass, and nonferrous metals are removed manually for salvage. Noncompostables, such as ceramics, are separated for clean landfill. Paper and rags (12 percent of the total input) are baled and sold. The remaining material is ground coarsely. Film plastic and light paper are pneumatically lifted to a burner. The remaining material is passed through a secondary grinder. Then ferrous metals are removed magnetically. Simultaneously, the Bird centrifuge has been drawing off an equivalent of five tons of dry solids of waste-activated sludge through an 8-in. cast iron pipe from a main Houston line. The sludge is thickened to 1 to 5 percent. The effluent is returned to the city line. (Ed. note: According to information received while on a tour of the plant in early 1969, no sewage sludge is being added to the refuse.) The Metro Waste process requires about 65 percent moisture for efficient digestion. After mixing with the sludge, the refuse is fed on a "layer" basis to the long, narrow digester tanks. Air is injected by forced draft for oxygen and temperature contol; fogging nozzles maintain needed moisture control. The total detention period in the digester is six days. The composted refuse is given a final grinding, is screened, and dried at temperatures as high as 1200°F to complete pathogen kill. It is then stockpiled for curing.

Harding, C. L.
"Recycling and Utilization"
Compost Science, 9(1):4, Spring 1968

Anaerobic decomposition of waste materials to produce soil additives has been practiced in Asia for centuries. Aerobic composting has been practiced in Europe since the 1920's and 1930's. (Ed. note: Aerobic composting has been practiced sporadically and on a very small scale in the U. S. since the 1950's.)

All composting operations can be broken into three basic steps: Refuse preparation, stabilization, and product upgrading. Preparation includes receiving, sorting and savaging, grinding, and the addition of moisture and nitrogen (when required). Stabilization is accomplished either in windrows or in mechanical plants. Product upgrading consists of grinding, enrichment, granulation, shipment, and marketing.

A good example of a windrow-type composting operation is the TVA-PHS Demonstration Compost Plant at Johnson City, Tennessee. Here the windrows are turned five to ten times with a Cobey-Windrow turner during about five weeks of composting. After composting, the material is cured two to four weeks. This process involves the use of relatively large land areas — about 30 acres/100,000 population.

Examples of mechanical compost systems are the Fairfield System, the International Disposal Corporation (IDC) System (formerly the Naturizer System), and the Metrowaste System. With these systems, the land requirement is about five acres/100,000 population.

A 25-ton/day Fairfield pilot plant is operated at Altoona, Pennsylvania. In this operation, suitably prepared refuse is fed to a digester having a perforated bottom built such that air can be conducted through it and forced into the composting mass. The digester is equipped with augurs fastened to a rotating arm. They serve to stir, mix, and inject air into the composting mixture. After a five-day detention period in the digester, the material is stacked in windrows and allowed to cure for about three weeks.

A 105-ton/day IDC plant is in operation in St. Petersburg, Florida. (Ed. note: This plant was closed about a year ago.) In this operation, the incoming refuse is sorted and ferrous materials are removed by a magnetic separator. The sorted material (compostable) is pulverized and moistened with an NH_4NO_3 solution. Upon leaving the pulverator, the material is passed through a flail grinder. While this grinder can effectively shred refuse, it leaves rags and plastic items almost intact. The plug-flow digester is housed in a vertical building with horizontal moving belts on which the ground refuse composts. Air is blown into the piles just above the belts to provide aeration. The material is reground after two days of processing. At the end of five days, the material is removed and screened to remove noncompostable items. The screened material is cured in windrows for about ten days.

A 350-ton/day Metrowaste plant is in operation in Houston, Texas. In this process, the material receives the usual pretreatment and is then discharged into the digesters, which are horizontal tanks having perforated bottoms. Air can be blown into the piles by way of the perforated bottoms. After a four to six-day residence period in the tanks, the material is reground and then transferred to an outdoor pile for curing and storage until it can be sold.

According to the article, the manpower requirement in mechanical compost systems is from 1 man/6 tons to 1 man/15 tons refuse processed/day. A cost not well documented but nevertheless very significant is that of hammer wear for grinding operations. This is reported to range from \$0.65 to \$1.25/ton refuse processed. (Ed. note: See abstract of "Gainesville Compost Plant - An Interim Report.") Aeration requirements range from 0.2 to 2 cfm/cu ft digester capacity. In the accompanying table, taken from the article, are given capital costs, and energy and labor costs for the three systems.

Capacity	Fairfield[a]			Metrowaste[a]			IDC		
tons/day	\$X 10^6	hp	Labor	\$X 10^6	hp	Labor	\$X 10^6	hp	Labor
100	1.4[b]	900[b]	8[b]	0.8	1,250	12	1.4	600	20
200	2.1[b]	1,400[b]	11[b]	1.2	1,700	17	2.1[b]	800[b]	28[b]
300	2.5	1,700	14	1.5	1,900	25	2.7[b]	950[b]	36[b]
400	3.2	2,500	20	1.6	2,000	30	3.2[b]	1,100[b]	45[b]

[a]Exclusive of cost of land and especial foundation preparation.

[b]Author's estimate based on chemical engineering estimating procedure.

"British Composting Firm Gets Research Group Backing"
Compost Science, 9(1):29, Spring 1968

The National Research Development Corporation of England has decided to back the Lowden Compost Process as a system likely to succeed in modern waste disposal practice. In the Lowden system, no pretreatment is accorded the refuse, which is passed directly into shredders capable of handling all incoming materials, even refrigerators. The shredded refuse (6-8 in. particle size) is conveyed to digesters in which moisture and aeration are carefully controlled. Judging from the sketchy drawing given in the article, the digester is a multiflow vertical affair, in which the shredded material is introduced on the top floor and gradually passed down from floor to floor, much as in the original Naturizer method. Apparently, by the time the material reaches the bottom floor (approximately five days), it is ready for curing. Upon leaving the digester, the material is fed into a 300 hp grinder in which all glass is ground to a powdery consistency and any remaining lumps of material are crushed.

According to the manufacturers, a population of 100,000 would require an $875,000 plant. Such a plant could produce a minimum of 300 tons of compost/week. Apparently others question this estimate.

"Practical Data on Composting"
The American City, 84(3):84, March 1969

The article is concerned with a description of the demonstration compost plant operating at Gainesville, Florida, under a grant from the Bureau of Solid Wastes Management to the Gainesville Municipal Waste Conversion Authority. The authority is governed by seven trustees representing the city of Gainesville, Alachua County, the University of Florida, and the Metropolitan Waste Conversion Corporation of Wheaton, Illinois. The Environmental Control Administration represents the federal government. The plant cost about $1.4 million. It began operations on 4 January 1968 by processing 19.1 tons of refuse. Production was sporadic thereafter due to shutdowns and equipment adjustments. Design capacity (150 tons/day) was reached in April of 1969. The activities, in addition to those concerned with the technological aspects of the operation, will include chemical and microbiological studies to learn more about the end product. Thus far, the bacteriological work has been concerned mainly with determining the microbiological parameters desired by the Florida State Board of Health.

A new concept tried was the separation of some of the plastics, paper, and metal within the primary grinder. The grinder included a ballistics separator to remove metal and an air system consisting of several blowers to force air into the secondary ballistics separator chamber. The particles were then carried by the airstream to burners. Unfortunately, separation was poor and wear excessive. A more conventional primary grinder is now being installed.

Inasmuch as the plant was only about a year old at the time of the writing of the news release, it was too early to report on equipment life (one of the aims of the study).

"Gainesville Compost Plant — An Interim Report"
Gainesville Municipal Waste Conversion Authority, Inc., prepared for the U. S. Department of Health, Education, and Welfare, Bureau of Solid Wastes Management, 1969

The report actually is a collection of three interim reports extending from the construction phase of the project through the "breaking-in" period of the equipment, i.e., through 1967 to August 1968.

This series of interesting and frankly-written reports should be read by everyone interested in composting. The experiences narrated in them serve as good examples of the difficulties to be encountered in any operation involving the processing of solid wastes. They serve to give a true picture of what is involved in setting up a composting operation. The report also gives valuable evaluations of specific pieces of equipment. Inasmuch as the report is too long and the material too diversified to be properly abstracted so as to include all of its worthwhile observations, only some of the highlights will be extracted and given here.

In the first interim report are detailed the background of the Demonstration Project, the design factors of the plant, a detailed description of the plant, construction of the plant and costs, operational phase of the project, technical program of the Gainesville compost plant, university (of Florida) related projects, and relationships with public health authorities. The construction phase was substantially accomplished by the end of 1967.

The second interim report covers the period January to April 1968. It includes a description of the final phases of construction, a discussion of personnel, mechanical and safety problems, a report on equipment and the problems encountered in placing them in operation, a description of the ballistic separator and other equipment, and information on the implementation of the biological program. Interesting facts are: a) It was concluded that the noise level in the sorting area (which is next to the primary grinder) is high enough to be a potential danger to the hearing of the men in this area. b) Another health hazard to the sorters is found in the presence of discarded hypodermic needles in wastes from hospitals and doctors' offices. Fortunately, this type of waste usually is discarded in blue plastic bags. The problem has been alleviated by discarding the unopened bag and its contents into the noncompostable container.

The major problem during this period was the malfunctioning of the primary grinder, which is a disintegrator-type of mill. It is a Centriblast mill and is designed to process 20 tons of refuse/hr. In operation, the output of the machine was only 5 to 10 tons/hr instead of the designed 20 tons/hr. The wear on the hammers was excessive. The particle size of the milled refuse was larger than anticipated. In the words of the report: "The Centriblast turned out to be a dirty machine, dropping out refuse and trash from underneath the lower apron feed conveyor. Another problem was found in the improper design of the bearings."

An interesting observation was made on the costs of resurfacing hammers for the two types of grinders used in the project. It was found that in the long run, it was cheaper to use low-cost alloys for resurfacing the hammers than to use the higher-priced materials, even though the hammers had to be resurfaced more frequently when the low-cost alloys were used. Taking into consideration the loss from "down-time," and labor and material costs, the cost/ton of ground material would be as high as $1.34 with the use of <u>Certanium</u>, a very hard alloy. Hammers surfaced with <u>Certanium</u> lasted through 805 tons of refuse. On the other hand, with the use of a softer, low-cost alloy, the cost/ton was $0.27, even though the hammers had to be resurfaced after only 600 tons of processed refuse.

The third interim report covers the period May to August 1968. Interesting observations in this report are: a) The equipment as designed could not handle trash. ("Trash" as used in the report apparently refers to garden debris and includes tree trimmings, stumps, large "globs" of dirt and debris, etc.) b) "We would have to state, at this time, after a fair trial of eight months, that the Centriblast has turned out to be a very disappointing piece of equipment." A total of $13,543.65 (exclusive of cost of down-time) was spent by the Authority in trying to make the machine workable. c) The ballistic separator did not function properly, and its use was discontinued. d) Wear and tear on the screens in the final-grind vertical hammermills were great. The longest a set of screens ($90.00/set) lasted was three weeks. e) Sales of compost have been negligible. "The compost sold, to date, is being put into test plots, particularly in the citrus industry."

An important feature of the project is the development of methods of chemical and microbiological analyses of "raw" and composted refuse. Many of the existing techniques were found to be inadequate for use in analyzing solid wastes. The average nitrogen content of the raw waste as received at the plant and of the composted product was less than 1 percent. It was interesting to note that the authors of the report came to the conclusion reached by workers at the University of California (Berkeley) in the early 1950's, namely, that a workable and yet satisfactory moisture content for municipal refuse is between 45 percent and 50 percent.

Research

Mercer, W. A., W. W. Rose, J. E. Chapman, A. Katsuyama, and F. Dwinnell, Jr.
"Aerobic Composting of Vegetable and Fruit Wastes"
Compost Science, 3(3):9, Autumn 1962

In preliminary studies, the following results were obtained and conclusions made: 1) Materials such as municipal compost and rice hulls can serve as absorbents of moisture from fruit waste solids and thus be used for adjusting the moisture content in composting. Shredded redwood bark failed to absorb moisture and apparently inhibited bacterial growth. Wheat straw did not provide the necessary structural strength to prevent compaction. White pine sawdust performed adequately in the absorption of moisture and the maintenance of porosity in the piles. 2) The optimum moisture content for composting fruit-waste-absorbent mixtures was from 60 to 65 percent. 3) Aerobic conditions could be maintained in the material in the bins by turning the mixture daily during the first four or five days after starting the compost process, and on alternate days thereafter until the composting process was completed.

Rose, W. W., A. Katsuyama, J. E. Chapman, V. Porter, S. Roseid, and W. A. Mercer
"Composting Fruit and Vegetable Refuse"
Compost Science, 6(2):13, Summer 1965

The work described in this paper is summarized in the final report (June 1968) issued by the National Canners Association under the authorship of Mercer and Rose. The paper is in the nature of a progress report and is divided into sections concerned with results obtained in preliminary studies, in bin-composting studies, in windrow composting, and in forced aeration composting.

In their discussion of the results of their experiments, the authors state: "The results of these investigations have indicated the potential feasibility of composting as a means of disposal for high-moisture fruit and vegetable wastes. Particularly encouraging was the absence of odor and fly problems during the composting experiments .... Since the moisture content of fruit waste is approximately 85 percent, the evaporation during the composting and subsequent drying produced large weight and volume losses in the initial mixture of waste and dry material. Most of the remaining fruit substances, comprising the other 15 percent, was converted to carbon dioxide, water, and other gases. As a result, recycling of the dry material produced only a slight increase in the final weight and volume .... Chemical additives such as lime and urea produced a more favorable environment for microbial growth during the compost process. Lime neutralized the fruit acids, thus bringing the pH level nearer that optimum for good microbial growth .... From the standpoint of considering composting solely as a means of fruit and vegetable waste disposal, and without regard to the production of a soil conditioner, particular emphasis was given to the frequency with which fresh water could be added to the compost piles. Rather than permit the compost process to go to completion, waste was added when the temperature was in the thermophilic range. At this stage, the loss of moisture and organic decomposition occurred at the fastest possible rate. However, the stabilization of fruit and vegetable wastes decelerated with subsequent waste additions. Apparently, microbial growth was inhibited by substances which gradually accumulated in the compost mass."

Mercer, W. A. and W. W. Rose
"Composting Fruit and Vegetable Refuse"
Western Research Laboratory, National Canners Association, 1950 6th Street, Berkeley, California 94710, Final Report, June 1968

The report deals with research aimed at the reduction of cannery wastes to a stable and innocuous residue by means of composting. Initial studies involved the use of small-scale batch-type operations to determine the requirements for composting the wastes. The first requirement was the use of an absorbent material to compensate for the high moisture content of the waste. Of the several types of absorbent materials tested, rice hulls and sawdust proved to be the most satisfactory. In the composting process, the wastes were mainly reduced to ammonia, CO_2, and H_2O. Very little solid residue remained to increase the bulk of the compost mass. Hence, the mixture of absorbent and residue remaining could be used for second, third, and so on, additions.

Utilizing the principles developed in the pilot study, operations were expanded to windrow composting. Rice hulls were formed into open windrows and preground cannery waste was added to the windrows. The materials were mixed and aerated by mechanically aerating the mass. To improve the waste handling capacity of the windrows, waste additions were made periodically after the compost mass had reached thermophilic temperatures. Inasmuch as additions of wastes could be made repeatedly without interrupting thermophilic conditions, the feasiblity of a continuous compost operation for the disposal of high-moisture organic wastes was demonstrated.

Some of the more interesting findings mentioned in the Summary section of the report are: 1) Because of the high moisture and organic content of fruit wastes, reductions in weight in batch-type composting amounted to 70 percent; and in volume, 59 percent. 2) The enrichment of the compost mixture with nitrogen additives hastened the compost cycle. 3) Although flies were attracted to the piles, no egg deposition took place. 4) In the bin-type experiments, it was found that the continued addition of produce-house wastes was accompanied by a buildup of inhibitory materials. A toxic material was extracted as a water-soluble, heat-resistant substance which inhibited the growth of bacterial vegetative cells and the germination of spores. 5) With the use of closed-wall windrows, the windrow height of rice hulls could be extended to five to six ft. In closed-wall windrows, air-injection into the compost mixture was needed to maintain aerobic conditions; whereas daily turning alone proved to be insufficient. 6) An automated system was developed to handle the waste, grind and transport the material to the windrow, to add the waste, and to turn the windrow.

Rose, W. W. and W. A. Mercer
"Fate of Insecticides in Composted Agricultural Wastes"
Western Research Laboratory, National Canners Association, 1950 6th Street, Berkeley, California 94710, Progress Report — Part I, July 1968

As is indicated by the title of the report, the study was concerned with following the fate of insecticides during the composting process. The method of composting followed by the researchers was one used successfully by them in previous studies. It involved the use of bins 8 ft wide, 8 ft long, and 4 ft high, each divided into sections 6 ft wide by means of a partition down the center of the bins. Alternate layers of waste and rice hulls were placed in one section of each bin. The contents were aerated in the batch-type process by periodically "turning" the contents of the bin; i.e., by shoveling the contents from the occupied section of the bin to the empty section. A total of 360 lb of rice hulls and 875 lb of wastes were placed in each bin. The insecticide to be tested was dissolved in three liters of alcohol and was sprinkled over the surface of the bin contents, and the latter was then turned, i.e., mixed. Decomposition of insecticide at mesophilic and themophilic temperatures was observed.

The presence of insecticides had no apparent effect on numbers of microflora. Although bacteria seemed to be present in comparable numbers in the batch-type and the continuous-composting processes, actinomycetes and fungi were more numerous in the batch-type process. A trend of decrease in total number of microflora characterized the extension of the compost time.

The concentration of diazinon and parathion declined rapidly in both composting processes. Thermophilic composting was more efficient than mesophilic composting in reducing the concentration of organo-phosphate insecticides. Some reductions in DDT concentration took place in the continuous thermophilic composting process, whereas none was observed in the batch-type process. On the other hand, dieldrin was more extensively broken down in the batch-type composting. Following the active compost period (120 days), the "curing" or "aging" phase of the compost had little or no further effect on the degradation of the insecticides added originally.

In the studies on DDT, no known breakdown products, not even DDE, were detected. Heat probably was the main factor in the small amount of loss from the composting mass that did occur. On the other hand, heat apparently was not the main factor in the loss of dieldrin. Here, microbial utilization probably played an important part in reduction of dieldrin from its initial concentration of 2.9 ppm to a final residue level of 0.2 ppm in the batch process and to 1.5 ppm in the thermophilic process. It required approximately 10 days in the thermophilic process and 28 days in the batch process to reduce the diazion concentration by 50 percent. Parathion dropped from the initial concentration of 3.3 to a final level of 0.0002 ppm after 42 days in the thermophilic process. In the batch process, it took 84 days to bring the parathion level down to 0.075 ppm, and 240 days to reduce it to 0.0345 ppm.

Jeris, J. S., R. Regan, and R. Gasser
"Cellulose Degradation in Composting"
Civil Engineering Department, Manhattan College, Bronx, New York, Progress Report, 31 December 1968

The research was divided into three phases. Work in the first phase was concerned with developing inocula rich in cellulose-decomposing organisms for use in the succeeding experiments. Bench-scale "composters" (horizontal plexiglass cylinders, volume 0.75 cu ft) were used in the second phase. The design was such that the major environmental conditions could be varied. In operation, the cylinders were filled to half their volume. "Shake flask" experiments were used in the third phase of the studies to consider the effects of environmental conditions not easily studied with the use of the "composters."

Phase I: "Enrichment" cultures of cellulose-degrading organisms from natural sources were maintained in liquid media and on agar plates. Optimal growth occurred within the pH range 7.0 to 8.0, and 45°C, the highest temperature tried. A yellow pigment, identified as α-carotene, found in many of the cultures, was used as an indicator of biological growth of these cultures. Growth increased with aeration.

Phase II: Rate of cellulose degradation was influenced by changes in pH, moisture, temperature, and presence of small amounts of nutrient broth. O_2 uptake at 40°C decreased from 0.45 g-moles/day at pH 7 to 0.195 g-moles/day at pH 6.0. Activity decreased when the moisture content dropped below 50 percent. O_2 uptake and CO_2 production increased almost sevenfold when the moisture content was increased from 48 percent to 60.5 percent. The addition of glucose (1 percent) and nutrient broth (2 percent) increased cellulose degradation by about 25.7 percent. Composting a partially-decomposed sample of mixed refuse at 50°C resulted in an average O_2 uptake of 1.63 g-moles/day, and a CO_2 production of 1.43 g-moles/day. Respiration quotients ranging from 0.8 to 0.95 were obtained.

Phase III: Potassium phosphate proved to be an effective buffer at pH 7-7.5. Rinsing the raw paper significantly reduced the required amount of raw paper. CO_2 production at 40°C doubled by adding 1 percent glucose and 2 percent nutrient broth.

Use of Compost Product and Sewage Sludge

Sanderson, K. C., H. P. Orr, and W. C. Martin, Jr.
"Utilization of Processed Garbage in the Production of Selected Ornamentals"
Paper presented before the 65th Annual Convention of the Association of Southern Agricultural Workers, Inc., Louisville, Kentucky, 5-6 February 1968

Processed garbage was utilized as a soil amendment and a mulch in a series of tests conducted on field and greenhouse production of the following selected ornamentals: *Camellia sasanqua*, *Chrysanthemum morifolium*, *Ilex cornuta Burfordii*, *Ilex crenata Hetzi*, *Juniperus conferta*, *Rhododendron obtusum*, and *Viburnum burkwoodii*. Chlorosis was observed in container plants within six months after potting. Processed garbage decomposed rapidly in greenhouse culture, causing nitrogen deficiency symptoms in chrysanthemums. Cut and potted chrysanthemums grown in garbage-amended media were shorter than plants grown in peat-amended media. Flower stems cut from plants grown in garbage-amended media weighed less than stems grown in peat-amended media. The older leaves of chrysanthemums grown in garbage-amended media exhibited injury, i.e., the margins were scorched. Spurway analysis of media containing 25 to 50 percent processed garbage revealed nitrates 0-2 ppm, phosphorus 0-5 ppm, potassium 20-40 ppm, and calcium 40-100 ppm. The pH ranged from 6.7 to 8.5. Solubridge readings were at 1:5, and soil water ratios ranged from 34 to 86. Both pH and soluble salts dropped rapidly with duration of culture. Garden chrysanthemums mulched with processed garbage produced results comparable to plants mulched with sawdust or pinestraw.

Sanderson, K. C. and W. C. Martin, Jr.
"Utilization of Processed Garbage as a Soil Amendment in the Production of Selected Greenhouse Crops"
Paper presented before the 65th Annual Meeting of the American Society for Horticultural Science at the University of California, Davis, California, 18-21 August 1968

Processed garbage was utilized as a soil amendment in a series of tests conducted with Chrysanthemum morifolium, Antirrhinum majus, Lilium longiflorum, and Petunia hybrida. Soil analysis of media containing 25-50 percent processed garbage revealed low nitrogen, phosphorus, and calcium levels, excessively high pH and high soluble salts concentrations. Processed garbage underwent a rapid breakdown in greenhouse culture causing nitrogen deficiency symptoms. Cut and potted chrysanthemums and Easter lilies grown in garbage-amended media were shorter than plants grown in peat-amended media. Flowering stems cut from chrysanthemums grown in garbage-amended media weighed less than those grown in peat-amended media. The leaves of chrysanthemums, snapdragons, and petunias often exhibited injury, i.e., scorched margins. Processed garbage apparently contains a phytotoxic substance. Potted chrysanthemums grown in garbage-amended media had more breaks per plant than peat-amended plants. Easter lilies grown in garbage-amended media had slightly fewer flowers than those grown in peat-amended media.

Orr, H. P., K. C. Sanderson, R. Self, and W. C. Martin, Jr.
"IV. Utilization of Processed Garbage-Sludge as a Media Additive in the Production of Woody Plants in Containers"
Research Results for Nurserymen, Horticulture Series No. 10, Agricultural Experiment Station of Auburn University, Auburn, Alabama, August 1968

"Identical experiments were established at Auburn University, Auburn, Alabama, and the Springhill Ornamental Horticulture Field Station, Mobile, Alabama, to compare processed garbage amended with raw sewage with other media additives in container plant production. Nine media mixtures ... were used to grow the following species: Camellia sasanqua, Ilex cornuta Burford, Ilex crenata Hetz, Juniperus conferta, Rhododendron obtusum japonicum, and Viburnum burkwoodii .... Spurway analysis of processed garbage-sludge revealed nitrates 0 ppm, phosphorus 0 ppm, potassium 20-40 ppm, and calcium 100 ppm. Soluble salts frequently exceeded 80, the toxic level. Following soil analysis, the pH of the nine mixtures was adjusted to either 6.0 ro 5.0, the lower pH being used on the azaleas and camellias. The pH adjustments were made with either limestone or dusting sulfur. Mixtures adjusted with sulfur received 2 lb of gypsum/cu yd. Superphosphate (0-20-0) was added to all the mixtures at the rate of 2 lb/cu yd. Fertilization consisted of four applications of 12-6-6 analysis fertilizer with minor elements added ... and one application of a 14-4-6 analysis fertilizer tablet during the growing season. The 12-6-6 analysis fertilizer was applied at the rate of one-half level teaspoon per container. One 12-g container tablet was placed in each container. The experiment was replicated four times at each location. Experimetally, there were two locations, four replications, six species, five plants per treatment, and nine treatments, for a total of 2,160 plants. A randomized block design was used at both locations. A mean height, spread, and dry weight, was determined for each species.

"Observations one year after planting showed high soluble salts and pH of processed garbage-slude had made it extremely difficult to maintain adequate plant nutrition. The soluble salts dropped rapidly following pH correction and culture (probably leaching). Some plants exhibited deficiency symptoms soon after planting but usually recovered normal color following fertilization. Winter injury killed 85 percent of the camellias and 20 percent of the azaleas in Mobile during the first growing season. Losses in Auburn were not as great, with 8 percent of the camellias and less than 1 percent of the azaleas being killed. The losses could not be correlated with treatment. The foliage color of the plants in Mobile was not as good as that in Auburn. Shore Junipers showed extreme chlorosis in the sand mixtures at Mobile. Best leaf color appeared in the vermiculite mixtures with the bagasse mixtures being next. Plants at Auburn did not display such great differences in leaf color. Increased rainfall in Mobile may have influenced the fertility of the mixtures and the results obtained."

"Land Reclamation Project"
Harza Engineering Company assisted by Bauer Engineering, Inc., prepared for the U. S. Department of Health, Education, and Welfare, Public Health Service, Solid Wastes Program, Cincinnati, Ohio, Interim Report, 1968

The report describes work done as a part of Demonstration Grant DO-21d-00080. The title of the grant is "Agricultural Benefits and Environmental Changes Resulting from the Use of Digested Sludge on Field Crops, and Development of Economic and Physical Characteristics Criteria for Use in Selecting Disposal Sites." The grantee is the Metropolitan Sanitary District of Greater Chicago. The project was started 1 March 1967, and is scheduled to end on 28 February 1970. The objectives are those implied by the title. In carrying out the grant, the Agronomy Department of the University of Illinois will conduct laboratory, greenhouse, and field investigations to determine: a) the most practical amount, frequency, economical method and time for applying digested sludge on cropland; b) the probability of contaminating surface water and groundwater aquifers with pathogens and molecular organic and inorganic ions; c) the changes in the soil related to such physical and chemical characteristics that might be expected from frequent and heavy applications of digested sludge; and d) the crops and cropping systems that will provide maximum absorption of certain essential and nonessential elements supplied to the soil by digested sludge applications. Concurrently, an investigation will be made by the above-named engineering companies to investigate and recommend disposal sites and means of transport and distribution.

A listing of chapters and some subheadings probably best gives an idea of the contents of the report. It is as follows: Introduction: Sludge Production, Investigation Objectives; Phases 1 and 2 – Sludge Utilization Program: Overall Development Schedule, Phase 1 – Equipment Demonstration, Phase 2 – Accelerated Application of Cook County Site General Plan, Potential Phase 2 Sites, Maximum Loading Rates, Operating Considerations, Phase 2c – Cooperative Sites; Route and Area Selection – Phase 3 Site: Criteria for Harza Studies, Part One – Preliminary Screening of Alternatives – Evaluation of Mine-Spoil Areas, Screening of Sandy Soil Areas; Part Two – Evaluation of Selected Alternatives – Alternative Conveyance Methods, Truck Transportation, Barge Transportation, Railroad Transportation, Pipeline Transportation, Comparison of Conveyance Alternatives; Agricultural Economics; Preliminary Design of Phase 3 Project; Environmental Considerations: Public Health, Dissolved Minerals Vectors, Esthetic Factors; Recommended Engineering Studies and Investigations: Research Program of the University of Illinois; Sludge Properties; Present Knowledge of Sludge Utilization for Agricultural Land Reclamation; Annotated Bibliography; Soil Considerations; Agricultural Development; Socio-Economic Characteristics; Environmental Considerations; Route Selection and Sludge Conveyance; Costs and Benefits.

SELECTED CONVEYANCE SYSTEM COSTS
(Costs in $1,000)

Method	Capital Cost[a]	Annual Costs		
		Fixed	M and O	Total (Rounded)
Truck	9,100	575	9,415	10,000
Barge	13,200	835	1,255	2,100
Rail	9,100	575	1,675	2,200
Pipeline	18,500	1,170	605	1,800

[a]Including engineering, contingencies, overhead, and interest during construction.

Sturkie, D. G., R. Dickens, A. E. Hiltbold, K. Sanderson, and H. P. Orr
"Conservation of Resources in Municipal Waste"
Auburn University Agricultural Experiment Station, Auburn, Alabama,
Progress Report for the period 1 April 1968 to 31 March 1969

The report is concerned with studies made on the use of compost in plant culture. It describes and discusses results obtained in 27 different tests. Space does not permit excerpting all of the tests, and hence only a few have been selected at random so as to give a better idea of the nature of the contents of the report.

Compost used in the tests was obtained from the Mobile, Alabama, compost plant. The first test was a comparison of compost with sawdust as a source of organic matter for fine turf grasses; a second objective was a determination of the value of compost as a nitrogen source for such grasses. It was found that frequent applications of nitrogen were required to maintain the grass in a satisfactory condition when either compost or sawdust were used. However, during the second year after establishment, the compost released some nitrogen, whereas the sawdust did not. Consequently a nitrogen deficit was maintained in the sawdust.

In other tests with Bahia, sericea, weeping love grass, and corn vetch, the plants generally grew best on soils receiving compost, provided sufficient nitrogen was added. The first year of application of the compost was the most critical with respect to nitrogen. The need for nitrogen dropped considerably in the second year. Soil tests showed that the addition of compost to a soil brings about a significant increase in the P and K content of the soil.

In tests made by A. E. Hiltbold and G. A. Buchanan, and which were concerned with the use of compost in the reclamation of soil containing toxic amounts of herbicides, it was found that compost reduced the toxicity of fluometuron and trifluralin to a considerable extent, particularly for cotton. Simazine dissipated rapidly regardless of the present co compost.

In experiments on the use of compost in the greenhouse conducted by C. E. Scarsbrook, it was concluded that: 1) The original compost requires extremely large amounts of fertilizer if Bahia-1-millet is to be grown. 2) If the compost is kept moist for about one year at greenhouse temperatures, it will support fair plant growth. 3) There is no evidence of a toxic effect on millet seedlings. 4) Plant response occurred with the addition of each nutrient of the Hoagland's solution to the compost.

The project leader for the year 1968 was K. C. Sanderson, and he was assisted by H. P. Orr. The work during this period was concerned with the use of compost as a mulch for annual beds, woody plants, and plants propagated by cuttings or seeded on highways. A second objective was to study the feasibility of using compost as a seed coating or slurry mixture in establishing plants on highway slopes. A third objective was a study of using compost with or without activated sludge as an organic soil additive. In general, compost as a soil amendment tended to promote more extensive flowering (chrysanthemums, gloxinias, Easter lilies, and geraniums) than does peat moss. On the other hand, stem length generally was less in compost-enriched soil than in peat moss-enriched soil. Weight of plants (flowering as well as vegetables – kale and beans) generally was less with compost as an amendment than with peat moss. Plants grown in compost-amended soil frequently exhibited foliar burn, probably because of the high concentration of soluble salts in the compost. This was confirmed in foliar analyses, in which it was found that the plant material (chrysanthemums) contained concentrations of Zn (6 to 12 times), Mn, Zn, and B (2 times) in excess of the optimum. N, P, and K concentration either approached or exceeded optimum. Seed germination was improved by the addition of compost.

The addition of sewage sludge generally improved the compost so far as plant growth was concerned.

In a comparison of various brands of compost, it was found that the product from the International Disposal Corporation (Florida) had a soluble salts concentration (1,000 mho's) great enough to cause appreciable foliar damage. Otherwise, the composts were much alike in terms of effect on plant growth. Recomposting municipally (Mobile, Alabama) produced compost resulted in the elimination of foliar burn and enhanced plant growth provided the N, P, K concentrations were maintained at a proper level.

Tietjen, C. and S. A. Hart
"Compost for Agricultural Land?"
Journal, Sanitary Engineering Division, American Society of Civil Engineers, 95(SA2):269, (Proceeding Paper 650C) April 1969

Composting is the biological stabilization of refuse and similar solid wastes. The end product of composting is a material of supposed benefit to the soil. However, experience has been that farmers generally do not use compost since they can obtain increased crop yields more economically with chemical fertilizers. Despite the absence of a demand for the compost product, composting has a significant potential as a method of solid wastes processing, if and when a reasonable system for disposing of the compost can be found. The authors propose that the land be considered as a sink or receiver of wastes, and therefore of the composted wastes. Starting with such an assumption, they feel that composting need not be approached on the basis of producing something that is beneficial to the land.

The paper includes a section on basic soil factors related to agriculture and agricultural productivity, results of soil organic matter research, including compost utilization, and avenues for compost discharge to the land.

The following are some of the interesting facts and conclusions to be found in the article: 1) Cured compost (allowed to stand six months to one year before use) benefited crop yield in the first year of application. 2) Fresh compost (five-day compost period in a Dano Composter) reduced yields because of competition by microorganisms with crop plants for available nutrients in the soil. In the second year after application, the crops were benefited. 3) "For the total nine years of experimentation, yields were 11.7 percent bigger with ripe compost and 11.1 percent higher with fresh compost than were the yields from the equivalent chemically fertilized but uncomposted plots."

Despite the increased yields, economics do not justify the use of compost. Example: Following a three-year rotation, 40 tons of cured compost would increase yields about as much as would 50 lb chemical nitrogen (25 lb with potatoes, and 13 lb each with rye and oats). The chemical nitrogen could be purchased and applied for less than $10, whereas hauling and spreading the 40 tons of compost would cost about $20, and would not include the purchase of the compost. However, yields should not be the sole factor in considering the use of compost. The nutrient level of crops grown on soil amended with compost is greater than that of crops grown on soil fertilized solely with chemical fertilizers. Example: Potatoes grown on compost averaged 6 percent more K, P, and N per pound of crop than did those grown in soils which were fertilized solely with chemicals. Moreover, compost does improve: a) the workability of the soil; b) the structure and resistance of the soil to compaction and erosion; and c) the moisture regime.

"What, then, is the reasonable potential for beneficial and economical compost utilization in the United States? An aggressive selling program might result in 1 percent or perhaps 2 percent of the domestic garbage (Ed. note: i.e., refuse) being converted to compost and marketed. The market for this compost would be the luxury trade, in competition with Milorganite, peat moss, and redwood bark; compost would be used as a soil conditioner and not as a fertilizer. For the foreseeable future, compost will not be used beneficially and economically in general agriculture."

The authors' conclusions are as follows: 1) The concept of compost for agricultural land should be changed to "land for compost." 2) The management of solid wastes will require alternative solutions in the future. If the advocates of composting would stop thinking of composting in Utopian terms and would begin thinking of it in terms of its waste-disposal potential, then composting could be regarded as having a significant future role in solid wastes management.

Hinesly, T. D. and B. Sosewitz
"Digested Sludge Disposal on Crop Land"
Journal, Water Pollution Control Federation, 41(5):822, May 1969

In their studies, the authors found that with good cultural practices corn and soybeans responded favorably to the application of digested sludge as high as 2.3 tons/acre. Offensive odors from well-digested sludge applications have not been a problem. From the standpoint of aesthetics, furrow irrigation would be preferable to sprinkler irrigation. A danger rests in the fact that when the sludge application rates are of a magnitude to supply nitrogen in an amount exceeding the nitrogen need of the crops, the excess is converted to NO_3, which can leach into the groundwater.

Harrop, R. R.
"Northwestern University Soil Enrichment Reclamation Project" and "Truck Spraying Grass Lands"
Journal, Water Pollution Control Federation, 41(5):828, May 1969

For some reason, the editors of the journal have labeled these two articles as Appendix A and Appendix B, respectively, apparently to the article by Hinesly and Sosewitz, "Digested Sludge Disposal on Crop Land" (see abstract for this paper).

The paper is a description of work done by the Metropolitan Sanitary District at the request of the Northwestern University Department of Buildings and Grounds. The work concerned a soil enrichment program on an approximately five-acre portion of the University's landfill campus expansion project. An application rate of 100 tons of solids (dry weight)/acre-yr was determined as appropriate for the dredged sand fill. The program involved ditching, filling with heated digested sludge solids, covering the ditch, and working the soil with a large tandem disc harrow.

After an application of 53 tons of solids, no signs of contamination have been found in test wells, in a lagoon in the affected area, nor in adjoining Lake Michigan waters.

At application rates of one ton of solids (dry weight)/acre to fertilize publicly-owned grasslands, parkways, and metropolitan-owned grasslands on a continuous basis, the response to the liquid digested sludge fertilization is "startling, as is evidenced by the check sections to the fertilized sections." The growth rate is 100 percent improved and the grass has taken on a deep blue-green color.

Status

Hampl, A.
"Composting Wastes in Czechoslovakia"
Compost Science, 8(2):27, (Autumn 1967-Winter 1968) 1968

Current systems of composting in Czechoslovakia process a wider variety of wastes than that expected to be encountered in a U. S. plant. The difference is in the amount of industrial wastes treated along with the refuse, among which are lignite dust, "reject" coal, sugar refinery sludge, slaughterhouse wastes, fruit and vegetable wastes, and lime wastes. A total of 450,000 tons of wastes are processed annually in 20 compost plants. This amount, in conjunction with 150,000 tons peat, results in an annual production of 600,000 tons of industrial composts.

The composting operation takes about 40 days and includes four phases, namely, setting up the windrows, "first shoveling," "second shoveling," and shipping. (Ed. note: No mention is made of grinding.) The windrows are 8-10 meters in width and 1.5-3 meters in height. In building a heap, the materials are layered in the following order: lignite, "saturation" sludges, peat, sprayed-on fresh sludges, screened wastes, etc. The heaps are crowned with a layer of peat.

The first shoveling is done with the use of an RK-25 type bucket excavator after the windrow is set up. The second shoveling is done seven days later. The bucket excavator has an output of 42 cu m/hr and a power input of 16 kw. It travels between the windrows on a 1435 mm gauge track, advancing at a speed of 2.8 m/min.

In Czechoslovakia, the annual generation of refuse amounts to 0.47 cu m/person. The density of this refuse is 0.53 tons/cu m. The winter refuse, because of its high ash content (from burning coal for heating), is poorly suited to composting.

Hart, S. A.
"Solid Waste Management/Composting European Activity and American Potential"
U. S. Department of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, Solid Wastes Program, Cincinnati, Ohio, Public Health Service Publication No. 1826, 1968

A report by Dr. Hart having the title listed above and issued in 1967 has been made into a U. S. Public Health Service Publication to ensure a wider distribution than would be possible in its original form. For a review of the report, the reader is referred to page 208 of the report Comprehensive Studies of Solid Wastes Management — Abstracts and Excerpts (SERL Report No. 68-3, Sanitary Engineering Research Laboratory, University of California, Berkeley, June 1968).

Hawkes, G. R.
"Urban Compost Has No Future in Agriculture"
Solid Wastes Management/Refuse Removal Journal, 12(5):22, May 1969

In line with its campaign against composting as a means for treating urban refuse, the journal has published the present article stressing that which already is well known, namely, the composted refuse can in no way be construed as a fertilizer. Inasmuch as the author of the article is an employee of the Chevron Chemical Company, a company which has an economic interest in chemical fertilizers, his views naturally would be expected to be influenced to some extent by his position in the company. The value of the article is in its giving reasons why the use of bulky soil conditioners are unsuited to large-scale agricultural practices. As the author points out, compost must compete with manure in use on the land. Since the farmer has to contend with manure generated on his land, his tendency would be to use the manure first and the compost as a last resort. Unfortunately, so far as compost sales are concerned, the supply of manure far exceeds the demand for it. Another factor militating against the widespread use of compost in agriculture is the expense of hauling the bulky material to the site at which it is to be used. The seasonal usage of fertilizers and, where used, of soil conditioners is another obstacle to the use of urban compost. In summary, the article makes a convincing case against the use of compost as a fertilizing substance. However, as stated previously, the lack of a demand for the compost and the economics leading to the absence of the demand have been recognized for some time.

Miscellaneous

Olds, J.
"What's the Best Way to Sell Compost?"
Compost Science, 8(2):3, (Autumn 1967-Winter 1968) 1968

The author recognizes the need for abandoning, at least for the present, the concept that in estimating the economics of a compost operation, the market value of the product should be taken into consideration. Experience in this country has shown that the market for compost needed to support large-scale operations is either negligible or very small. The problem then becomes one of what to do with the product. The author reasons that just as it is the responsibility for the city to dispose of its refuse (whether it be by private contractor or by municipally operated facility), it should be the responsibility of the city to dispose of the composted refuse. In other words, it is the responsibility of the city to arrange for the ultimate distribution of the product. The author lists the choices available to the municipality as follows: 1) Spread the compost on municipally-owned land. 2) Spread it on privately-owned land. 3) Spread it on state-owned land. 4) Spread it on federally-owned land.

"Nine times out of ten, I believe, a private compost plant is doomed to failure if it must not only treat the wastes but distribute them as well. As long as this present thinking is made to prevail, improved waste treatment methods such as composting will not be allowed to succeed." The author points out that if the city retained "ownership" of the "refuse that has been turned into compost," a number of approaches become possible. The compost — a completely stable, innocuous material with a potential as a soil conditioner — can be used to reclaim land or even as cover in a landfill.

If compost is to be sold, the fertilizer companies are the logical candidates for the function, inasmuch as they have the facilities to do so, and the use of compost is closely allied with that of fertilizers.

The following quote from the author is worthy of note: "It is time to experiment — to apply a new philosophy to wastes. Until now, we have stopped short — content to arrange for the development of a process that would convert a waste to an asset. But the asset becomes suspect and remains a burden if there is no place to put it."

"Only Subsidy Keeps Composting Open in Israel's Largest City"
Solid Wastes Management/Refuse Removal Journal, 11(7):8, July 1968

As the title of the story implies, the article is a rather unfavorably biased description of a composting operation being carried on in Israel. The site of the operation is Tel Aviv, Isreal. The city officials selected composting as the method of waste treatment best suited to Israeli conditions. These conditions were: 1) the need to economize on foreign expenditures; 2) a need for the compost product to convert desert soils into useful production, and 3) the amenability of the city's refuse to composting. The need to minimize foreign expenditure was the deciding argument against the use of an incinerator. A shortage of land ruled out sanitary landfill. With respect to the composition of the city's refuse, it is about 60 percent organic in nature, and it has a moisture content ranging from 65 percent to 80 percent. Although the proportion of noncompostable material has been rising, it is as yet lower than that of refuse from other countries.

The system used in the Tel Aviv-Jaffa plant involves a preliminary sorting and salvage step. The wastes are then moved into drums 12 ft in diameter and having the bottom plates perforated with holes 1 in. in diameter. A rasping hammer crushes the material and forces it through the perforations, thus accomplishing pulverization. The crushed material is next subjected to ballistic separation to sort out bits of glass, metallic objects, and other heavier fragments. The compostable material is then windrowed and allowed to "mature" for about two months. It is turned at intervals by a tractor.

The noncompostable materials comprise about 20 percent of the incoming raw refuse. The total amount of refuse coming in daily amounts to 400 tons.

Although built by the city, the plant is operated by a private company. Thus far, sales have not been sufficiently great to result in a profit. (Ed. note: Of course, in the other conventional methods of treatment, viz., landfill and incineration, no profit is expected. If, under the circumstances, composting proves to be an effective method of treatment, the reasoning applicable to the conventional methods should also hold for composting — i.e., at least in Israel.)

Lefke, L. W.
"Solid Wastes Composting"
Journal, Water Pollution Control Federation, 41(6):1186, June 1969

The article is a comprehensive review of the literature on composting, and is a part of the edition annually set aside for the review of the 1968 literature on wastewater and water pollution control. Because of his position in the Bureau of Solid Wastes Management, Mr. Lefke is in an advantageous position with respect to being conversant with the latest developments in solid wastes management, and thus was able to turn out the thorough evaluation and review given in the journal.

Among the references covered in the review, one concerning a solid waste composting-incineration plant planned for Mittelwallis, Switzerland, is a good example of a possible application of composting in modern wastes management. The facility described in the reference is designed to serve 51 municipalities having a total population of 80,000. The incinerator portion has a capacity of 18,700 tons/yr or 75 percent of the anticipated total solid waste production in 1990. All compostable material which cannot be marketed will be incinerated.

The author refers to little heard-of use of the compost product in Berlin. Here a manure, wastewater sludge, and soft coal ash mixture compost is being used to revitalize 12,000 ha of leached-out soil used for wastewater spreading. The leached soil cannot retain sufficient water to support vegetation. However, the soil is responding well to the compost application.

Cameron, D.
"Why Composting?"
Public Cleansing, 59(7):67, July 1969

Contrary to the generally downward trend in composting, the city of Paisley (Scotland) has decided to drop incineration after almost 70 yr of using it as a disposal method. Paisley had been one of the first of the local authorities in Scotland to adopt incineration as a disposal method. The original incinerator was built in 1900. Its successor, built in 1939, has now been replaced by a Dano composting plant.

By the late 1950's, the volume production of refuse was such as to exceed the capacity of the incinerator. This factor, coupled with increasing mechanical inefficiency of the plant, led to a decision that it either be replaced by a new plant or that some other method of disposal be found. After due consideration, it was decided to construct a Dano-type compost plant because such a plant would cost 15 percent less than a new incinerator, would not require a chimney (as would be the case with an incinerator), and it could be used for the disposal of the sewage sludge to be produced at the completion of the town's new sewage treatment plant. Although an attempt will be made to sell the compost product, hopes are not sanguine that the effort will meet with success. Should no market materialize, the compost will be used for top-dressing refuse tips, for parks, and for the surfacing "of the many open spaces in various housing schemes."

The compost plant was placed in operation during June of 1968, i.e., three months prior to the time at which the article was written. The plant is composed of two completely independent units, each of which can be operated entirely separately of the other. The crude refuse hoppers are each of approximately 130 cu yd capacity. Inasmuch as at present paper bags instead of metal containers are used for refuse storage in Paisley (6,500 houses), provision had to be made for shredding these sacks, along with their contents. The shredder presently in operation is not fully satisfactory. The shredded refuse is passed over two "picking" belts, at which point salvage and noncompostable items are removed. Ferrous metals are removed by magnet. The tailings from the picking belt are discharged into a rotating, 80-ft long Dan Stabilizer Drum (12 ft in diameter). Sewage sludge or water is added at 50 gal/ton. Air is injected into the drum. The retention time in the drum is about five days.

Recently, the Town Council has agreed to the erection of an incinerator to handle "trades wastes." The capacity of the plant will be 20 tons/working day. It will be used in the disposition of old furniture, condemned foodstuffs, carcasses, trades wastes, and other materials unsuited to composting.

SPECIAL METHODS

Lagooning

McCoy, E.
"Lagooning of Liquid Manure (Bovine): Bacteriological Aspects"
Transactions of the American Society of Agricultural Engineers, p. 784, 1967

The paper (No. 66-9268) was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Illinois, December 1966.

The highly fermentative bacterial flora of the rumen and bovine feces changes to a predominantly proteolytic flora in a manure lagoon. The population in the lagoon water is in the range of millions/mℓ of aerobic facultative types, as high as or higher than in rich agricultural soil. It is well balanced in kinds to carry out decomposition of the diverse organic compounds in manure. The pollution types of bacteria, viz., coliform and enterococci, die off rapidly in the lagoon and in soil. Thus there is no need for concern for a water pollution hazard and from lagoon treatment of liquid manure.

Dugan, G. L., C. G. Golueke, and W. J. Oswald
"Photosynthetic Reclamation of Agricultural Solid and Liquid Wastes"
Paper given at the Engineering Foundation Research Conference Solid Waste Research and Development, II at Beaver Dam, Wisconsin, Engineering Foundation, 345 E. 47th Street, New York, New York, July 1968

The paper describes a process which involves an integrated anaerobic fermentation and algal growth partially closed system designed for the treatment of wastes generated in a liquid-manure system of wastes handling. In the study, a pilot plant facility was constructed and operated. The facility consisted of a conventionally-designed chicken coop housing 105 egg-laying hens kept in elevated chicken batteries (wire cages 16 in. x 16 in.). A trough is placed directly underneath each of two rows of batteries to catch the droppings. The troughs are flushed once each hour by way of a tipping bucket into a sedimentation tank. Supernatant from the tank is pumped directly to the algae pond. The settled solids are discharged into a digester. Supernatant from the digester is discharged into the algae pond. Periodically, a portion of the digested sludge is removed, dewatered, and wasted. Depending upon algal and suspended solids concentration, pond effluent either is passed through a settling tank, or is discharged directly into the tipping buckets in the henhouse. If a settling tank is used, supernatant from the tank is discharged into the tipping buckets, while the settled solids are dewatered and wasted. The liquid phase of the system is not completely closed, in that water lost by way of evaporation or occasional deliberate discharge is replaced by tap water wasted from the drinking troughs in the henhouse. (The effluent parts of the drinking troughs are placed directly over the manure troughs.)

Bhogat, S. K. and D. E. Proctor
"Treatment of Dairy Manure by Lagooning"
Journal, Water Pollution Control Federation, 41(5):785, May 1969

In their studies involving the use of anaerobic lagoons, the authors obtained average removals of BOD, COD, total and volatile solids in excess of 86 percent at an applied loading of 70 lb volatile solids/day/1,000 cu ft pond volume. Removal here does not necessarily mean "the complete reduction of solids, but means partial stabilization of the degradable fraction and complete retention of the nondegradable settleable solids." Decomposition-resistant material forms a floating crust which can be removed and disposed of as infrequently as once every two years. The crust may be used as a soil conditioner. The authors conclude that "hence an anaerobic lagoon can act as a sedimentation, flotation, and anaerobic digestion process while simultaneously providing long-term storage for nondegradable solid residue."

The effluent from their anaerobic lagoons was too potent for direct discharge to a receiving body of water. The effluent can be disposed of either by spreading it on fields or by giving it aerobic treatment. Aerobic treatment can be accomplished through the use of an aerated lagoon, oxidation ditch, or oxidation pond. If an oxidation pond is used, the algal crop may be such as to require its removal before discharge into receiving waters. Removal of algae is not economically feasible. (Ed. note: Golueke and Oswald have shown that algae removal is economically feasible, provided the algae concentration is at least 200 mg/ℓ.)

Under climatic conditions which militate against the use of an oxidation pond, an aerated lagoon or an oxidation ditch could be used to supply the secondary treatment. Results of a batch-type aerobic treatment indicate that "an effluent BOD of 20 mg/ℓ can be achieved by a 24-hr aeration period." It is possible that the effluent from the secondary treatment plant could be used for the flushing of manure from the slabs.

Pyrolysis

Kaiser, E. R. and S. B. Friedman
"The Pyrolysis of Refuse Components"
Reprinted from Combustion, May 1968

Heating organic refuse without allowing contact with outside air results in the production of water, gases, and distillation liquids. A char residue is left. Ten refuse components from domestic wastes were distilled in a laboratory study, the gaseous products were analyzed, and the amount of yield was determined. The gases included mainly CO_2, CO, H_2, CH_4. Calorific values ranged from 300 to 400 Btu/standard cu ft. The yield weights were roughly divided among water, gas, organic liquids, and char. The rate of heating affected the yields. Increased heating rates decreased the char, water, and CO_2, and increased CO. The highest gas yields may be expected to be associated with flash heating.

The paper includes tables showing the composition and analysis of refuse, the proximate and ultimate analysis of refuse components, typical gas volume as a function of temperature, analysis of product gas, yields of products in terms of lb/ton of refuse, and various other tables.

The following is the author's summary: "1) By heating to 1500°F out of contact with air, the organic matter of municipal refuse can be converted to gas, organic liquids, water, and char in roughly equal proportion by weight. 2) The relative yields will be affected by the rate of heating. Higher yields of gas result from rapid heating. 3) The fixed gases have a calorific value of 350-400 Btu/standard cu ft. The organic liquids range from alcohol to pitch."

"Pyrolitic Decomposition of Solid Wastes"
Public Works, 99(8):82, August 1968

In late spring of 1968, the Ford Motor Company at San Jose, California, was scheduled to begin test runs with a Lantz Converter to pyrolyze from 40 to 50 tons of industrial wastes/day. This includes 9 to 10 tons of paint sludge/day. Four Bay Area cities (South San Francisco, Brisbane, San Bruno, and Millbrae) also are considering the process as a means of disposing of their wastes. The pyrolysis process involves the production of tars and intermediate products and charcoal. The charcoal can be burned to supply energy to the process. If the charcoal is burned, the resulting ash is only 2 to 3 percent of the original volume of the char.

Disposing of wastes at its San Jose assembly plant has been costing Ford about $425,000 annually. Since almost all of the 45 tons/day produced by the Ford plant is combustible, the Lantz process is expected to work quite well. The principal uncertainty is the paint sludge. However, tests showed that it could be pyrolyzed. Products of combustion proved to be 98 percent CO_2 and H_2O vapor. The cost of the facility is estimated as being $385,000. Initially, PAR (Pan American Resources) will operate the facility and will charge Ford an annual fee.

Early in January, PAR signed a $1.6 million contract with two Bay Area collection companies to build and operate a waste disposal facility near the San Francisco International Airport. The facility is expected to process from 280 to 300 tons/day. PAR will charge the companies a fee of $3.50 to $4.00/ton.

The Lantz Converter is a sealed, airtight retort cylinder inside a heavily insulated jacket. The gas-fired retort, usually about 20 ft long, revolves slowly on a slight incline from infeed to outfeed. Wastes are injected through a seal area that intermittently opens. Inside, ground wastes are subjected to a temperature of 1200°F (± 300°) in an essentially O_2-free atmosphere and are pyrolyzed into steam, CO_2, volatile vapors, and charcoal. Steam, CO_2, and CO are trapped and then vented, used to dry moist garbage, or to condense the steam into water. The volatile gases typically include H_2, CH_4, CH_2:CH_2, and CH_3:CH_3. About 25 cu ft of combustible gases are produced/cu ft of waste. Energy value generally is from 400 to 500 Btu/cu ft. A 100 ton/day plant is expected to produce enough excess gas to create 400,000 kw of electricity/day. The surplus gas cannot be piped over great distances or be stored, since upon cooling pyroligneous acids begin to form, thereby reducing the heat value to 350 Btu/cu ft and the volume by as much as 80 percent. The liquid condensate thus formed constitutes a cresotar. Generally, 30 to 35 percent of input weight becomes charcoal. Each pound of charcoal has a heat value of 12,000 Btu.

Required auxiliary equipment are a hogger-grinder, a magnetic separator, conveyors, and storage facilities. Intake-to-discharge cycles average 12 to 15 minutes in required time.

Miscellaneous

Golueke, C. G. and S. A. Klein
"Treating Combined Liquid and Solid Wastes"
Paper presented before the 1968 Conference of the California Water Pollution Control Federation at Santa Rosa, California, 24-25 April 1968

The traditional distinction between solid and liquid wastes in respect to both classification of material and method of treatment is increasingly difficult to maintain, and may tend to disappear altogether as technology of wastes management grows in sophistication. Contributing factors include: a) a movement from fragmented jurisdiction concerned with fractions of community wastes to regional authorities dealing with the overall problem of wastes; b) a trend toward industrializing the production of animals for slaughter and of animal products such as eggs and milk; c) a change from automotive to hydraulic transport of domestic, light commercial, and certain types of solid wastes; and d) the processing of wastes to reclaim resource materials.

At least four methods — anaerobic digestion, wet oxidation, biological fractionation, and photosynthetic reclamation — can be used in treating aqueous suspensions of the organic fraction of wastes. Research and practical experience demonstrate that the addition of the garbage fraction of solid wastes imposes no need to alter present anaerobic digestion practices. These findings have been augmented in studies in progress at the University's Sanitary Engineering Research Laboratory. In these studies, it was found that the maximum permissible loading to a digester fed exclusively on garbage can be as much as 50 percent higher than that to one receiving only raw sludge; that paper pulp can be readily digested provided the C:N ratio is lower than 50:1; and that sewage sludge or animal manure can be used to supply the nitrogen needed to maintain the required C:N ratio. If chicken manure is the nitrogen source, the upper C:N ratio limit may be as high as 60:1. The scope of the study recently was expanded to include an investigation on the digestibility of wood.

Research on the use of wet oxidation, biological fractionation, and photosynthetic reclamation in treating aqueous suspensions of solid wastes is as yet in the preliminary stage. However, in view of the principles involved, there is no reason for doubting that the systems can be successfully applied to solid wastes to produce useful materials as a part of the treatment process.

The result of a trend to biological treatment of organic wastes is, of course, an increased concern for water quality management. Thus, men concerned today with waste treatment will become involved in the operation and management of similar systems designed to handle a combination of what is now known separately as "liquid wastes" and "solid wastes."

"A Proposed System for Refuse Disposal by Wet Air Oxidation"
ZIMPRO, Division of Sterling Drugs, Rothschild, Wisconsin 54474, July 1968

According to the proposed method, refuse material is first passed through a wet grinder or pulper where it is ground in a wet state to a slurry. The slurry is then pumped, through a closed system, to a wet air oxidation system (ZIMPRO Unit) where the refuse is oxidized to a sterile, odorless, flowable slurry which can be discharged directly to the sewer system to be transported to the sewage treatment for ultimate treatment and disposal.

Hardware in the oxidation system consists of a refuse wet grinder or pulper, slurry pump, storage tank, and wet oxidation unit.

In test runs at the ZIMPRO Research and Development Center, a wide variety of materials have been oxidized. At temperatures over 210°C cellulose is oxidized readily, and the remaining organic matter is essentially in soluble form. Oxidation of animal fat was as follows:

Temperature °C	Oxidation %
175	26.0
200	40.0
225	47.5
250	70.0
300	79.1
320	82.8

At 175°C, unoxidized fat remained essentially separated from the liquid, while at higher temperatures the fat became dispersed in the liquid medium. In general, garbage components (whole beef bones, chicken bones, coffee grounds, rubber, and plastic) were sufficiently disintegrated at temperatures above 200°C to pass a 20-mesh screen. In general, at temperatures in excess of 200°C, plastics (polyethylene, polyurethane, polystyrene) were completely solubilized.

Ordinarily the products in the liquid phase from wet air oxidation of refuse are simple organic compounds readily oxidized biologically. The end products are mainly formic, acetic, propionic, and butyric acids plus some formaldehyde and acetaldehyde. Under very high oxidation conditioning (95 percent), essentially all of the soluble organics are acetic acid. Under low oxidation conditions, the remaining solids are made up of a fibrous, pulpy, easily drainable and filterable material. Under high oxidation, the remaining insoluble organic material is oxidized, ultimately leaving an essentially inorganic ash material.

Zaltzman, R. and A. Tarquinio
"Biological Decomposition of Cellulose: A Literature Review and Annotated Bibliography"
Engineering Experiment Station, West Virginia University, Morgantown, West Virginia, Report 6, March 1969

The report is the excellent result of an exhaustive search of the literature on cellulose decomposition. The range of coverage is from the fundamental to the applied. The report has an opening chapter concerned with an overall review of the literature on cellulose decomposition. Metabolic pathways, nutritional requirements, physiological characteristics, are only a few of the subjects included in the bibliographical section.

The authors summarize the chapter on the overall review as follows: "Despite the large amount of work which has been done on cellulose decomposition by micro-organisms, only one researcher investigated the degradation of newspapers and other cellulose-containing materials during sludge digestion. There is an obvious lack of data concerning aerobic digestion of sludge containing varying concentrations of wastepaper. In addition, there are no data describing the effects of cellulose particle size in a quantitative fashion as would be necessary for treatment plant design, or accurate accounts of the effects of the organic filters and other materials contained in commercial products with a cellulose base on biological cellulose decomposition."

(Ed. note: S. Klein has been conducting studies on the digestion of paper fibers during the past two years. Results obtained were reported as contributions in two reports, viz., the reports "Comprehensive Studies of Solid Wastes Management" – First and Second Annual Reports. See abstract for Golueke and McGauhey, "Comprehensive Studies," etc.)

GRINDING (PULVERIZING) AND COMPACTION (BALING)

"News From SFM Corporation"
SFM, 2414 Morris Avenue, Union, New Jersey, 1(1):1, July 1968

The item is a newsletter in which is described the introduction of the SFM's new solid waste processing unit. It consists of a combination of a vertical hammermill and a hydraulic ram compaction unit. A compaction ratio of up to 15:1 is claimed, depending on the kind of solid wastes introduced into the system. Three models are available:

	Basic hp	Basic Throughput (lb/hr)
1	20 - 40	600 - 1,200
2	50 - 150	2,000 - 10,000
3	150 - 200	15,000 - 30,000

"Chicago Will Compact Its Refuse"
The American City, 83(6):58, June 1968

The Chicago Department of Streets and Sanitation, in cooperation with the American Public Works Association and Northwestern University, will conduct a study financed by a U. S. Public Health Service Study and Investigation Grant in which refuse will be compressed into dense cubes to fill low lakeshore property, or for easy transport for disposal in less populated areas. The Logemann scrap baler press will be used. The ultimate objective of the project is to "determine the optimum requirements for the design of suitable production scale equipment to compress solid wastes to high-density, economical payloads for transport by rail and other methods, and to test the operational aspects of the system."

Rabins, M.
"Meeting the Challenge of Stationary Compaction"
Solid Wastes Management/Refuse Removal Journal, 11(8):6, August 1968

In his introduction, the author mentions an interesting fact for economists, viz., that the average solid wastes hauler has "approximately 80 to 90 cents of fixed asset cost for every $1 annual gross revenue." He states that according to his investigations the ratio will remain approximately the same, or possibly a little greater. He points out that years of rate analysis in the transport industry shows that high-density material is cheaper to ship than is low-density material. This rests upon the related facts that with highly dense material it is likely that the weight-bearing capacity will be reached before the volume-bearing capacity is filled, and that obviously the "operating cost for a fully-loaded vehicle is minimal compared to the partially loaded one." The idea of the stationary compactor is merely to take advantage of this minimal differential and greatly increase the revenue per man-truck-hour. The resulting ecbnomies make it possible to reduce the overall cost to customer even though the proportion of the overall cost relating to equipment is increased.

The author gives as an example his company's dealings with a large industrial firm in the Los Angeles area. The industrial account had been changed from $30,000 to $32,000/yr for service, and the author's company (the "hauler") had about $5,000 invested in containers used for the account. The hauler reached an agreement with the firm, according to which the hauler made an expenditure of about $28,000 for a compaction unit, transfer bodies, containers, and a self-loading mechanism for the stationary packer. The customer is charged a fixed monthly rate regardless of the amount of waste generated. In addition, a per-load charge is made for compacted wastes hauled away. After paying the fixed monthly charge and applying at least a 3 to 1 compaction ratio to the refuse, the charges to this customer will be about $24,000/yr. Thus the customer has a net savings of about $6,000/yr. Yet because of the savings involved in the use of the compactor, the profit margin for the hauler is now increased by a minimum of 2 to 3 percent. The fixed monthly charge is predicated on 5-yr depreciation. (In all probability, the real life of the machine will be from 8 to 10 yr.) Thus, at the end of 5 yr the equipment will have been paid for by the customer, and yet will remain the property of the hauler. Trips to the account have been reduced from the original 4/day to the present 1/day. Despite the fact that a cost of $28,000 is involved for the equipment used on the job and that return in gross revenue is only $24,000/yr, the venture will be a most profitable one to the hauler.

The author states that his company prefers to own the equipment, since the majority of its operations are in highly competitive areas. Owning the equipment located on the customer's premises and made a part of his wastes handling routine gives the hauler an "edge" when the time comes for negotiations for contract renewal. Generally, an accelerated depreciation schedule is used. This gives the added advantage of reducing the customer's flat rate charge each year and assures the contractor of the continuation of his relationship with the account.

Reinhardt, J. J., G. Rohlich, and the City of Madison Engineering Staff
"Solid Waste Reduction/Salvage Plant"
Interim Report on the City of Madison, Wisconsin, Pilot Plant Demonstration Project (14 June—31 December 1967) prepared for the U. S. Department of Health, Education, and Welfare, Public Health Service, Solid Wastes Program, 1968

A Gonard mill powered by a 150-hp motor was used for grinding mixed refuse. Hourly production rates were somehwat lower than were expected on the basis of European experience. The difference probably was due to differences in the nature of the refuse. No odors, larvae or other objectionable features were noted in milled refuse left exposed. There is little difference in external characteristics between milled rubbish and milled combined refuse. On the other hand, milled garbage is not satisfactory for uncovered landfill. The milled material is easily handled by landfill equipment.

"Solve Solid Waste Disposal Problems with Concentric Engineering Company Compactor Systems"
Concentric Engineering Company, 9868 Monroe Drive, Dallas, Texas 75220, Bulletin No. CB-68-0, 1968

As the title implies, the brochure describes a system for compacting refuse. According to the system described, it is possible to reduce refuse volume "in the ratio of up to 20:1 of its original volume...." The system is a "permanent installation which houses the machinery for volume reduction, capable of handling all municipal refuse including stoves, water heaters, tree limbs, stumps, rubber tires, etc." According to the diagram given in the brochure, refuse is dumped on a collection conveyor belt, passed through a shredder, and then through a baler. The baled refuse is ready for landfill or sea disposal, or for rail transportation. A density in excess of 65 lb/cu ft is expected. Specifications as given in the brochure are as follows: Overall length, 29 ft 3 in.; width, 88 in.; height, 106 in.; gross baler weight including feeder, 16,400 lb; size of bale, 20 in. x 24 in. x 36 in.; size of bale chamber, 20 in. x 24 in. x 36 in.; weight of 20 in. x 24 in. x 36 in. bale, approximately 650 lb; density of bale, average 65 to 70 lb/cu ft; density of bale, option up to 100 lb/cu ft; press cylinder, 12 in. diameter x 36 in. stroke, maximum pressure 5,000 psi; auxiliary cylinder for doors, 8 in. diameter x 8 in. stroke, maximum pressure 5,000 psi; hydraulic power unit, maximum pressure 5,000 psi 0.85 gpm, variable displacement piston pump; engine specification — Diesel, 160 hp at 1800 rpm; baler capacity, 40,000 lb shredded, 20,000 lb loose refuse; feeder and hopper capacity, 7.0 cu yd; drive for feeder, hydraulic motor with gear box approximately 10 hp; automatic adjustable bale density, 20 lb/cu ft to 100 lb/cu ft; baler mounted on heavy duty skid — standard equipment; strapping mechanism for bales — optional.

"The Heil-Tollemache Pulverizer System"
Heil Company, 3000 W. Montana Street, Milwaukee, Wisconsin 53201, 1968

The system described in this brochure consists of a vertical shaft ballistic sorter pulverizer. The machine consists of a base to which is fixed a flanged motor driving the vertical shaft. The pulverizer is of cylindrical construction surmounted by an inverted cone, the shaft being supported above the top of the cone by a double-row spherical roller bearing and continues downward past the neck at the bottom of the cone into the grinding box. At the bottom of the box is a heavy plate which carries the lower bearings below it. The hammers are carried on three sets of pins in the prebreaking section.

Four functional sections are as follows: 1) Top conical prebreaking section: A few thin hammers which reduce the compostable refuse to less than 1.5 in. 2) Rejection section: Narrowest section. The hammers pass within 1-1/2 in. of the neck 80 times/sec. Ungrindable objects cannot drop below this section because of the high velocity of the hammers; such material is caught and ejected upward by the rotating hammers. The objects are rejected via a reject chute. The chute can be adjusted to vary the minimum size at which an object would be rejected. 3) Grinding section: This surrounds 100 percent of the periphery of the hammers. (Ensures complete pulverization of all glass passed through the machine, in contrast to vertical mills from which an appreciable amount of partially broken glass is ejected, since only about 30 percent of the periphery of the hammers can be closed.) The size of the product can be changed by changing the number of grinding bars and adjusting the depth of the grinding section. 4) Exit section: The exit section is the lowest section of the mill. It has no grills. The fan action of the hammers pulls a strong current of air downward through the machine.

Because by its ballistic separation principle, the pulverizer protects itself. There is no need to precede the machine with sorting equipment.

The Tollemache is 10 ft x 10 ft x 15 ft high; uses a 200-hp motor at 10 kw-hr/ton. Production is 12 tons/hr. A practical production average (allowing for hammer and mill maintenance) is 10.8 tons/hr. (Based on actual experience.)

"Transfer Station Operation for Combined Refuse Using the Heil-Tollemache Pulverizer"
Heil Company, 3000 W. Montana Street, Milwaukee, Wisconsin 53201, 1968

The company urges the use of their pulverizer in conjunction with a transfer station, when the latter is warranted. The advantages are obvious: easier handling, greater compactibility, and improved appearance. According to the brochure, the volume of the material is reduced by 50 percent before compaction.

The informative value of the brochure is in the cost figures for grinding when used in conjunction with a transfer station. (These costs differ from those when the machine is used as part of an incinerator operation. Labor requirements, hence costs, are higher with a transfer station. However, operating costs go down.)

Grinder costs (December 1968): 1) 172 tons/day (1 grinder, two 8-hr shifts): Labor, \$2.102/ton; Equipment, \$0.570/ton; Operating charges, \$0.9157/ton; Total: \$3.5877/ton. 2) 344 tons/day (2 grinders, two 8-hr shifts): Labor, \$1.191/ton; Equipment, \$0.409/ton; Operating charges, \$0.8632/ton; Total: \$2.4632/ton. 3) 516 tons/day (3 grinders, two 8-hr shifts): Labor, \$1.026/ton; Equipment, \$0.398/ton; Operating charges, \$0.8456/ton; Total: \$2.2695/ton.

"Korblock"
Korblock Corporation, Box 234, Hornell, New York 14843, 1968

The interesting feature of the brochure is its description of a process of manufacturing building blocks by encapsulating cores consisting of compressed scrap metal from junked automobiles with concrete. The steel core has either a 6-in. or 8-in. cross section. The resulting block obtains its strength from this core and has one to two inches of nonload-bearing facing covering all sides of the core.

Shape of block — 4 ft x 2 ft x 1 ft; and cylinders, 2 ft in diameter x 4 ft. Blocks averaged 960-1,000 lb; the cylinders, 1,760 lb. Ultimate load at failure ranged from 580,000 lb for a single 2 ft x 4 ft x 1 ft block to 950,000 lb for a rectangular wall 12 ft x 6 ft x 1 ft. Lateral deflections from the original position did not exceed 0.007 in. in the cylinder and 0.011 in. in the blocks. 1,050 to 1,100 lb of scrap steel (average-sized 8- to 10-yr old Chevrolet, Ford, or Plymouth) will make 3 cores of 8 in. x 18 in. x 42 in., each suitable for an 8 cu ft block.

"Compacted Bricks May Be Used As Fill For Submerged Area"
Solid Wastes Management/Refuse Removal Journal, 12(1):22, January 1969

The article is not confined to the subject implied in the title, but is actually a listing and summarization of a number of demonstration grants concerned with various subjects. The grant named in the title was given by the Solid Wastes Management Bureau to the Cleveland Department of Public Health Service. The activities include the operation of a test facility in which a combination of shredded refuse, fly ash, dried sewage sludge, river and lake dredgings, and incinerator residue will be compressed into small bricks 9 x 4 x 3 in. in size. The bricks will be placed in a container through which water will be recirculated. Samples of the water will be analyzed periodically for the presence of harmful chemicals, bacteria, and viruses.

Another grant was made to the city of Clinton, Alabama, for the construction of a 33-acre, centrally located sanitary landfill to serve four incorporated towns plus 16,000 rural residents. Open dumps presently in operation will be closed and replaced by approximately 40 large, covered waste deposit receptacles which will be transported as needed by the county to the landfill site.

A third grant was made to the city of St. Louis, Missouri, to conduct a study to determine the practical feasibility of using carefully controlled blends of properly prepared refuse and coal as fuel in large coal-fired boilers. If the preliminary study shows that the practice would have a favorable economic potential, a full-scale demonstration will be conducted by the Union Electric Company in the city.

A grant has been made to the Regional Development Authority of Charleston, Kanawha County, in West Virginia, to devise an areawide solid waste management program for the county's metropolitan region that will serve its 252,925 residents.

The city of Inglewood, California, has received a grant to evaluate the use of plastic and paper sacks for solid waste collection as a means of reducing collection time and costs. The study will involve both industrial engineering time motion studies and field observations of the refuse collection operation. One thousand homes and commercial establishments in a representative area of the city will take part in the study. One-half will use plastic bags and the other half paper bags. Residents in a similar area will continue to use conventional methods; their area will serve as the "control" area.

The Regional Planning Council of Baltimore has received a grant to develop an effective, economical solid wastes disposal plan for the metropolitan area which can be incorporated into a comprehensive plan already established by the Council. Four counties and the city of Baltimore are covered in the plan, and the population involved is 1,805,000.

As a part of a demonstration grant, the city of Freeport, New York, is conducting a study to evaluate various test models of air pollution control equipment and determine which type can best help in making their 150-ton/day, batch-fed incinerator meet local air pollution recommendations. To be tested are pilot models of wet scrubbers and two electrostatic precipitators. A determination will be made of operational costs and of water and power requirements.

The Maryland State Department of Health has received a grant to develop an economical plan for handling discarded large metal objects such as automobiles, refrigerators, and washing machines. Central receiving and processing depots will be the principal study innovation. Emphasis will be on methods for transporting junked items to central yards and breaking them down into salvagable items such as motors, generators, scrap metal, and waste materials such as upholstery, plastic, and rubber.

A grant has been made to Los Angeles County to study methods of improving solid wastes handling systems in multistory office buildings, hospitals, and jails.

"Comminutors Chew Up Bulky Items"
The American City, 84(1):24, January 1969

The comminutor in question is the Von Roll machine, and is in use in several European cities to cut bulky items (tables, beds, logs, refrigerators, etc.) into pieces small enough to be fed into an incinerator. Maximum throughput depends on the composition of the waste, ranging from 4,250 to 7,000 cu ft/hr. The horizontal charge opening is 12 x 11 ft.

Essentially, the machine consists of two steel frames which, when open, form a V. The fixed frame includes seven parallel steel members, one foot wide, and spaced one foot apart. Cutters of special steel are bolted to the edges. The movable frame consists of two rake sections of three beams each, which at their upper ends are rigidly interconnected by a cross-member. Below, they pivot on a shaft. The width of the beams and their spacing correspond to those of the fixed frame; cutters also bristle at their edges. The pivoted rake sections move back and forth propelled by two double-acting hydraulic cylinders. When closing, the beams of the movable system swing into the spaces of the fixed frame. Thus, bulky refuse is caught and sheared by the cutters. The movement proceeds slowly but with great power.

The system comminutes practically all types of bulky refuse. The actual cutting takes place on wear-resistant replaceable cutters, each having four tool-steel cutting edges. Only one is engaged and the cutters can be turned three times before regrinding is necessary.

"Scots Will Pulverize; Consider it Superior to Incineration"
Solid Wastes Management/Refuse Removal Journal, 12(2):24, February 1969

The cities of Aberdeen and Dundee, Scotland, have decided to resort to compaction and subsequent landfill instead of incineration as a means of disposing of their refuse. The respective populations of the cities are 184,000 and 183,000. At first composting was considered, but when no potential market for the product could be assured, the idea was abandoned. Factors in favor of pulverization were an immediate reduction in volume of the refuse to be buried — about 80 percent, and a rapid breakdown of the decomposable material — and hence a shorter settling period. A British Jeffrey-Diamond swing hammer pulverizer was selected for the grinding operation. The machine is 54 in. in diameter and 48 in. wide. The throughput capacity is 20 tons/hr. The pulverized refuse is compacted by means of stationary compactors. Only 18 workers are needed in the operation of the 300-ton/day pulverizer facility. (The incinerator previously used had only a 75-ton/day capacity and yet required a crew of 36 men.)

"Pulverization Makes Gains as British Open New Units"
Solid Wastes Management/Refuse Removal Journal, 12(3):32, March 1969

Contrary to the implication given by the title, the article deals with a single installation, namely, the one in the seaport town of Poole (population, 96,000) in Dorset on the English Channel. The plant has a capacity for processing 150 tons of refuse/day. The end product of the process is a homogenous material which will be used to reclaim some 150 acres of existing mudland.

All incoming refuse vehicles go directly to the reception building, a step which provides full protection to the vehicles and minimizes the nuisance of blowing paper and dust. The refuse is dropped into a 12-ft deep reception pit emptied by a 4 cu yd clam into a small plate feeder, where a special full wet-dust extraction process is applied. The waste is then transported by conveyor belt to the "picking" section. Here, a single operator hand-sorts all salvagable material or that unlikely to break down. The refuse is discharged from the conveyor belt into a "tripper" traveling crane and thence to the plant's five pulverizers.

The pulverizers are giant drums called "fermascreens." Each drum holds 45 cu yd of picked refuse (about 8 tons). The filled drum is rotated at 4.5 rpm. As it rotates, it is sprayed with about 400 gal of water. The tumbling action, the flailing of the dense particles within the refuse, together with the weakening of the fibrous material brought about by the water, are intended to bring about a "breaking down of the bulk" to a degree at which the material will pass through the

2-in. screens mounted on the periphery of each drum. A large scoop located below the drum catches all pulverized refuse passed through the screen and transfers it by means of squeegee paddles into a 36-in. conveyor. The entire fermascreen process supposedly takes a maximum of 2 men. The conveyor belt transports the material past an overband magnet to the discharge point.

"The Eidal SW-100 Shredder"
Eidal International Corporation, P. O. Box 2087, 250 Woodward Road, S.E. Albuquerque, New Mexico 87103, 1969

The brochure describes three models of shredders manufactured by the Eidal Corporation. The SW-20 Mini-Mill is a 3-ton/hr shredder suitable for household refuse or light industrial refuse, excluding heavy metal objects and similar materials. The dimensions of the machine are 9.25 ft by 3 ft. The height is 5.25 ft. The overall weight is 3.5 tons. The SW-100 is a 40-ton/hr shredder capable of grinding municipal refuse as collected from standard packer trucks, excluding steel plates, reinforced concrete, and other similarly highly dense materials. The overall weight is 50 tons. Total height, including the chute, is 18.75 ft. Base measurements are 13 ft by 8 ft. The SW-200 is an 80-ton/hr shredder suitable for grinding municipal refuse as collected in standard packer trucks, including properly prepared automobile bodies, and excluding steel plates, reinforced concrete, and other highly dense materials. The base is 24 ft by 8 ft. Excluding the intake chute, the height of the machine is 9.75 ft. Overall weight is 200 tons.

The machine description of the SW-200 as given in the brochure is as follows: "Steel shell with replaceable hardened liner plates, which are bolted to steel. Shell is sectional to permit opening for inspection and access to internal parts. Complete shell weight with liners, 45,000 lb. Door weight, 7,000 lb. Two rotors each with 60 grinders. Each grinder is adjustable to four positions to accommodate various materials and desired fineness of grind. Each rotor (three sections) is supported by upper and lower Heavy Duty Anti-Friction Bearings, with positive lubrication. Primary shredding is accomplished by massive Breaker Bars. Secondary shredding is done by 24 heavy 16 in. diameter grinders, each weighing 110 lb. The final grinding to size is accomplished by ninety-six 12-in. diameter grinders, each weighing 66 lb."

"The Tezuka Refuse Compression System"
American Public Works Association Research Foundation, Chicago, Illinois, for the U. S. Department of Health, Education, and Welfare, Consumer Protection and Environmental Health Service, Bureau of Solid Wastes Management, Cincinnati, Ohio, Preliminary Report, 1969

The Tezuka Refuse Compression System was developed in Tokyo, Japan. Evaluations made in the report rely to a great extent on the data presented by the Tezuka Kosan Company. The system consists, basically, of three major system building blocks: 1) the preliminary compression system; 2) the main compression system; and 3) equipment to add additional cover material such as asphalt or cement to the bales previously compressed within an enclosure such as chicken wire mesh.

Two kinds of preliminary compression systems are planned. In one, the pressures exerted on the refuse amount to about 221 psi; in the second system, the amount would be 425 psi. Specifications for the latter system are not available, and it has not been built as yet. The standard components of the main compression system are the main press, a mobile compression chamber, and an associated bale enclosure; a compression chamber-moving device; a device for closing the bale enclosure on top of the compacted bale; and a push-up device to remove the bale from the compression chamber. The main press operates vertically; pressures exerted on the main ram are quoted as ranging from 1,200 to 1,600 metric tons. Pressure face dimensions range from 63 x 63 to about 71 x 71 in. The main ram and its pressure face perform four different compression operations successively. The pressure face is subdivided into three sections. In the first step, a pressure of about 6.75 psi is exerted by all three pressure face sections. In the second step, a force of only 600 metric tons is applied to a cylinder 18 in. in diameter and 19 in. long. The cylinder moves downward out of the center of the main pressure face. A pressure of 5,120 psi is exerted on the refuse. In the third step, 12 smaller cylinders distributed over the pressure face are pushed downward. Each cylinder is 6.8 in. in diameter and 19 in. long. A total force of 1,080 metric tons is applied to the 12 cylinders — 90 metric tons each, each exerting a pressure of 5,278 psi on the refuse. In the fourth compression step, the remainder of the original compression face is moved downward with the application of a total compression force of 1,300 metric tons — 814 psi applied to the refuse. Operating time is 10-15 min/5-ton bale (63 x 63 in. by a height of 37 to 70 in.).

Apparently larger bales are always encased in chicken wire. Refuse used in the tests by the Tezuka Company consisted by weight of about 40 percent paper, 25 percent kitchen garbage, 10 percent each of plastics, rags, and cans, plus bottles, and 5 percent wood; moisture content — 60 percent by weight. Claims made for the characteristics of the bale are confusing and subject to doubt. The physical stability of larger bales is not known; apparently, an enclosure is needed to hold them together. Quoted in the Tezuka literature, densities range from 64 to 120 lb/cu ft. The maximum density of dry Tokyo refuse should be no higher than 65 lb/cu ft. Tezuka claims that moisture is removed during compaction by high temperature. However, there is nothing in the process that could bring these high temperatures. Indications are that aerobic bacteria are active in the bales. To produce a bale of the dimensions given and to economize on pressures involves a corresponding increase in production time and an elaborate process setup. Price of equipment is $370,000 for a 150-ton/24-hr installation. Transportation costs from Yokohama to Chicago would be equal to 25 to 30 percent of the equipment cost. Operating costs are: ($750 ton/24-hr plant): $0.43/ton for depreciation (25-yr service life), $0.70 for labor; $0.10 for electrical energy, and $0.50/ton for chicken wire. At present, the delivery time is 10 months; and assembly and erection time, 2 months.

In conclusion, on the basis of the incomplete and confusing information available, it may be said that the Tezuka system is a complicated, and in part, cumbersome system. Productivity of the press in terms of tons/day/dollar of investment decreases with increase in size of the bale. (Bales of 3 x 3 x 3 ft can be produced with existing U. S. equipment.)

Brown, R. R. and F. E. Block
"Copper Removal from Steel Scrap by Thermal Treatment"
U. S. Department of the Interior, Bureau of Mines, Washington, D. C., Report of Investigations 7218, 1968

"The Bureau of Mines undertook a limited feasibility study to determine the practicality of removing copper from automobile scrap by thermal treatment. Test specimens, prepared by wrapping bare and insulated copper wire around small steel coupons, were heated at 600° to 1,150°C in various atmospheres for different lengths of time under both static and dynamic conditions. The tests indicated that adequate removal of copper cannot be effected by thermal treatment of scrap above the melting point of copper. Tests showed that copper present in scrap as insulated wire is embrittled by thermal treatment at 800° to 900°C if the insulation contains lead, and that the embrittled copper is almost completely removed by a mechanical action such as tumbling. Also chemical pretreatment of specimens to effect embrittlement of copper and the magnetic separation of oxide scale were studied. Tests showed that bare copper can be embrittled by depositing water glass (Na, Si_4O_9) on copper prior to thermal treatment."

Rampacek, C. and P. M. Sullivan
"U. S. Bureau Seeks Low-Cost Method to Reclaim Valuable Minerals"
Solid Wastes Management/Refuse Removal Journal, 11(11):32, November 1968

The article describes work done on incinerator residue obtained from various incinerator furnaces in metropolitan Washington, D. C. The studies include the making of a comparison between the residues from several grate-type furnaces and those from a rotary kiln furnace. Rotary kiln furnaces tend to produce better burnout and are operated at temperatures 400° to 500°F higher than those found in grate-type furnaces. The following table shows the composition of the residues from the two types of furnaces.

Item	Percentage	
	Grate-Type	Rotary Kiln
Tin cans	17.2	19.3[a]
Mill scale and small iron	6.8	10.7
Iron wire	0.7	0.5
Massive iron	3.5	1.9
Nonmetallics from shredded iron	-	6.5
Nonferrous metals	1.4	0.1[b]
Stones and bricks	1.3	-
Ceramics	0.9	0.2
Unburned paper and charcoal	8.3	-
Charcoal	-	3.4
Partially burned organics	0.7	-
Fines, minus 8-mesh (ash, slag, glass)	-	36.2
Glass and slag, plus 8-mesh	-	21.2
Glass	43.8	-
Ash	15.4	-

[a]Shredded [b]Hand picked

For additional information on the work reported in this article, see the abstracts for: 1) "Composition and Characteristics of Municipal Incinerator Residues" (Kenahan, C. B., P. M. Sullivan, J. A. Ruppert, and E. F. Spano), and 2) "The Bureau of Mines Looks at Refuse Disposal and Recovery" (Reynolds, W. F.).

"Discarded Tires will Become a Basic Chemical Feedstock Instead of a Junkyard Eyesore"
Under the feature, "Chementator," Chemical Engineering, p. 53, 2 December 1968

Engineers at the U. S. Bureau of Mines Coal Research Center have recovered economically promising gaseous, oily, and tarry product streams by heating shredded tires in a reactor. In one series of runs at 930°F, a ton of tires yielded 140 gal of oils and 1,500 cu ft of combustible gas. Among the specific components given off are benzene (12 gal/ton), styrene, butadiene, methane, and ethane. About 100 million tires, weighing about one million tons, are discarded annually in the United States.

Reynolds, W. F.
"The Bureau of Mines Looks at Refuse Disposal and Recovery Possibilities
Public Works, 99(12):85, December 1968

Bureau officials state that there are about $1 billion in ferrous and nonferrous metals reclaimable from dumps, and about $7 million in gold and silver reclaimable from the fly ash produced by refuse incinerators.

A new process has been developed by which ferrous and nonferrous metal mixtures can be reclaimed from incinerator residues. In the process, waste material is screened, magnetically separated, shredded, crushed, and ground. Fractions rich in metal are then melted and analyzed. Copper and tin are removed from the iron fraction by leaching. A high-quality metal can thus be obtained from scrap metal. Preliminary findings indicate that municipal refuse contains about 550 lb of metal/ton of residue. About 500 lb of this is iron; the remainder consists of aluminum, copper, tin, and zinc.

At present, only about 12 percent of the metals in the total fly ash production is recovered in the U. S., as compared to as much as 65 percent in some countries. In the District of Columbia, an average ton of refuse contains from 2 to 9 oz of gold.

Another challenge faced by the Bureau is the recovery of waste metals contained in tailings. An example is the aluminum in the red muds generated during the production of aluminum. Scrap processing is another source of reclaimable metal — especially junked automobiles, stoves, refrigerators, etc.

Elger, G. W., W. L. Hunter, and C. E. Armantrout
"Removal of Nonferrous Metals from Synthetic Automobile Scrap on Heating in a Rotary Kiln"
U. S. Department of the Interior, Bureau of Mines, Washington, D. C., Report of Investigations 7210, 1968

To determine the feasibility of removing nonferrous metal impurities from automobile scrap by thermal treatment in a rotary kiln, the Bureau of Mines conducted four series of tests with synthetic scrap mixtures heated at various temperatures under oxidizing and reducing conditions. The treated scrap mixtures were melted in an electric-arc furnace and cast into small ingots for impurity evaluation. Analyses showed that the ingots were essentially free of residual metal impurities except for copper. Test data indicated that in an oxidizing atmosphere the percentage removal of copper increased with treatment temperature. Percent of copper removed in a reducing atmosphere was found not to be temperature dependent. A significant finding was that copper was embrittled under some of the operating conditions and was mechanically removed by fragmentation.

"Scrap Tires: Materials and Energy Source"
Environmental Science and Technology, 3(2):119, February 1969

Approximately 100 million worn-out tires are discarded each year. Scientists and engineers at the Firestone Tire and Rubber Company and the U. S. Bureau of Mines Coal Carbonization Laboratory (Pittsburgh, Pennsylvania) are investigating the possibility of using these tires as a source of energy and chemical raw materials. Shredded tires are coked much as coal is coked for the steel industry, and thereby various chemicals, liquid oils, gas, and tars are extracted. From 40 percent to 60 percent of the tire materials can be recovered in a gas or liquid form. Pyrolyzing a ton of tires at 500°C results in the formation of 140 gal of liquid oils, 1,500 cu ft of gas (heating value equivalent to that of natural gas), and a solid residue of friable, high-carbon content material. (It is interesting to note that at the time they are discarded, tires still have as much as 80 percent of the total manufacturing value that has been added.)

Although scrap rubber has a heating value higher than that of most coals, incinerating them for power generation has many drawbacks. The sulfur content of rubber often exceeds that of high-sulfur coal. Scrap rubber reclaimed and used in the production of rubber goods is quite small in the U. S. only about 10 percent of the new rubber production. (In 1945, it was 30 percent.) Reasons for the small amount of reuse are the high costs of collection, transportation, and reprocessing — costs which generally exceed new production costs of the cheaper synthetics. Another reason is the increasing use of oil-extended synthetics.

Hardy, H. L.
"Asbestos Related Disease"
The American Journal of the Medical Sciences, 250(4):49/381, October 1965

According to Dr. Hardy, past and present evidence points to the potential hazard posed by asbestos exposure to both worker and neighbor. Evidence is impressive that asbestos exposure, often delayed in effect, will in the future be responsible for an important amount of pulmonary disease, especially chest tumors. In addition, new evidence points to asbestos exposure as significantly associated with abdominal tumors as well.

"Asbestosis"
Editorial from the British Medical Journal, 3:62, 8 July 1967

Although asbestos has been used for at least 4000 years, it was not until the end of the last century that it became an important industrial mineral. Since then, its output has risen from about 500 tons to more than 3,000,000 tons/yr. While the biological significance of pulmonary asbestos bodies is not clear, they have been found in a large proportion of necropsies in widely separated areas. The pulmonary fibrosis caused by asbestos is a disabling condition and is complicated by the fact that it carries a serious risk of malignant neoplasia of the bronchus and of the serous membrane, and possibly also of carcinoma of the gastrointestinal tract.

The most important of the problems awaiting solution are: "The type of asbestos as a factor in the risk of asbestos and malignancy; the excess risk of malignancy from manifestations of asbestosis; the organization of prospective surveys to establish the risk to industrial and residential populations; agreement on the clinical, lung function, and the notoriously difficult radiological criteria for diagnosing asbestos; agreement on the most accurate type of dust measurements; and the clinical significance of pleural plaques and of asbestos bodies."

Tabershaw, I. R.
"Asbestos as an Environmental Hazard"
Journal of Occupational Medicine, 10(1):32, January 1968

The author summarizes his paper as follows: "... if one accepts the assumptions 1) that asbestos minerals increase the risk of lung cancer in occupational groups, 2) that they lead to an unusual risk of mesothelioma of the pleura and peritoneum in occupational groups and those living near asbestos plants, 3) that such malignancies usually result from exposures 30 to 50 years earlier, 4) that the 'asbestos bodies' may result from recent exposure as well as those of many years earlier, 6) that world production and use of asbestos has increased from 500,000 tons to 3,500,000 tons in 30 years, it is important to consider whether or not asbestos is a major threat to public health. One is not yet justified in such a conclusion, in view of the fact that much of the world tonnage goes into uses that do not lead to air contamination; that asbestos is not actually indestructible, that the effects are dose-dependent, and that low doses probably lead to lower rates and longer latency."

The author does feel there is a need for: 1) epidemiologic studies directed to groups with intermediate exposure; 2) experimental and industrial hygiene studies to determine the nature and degree of exposure; and 3) biologic studies centered on the meaning of "asbestos body."

Of the references listed by the author, the following two should be of interest. 1) Cooper, W. C. "Asbestos as a Hazard to Health — Fact and Speculation," Archives of Environmental Health, 15:285, September 1967, and 2) Thomson, J. G. "Asbestos and the Urban Dweller," Annals of the New York Academy of Sciences, 132:196, December 1965.

"Behavioral Toxicology Looks at Air Pollutants"
Environmental Science and Technology, 2(10):731, October 1968

The interest of this article rests in its description of a broadened approach to the evaluation of the effects of environmental pollutants on man. Heretofore, the emphasis has been on the anatomical effects of toxic wastes substances on man; the research efforts described in the present article extend the scope to the behavioral aspects, i.e., to the effects of the chemicals on the neurochemistry and neurophysiology of an individual.

The studies are headed by Dr. Charles Xintaras of the National Air Pollution Control Administration. The three pollutants receiving attention by his group are CO, ozone, and lead. The primary effect of CO on the brain appears to be through an interference with the subject's awareness of his environment. Effects of ozone appear to be an impairment of vision and depressing of body temperature. Lead and other heavy metals are among the few foreign materials that can enter the brain by way of the bloodstream. The metals apparently interfere with brain function rather than damage the cells themselves. Research by Xintaras indicates that lead shortens the period of deep, or dream, sleep — making it less stable. Changes in dream sleep may involve the mechanism responsible for controlling transitions between the various levels of consciousness, and hence may account for the sluggishness associated with exposure to lead and other toxic metals.

Dedolph, R., R. B. Holtzman, and H. Lucas, Jr.
"The Sources of Lead in Perennial Rye Grass and Radishes"
Abstracts. Papers presented in 157th American Chemical Society National Meeting, American Chemical Society, Division of Industrial and Engineering Chemistry, Minneapolis, Minnesota, 14-18 April 1969

Experiments designed to assess the relative importance of air, water, and soil as sources of lead in perennial ryegrass and radishes showed that only air and soil were significant. Subsequent experiments revealed that both grass and radish leaves derived 2 to 3 micrograms of lead per gram dry weight from soil sources. Leaf-lead levels in excess of this were derived from, and quantitatively related to, atmospheric lead concentrations. Lead levels in radish roots were less than or equal to the soil-derived lead levels. The lead concentration in this edible portion of the radish plant was apparently unaffected by variations in lead concentrations in either soil or air. Collectively, data on lead levels in the case of these plant species permit one to infer the existence of a mechanism discriminating against accumulation of soil-lead by plants. The existence of such a mechanism suggests that soil-lead may have been a factor in plant natural selection through the eons of prehistoric evolutionary time, and that prehistoric, like contemporary plants, derived a portion of the lead they contained from the soil. These data consequently would not support contentions that prehistoric man ingested only a small fraction of the lead ingested by contemporary man, unless one assumed that prehistoric man assiduously eschewed plants as a food source.

Haley, T. J.
"Environmental Lead and Air Quality"
Abstracts. Papers presented in 157th American Chemical Society National Meeting, American Chemical Society, Division of Industrial and Engineering Chemistry, Minneapolis, Minnesota, 14-18 April 1969

Lead is widely distributed in the earth's crust, in water supplies, and in the foodstuffs consumed. Soil samples indicate a varying lead content up to 95.7 ppm with an average in the range of 10 to 15 ppm for agricultural areas. Water supplies are of greater importance as sources of environmental lead because, here, the element is in a soluble, more easily assimilable form. Drinking water lead content varies from 1.0 to 40 $\mu g/\ell$. Other beverages can be contaminated by use of lead in the water storage tanks, in capping, or by the consumption of contaminated forage. The greatest source of environmental lead is in foodstuffs where almost every form of consumed food contains some lead. Food processing can also be a source of lead contamination. Lead in the air from the processing of this element also contributes to the total environmental lead to which the individual is exposed. Ambient air gets most of its lead content from burning coal and leaded gasoline, but pulmonary retention is so slight as to make this only a very small part of the daily lead intake. Furthermore, there are no known cases of plumbism associated with such exposures. The respiratory system is very efficient in eliminating inhaled lead. There is no general agreement as to the best method for sampling respirable lead. The body burden of lead is greatest in the skeleton, but soft tissues also contain varying amounts of the element. The interrelationship of all of these factors are discussed in relation to air quality criteria.

Ter Haar, G. L.
"Air as a Source of Lead in Edible Crops"
Abstracts. Papers presented in 157th American Chemical Society National Meeting, American Chemical Society, Division of Industrial and Engineering Chemistry, Minneapolis, Minnesota, 14-18 April 1969

The effect of airborne lead on the lead concentration of the edible and nonedible portions of several important types of food crops was studied by growing crops in greenhouses supplied with filtered and ambient air, and in plots planted in long rows perpendicular to a busy highway. The edible portion of most of these crops was not affected by the concentration of lead in the air. The normally uneaten portions of some plants was somewhat affected by the concentration of lead in the air. In almost all of the vegetables studied, which were selected because of their importance in the human diet, airborne lead did not significantly increase the lead content of the edible portion.

Witzel, S. A., E. McCoy, L. B. Polkowski, O. J. Attoe, and M. S. Nichols
"Physical, Chemical, and Bacteriological Properties of Farm Wastes (Bovine Animals)"
American Society of Agricultural Engineers, Management of Farm Animal Wastes, Proceedings, National Symposium, St. Joseph, Michigan, 5-7 May 1966

Wastes used in the study were collected from three sources, namely, dairy bulls, dairy cows, and beef cattle. Wastes from the 68 dairy bulls were obtained as liquid manure and were screened through a 1/4 in. mesh screen prior to analyses. Waste samples collected from the two dairy cows and two beef steers were composited over a three-day period, mixed, and an equal volume of water added and again stirred before being subjected to analyses. The water added to the raw wastes was to approximate the minimum water requirements in a wet manure system.

The following tables, taken from the report, summarizes the results.

TABLE 1

CATTLE WASTE CHARACTERISTICS

	Dairy Bull	Dairy Cow	Beef Cattle
BOD K rate (20°C)	0.176	1.93	0.089
5-day BOD (lb/day-unit 20°C)	0.76 [a]	1.32[a]	1.02 [a]
COD (lb/day-unit)	4.19 [a]	5.78[a]	3.26 [a]
Total Solids (lb/day-unit)	4.21 [a]	6.80[a]	3.62 [a]
Volatile	3.26 [a]	5.68[a]	3.17 [a]
Fixed	0.95 [a]	1.12[a]	0.45 [a]
N (lb/day-unit)			
NH_3-N	0.15 [a]	0.23[a]	0.11 [a]
Organic-N	0.09 [a]	0.14[a]	0.15 [a]
Total Kjeldahl-N	0.24 [a]	0.37[a]	0.26 [a]

[a]Based on 1,000 lb live weight/unit

TABLE 2

CATTLE WASTE CHARACTERISTICS (SETTLEABLE SOLIDS[a])

	Dairy Bull	Dairy Cow	Beef Cattle
5-day BOD (lb/day-unit 20°C)	0.99[b]	0.36[b]	0.42[b]
COD (lb/day-unit)	1.48[b]	2.88[b]	1.47[b]
Total Solids (lb/day-unit)	2.94[b]	5.60[b]	2.89[b]
Volatile	2.57[b]	4.97[b]	2.67[b]
Fixed	0.37[b]	0.63[b]	0.22[b]

[a]Based on 1-hr quiescent settling
[b]Based on 1,000 lb live weight/unit

TABLE 3

CATTLE WASTE CHARACTERISTICS (SUSPENDED SOLIDS[a])

	Dairy Bull	Dairy Cow	Beef Cattle
5-day BOD (lb/day-unit)	0.44[b]	0.70[b]	0.75[b]
COD (lb/day-unit)	3.02[b]	4.59[b]	2.47[b]
Total Solids (lb/day-unit)	1.94[b]	4.42[b]	2.29[b]
Volatile	1.73[b]	3.95[b]	2.09[b]
Fixed	0.21[b]	0.47[b]	0.20[b]

[a]Whatman No. 1 filter paper
[b]Based on 1,000 lb live weight/unit

TABLE 4

PERCENT BOD

	Settleable Solids	Suspended Solids
Dairy Bull	12.0	57.8
Dairy Cow	27.5	52.8
Beef Cattle	41.1	73.2

TABLE 5

PERCENT COD

	Settleable Solids	Suspended Solids
Dairy Bull	35.1	71.5
Dairy Cow	49.8	79.5
Beef Cattle	45.2	76.0

Loehr, R. C.
"Animal Wastes — A National Problem"
Journal of the Sanitary Engineering Division, American Society of Civil Engineers, 95(SA2):189, (Proceedings Paper 6493) April 1969

A state of the art summary is given of the control and management of the pollutional problem that has been caused by animal wastes, of feasible treatment processes, of major problem areas, and of areas for future activity. The problems currently associated with the handling, treatment, and disposal of animal wastes will be magnified in the future. Ultimate disposal techniques for untreated animal solids and liquids, as well as the residues from waste treatment processes, should be integrated with feasible handling and treatment processes to develop suitable waste control and treatment systems. Large-scale animal production facilities should be considered as individual industries responsible for pollution abatement.

The following list of table titles gives an idea of some of the information contained in the article: Table 1 — "Animal Waste Characteristics," Table 2 — "Livestock Waste Characteristics," Tables 3a and 3b — "Nutrients in Animal Wastes," Table 4 — "Characteristics of Animal Manures," Table 5 — "Pollutional Characteristics of Animal Wastes Weight Units," Table 6 — "Average Animal Waste Characteristics," Table 7 — "Equivalent Population of Animals in the United States in Millions," Table 8 — "Characteristics of Mixed Liquor — Anaerobic Digestion of Animal Wastes," Table 9 — "Effluent Quality of Anaerobic Lagoons Treating Livestock Waste." According to the data listed by the author in Table 9, the COD of the effluent from anaerobic lagoons treating swine wastes ranges from 940 to 3,850 mg/ℓ; from lagoons treating poultry wastes, 590 to 2,550 mg/ℓ; and from lagoons treating beef cattle wastes, 4,700 mg/ℓ in one study and 5,500 mg/ℓ in another.

The article has an especially good section on "Health Aspects." The author points out that the list of disease organisms common to man and other animals is lengthy, including a number that can be waterborne. As an example, he tells of an incident in which a number of young people swimming in the Cedar River (Iowa) were infected with leptospirosis while swimming downstream from an area where leptospirosis infected cattle had access to the river.

MISCELLANEOUS PUBLICATIONS OF THE BUREAU OF SOLID WASTES MANAGEMENT

"Solid Wastes: A List of Available Literature - October-December 1968"
U. S. Department of Health, Education, and Welfare, Consumer Protection and Environmental Health Service, Bureau of Solid Wastes Management, Cincinnati, Ohio, 1968

The brochure gives a list of 53 publications. It includes a Reader Inquiry Card to be used in obtaining copies of the listed publications.

Connolly, J. A., ed.
"Abstracts: Selected Patents on Refuse Handling Facilities for Buildings"
U. S. Government Printing Office, Washington, D. C., Public Health Service Publication No. 1793, 1968

This volume contains 261 abstracts of patented equipment and methods for refuse handling in residential and office buildings. These inventions are not necessarily limited to use within buildings. Areas of interest include baling machines, bulk presses, refuse chutes, crushers, domestic and on-site compactors, grinders, sackholders, receptacles, refuse vehicles with detachable containers, and miscellaneous items. Equipment diagrams accompany many of the abstracts. Indices of contributing inventors and supporting companies are supplied.

This volume is designed to aid investigators seeking original ideas relating to solid waste handling. The objectives of each invention are presented, as well as the apparatus involved in its application.

Lefke, L. W., comp.
"Summaries of Solid Wastes Research and Training Grants 1968"
U. S. Government Printing Office, Washington, D. C., Public Health Service Publication No. 1596, 1968

This publication is a new compilation of summaries of all research and training grants (both terminated and active) funded by the Solid Wastes Program of the U. S. Department of Health, Education, and Welfare. The compilation includes progress through 31 December 1967. The majority of the research has been underway for three years or less.

Since the characteristics of solid wastes are constantly changed by product innovations, industrial process modifications, consumer buying patterns, etc., the effort of the Solid Wastes Program is to develop efficient and economical management practices to meet the changing national needs. Thus, many solid wastes problems are being investigated by the program. Some of these studies are carried out through research grants and include such areas as bacterial contamination from hospital solid wastes; physical and chemical composition of municipal refuse; handling, treatment, and disposal of animal wastes; utilization of agricultural wastes; pipe transport of wastes; and pyrolysis of wastes. A total of 53 research grants are summarized.

The training grant program has as its objectives the development of qualified, professional personnel in the solid wastes field in order to utilize the results of research. Institutions involved in the eight solid wastes training grants are presented, as well as a brief description of the respective programs. Research project and training program directors are indexed.

Sponagle, C. E.
"Summaries: Solid Wastes Demonstration Grant Projects – 1968"
U. S. Government Printing Office, Washington, D. C., Public Health Service Publication No. 1821, 1968

The Demonstration Grants Activity of the Solid Wastes Program, U. S. Public Health Service, has compiled summaries of the demonstration grant projects awarded Program support during the period 1 June 1966 to 31 December 1967. This volume supersedes the earlier publications Demonstration Project Abstracts: Solid Wastes Program and Supplement A.

The projects are of two kinds. Some are designed to demonstrate the feasibility of new and improved technology for solid wastes disposal. Others are to investigate the development of area-wide solid waste management systems to replace unsanitary and uneconomic operations by individual communities.

Subjects which relate to solid waste management, such as incineration, sanitary landfill, composting, salvage, storage, etc., are included in the 53 project summaries. Remarks within the introduction serve to clarify the significance of items contained in the volume. Five indices – subject, geographical, grantees, project directors, and consultants – provide cross-reference for the reader.

Muhich, A. J., A. J. Klee, and P. W. Britton
"Preliminary Data Analysis: 1968 National Survey of Community Solid Waste Practices"
U. S. Government Printing Office, Washington, D. C., Public Health Service Publication No. 1867, 1968

Through provisions of the Solid Waste Disposal Act of 1965, the Solid Wastes Program of the Public Health Service has undertaken a nationwide survey of solid waste disposal practices and problems. The survey is being conducted in conjunction with a state and interstate planning grant program. Data from thirty states and the District of Columbia received before 1 July 1968 are included in this publication. Information from three additional states partially surveyed by Solid Wastes Program personnel is also presented.

The present report is the first in a series of papers based on statistical analyses of the national survey data. The publication gives basic statistical summaries of the national survey data. It not only reports on community practices but assesses disposal sites and facilities as well. National analyses are presented for community data and land disposal sites and facilities; regional analyses are given for the community data and the land disposal sites. In addition, an urban-rural comparison is provided for the community data. A separate analysis for incinerators is given. It deals with attributive and continuous types of response. "Sample size" and "percent response" are given for both types. Attributive response applies when an answer can be placed in a limited number of categories, e.g., "Yes" or "No"; "regulations enforced," "no regulations," or "regulations not enforced." The continuous response, dealing with quantitative data, is treated somewhat differently. Such data apply when an answer is a count or measurement (number of animals, estimate in yards, etc.), and are summarized as "total," "mean," "standard deviation," "1967 population responding" and "mean per thousand."

Vaughan, R. D.
"The Federal Solid Wastes Program"
Civil Engineering – American Society of Civil Engineers, 39(2):69, February 1969

"In the national Solid Wastes Program, an impressive variety of studies and programs are underway, ranging from production of technical manuals and short courses, to research in generating power from waste heat in incineration, and degradation of wastepaper into protein for use as animal feed." The Solid Waste Program at present employs more than 200 professionals. The program has defined four operational areas for fulfillment of its responsibilities on an in-house basis: research and development; technical services; systems and operations planning; and training.

Public health effects of solid wastes and of various solid wastes management systems are being determined by measurement of associated pathologic and toxic agents. It has generally been assumed that pathogens are effectively destroyed by incineration. Recent studies indicate, however, that such organisms may survive in significant numbers in incinerator residues.

Basic research in characterizing solid wastes is an important step in arriving at a scientific evaluation and control of solid wastes management systems.

The lack of valid and exact information on the status of solid wastes practices constitutes an obstacle to the effective assessment of processes and unit operations, and to the planning of a course of action on wastes management.

Contracts are let to perform specific tasks if such work would require expertise not readily available within the program. Grants of up to two-thirds of project costs are awarded to public and nonprofit agencies only, and support work in several areas of need. State planning grants for solid wastes management have encouraged a systematic and regional approach to problems of organization and administration. Research grants are awarded to complement work performed in-house and by contractors.

"State/Interstate Solid Waste Planning Grants and Agencies – January 1969"
Bureau of Solid Waste Management, U. S. Public Health Service, Rockville, Maryland, Public Health Service Publication No. 1912, 1969

The publication lists the names and addresses of the solid waste planning agencies for all States, Territories, and the District of Columbia. It also gives certain additional information for the State and Interstate agencies with solid waste planning grants.

Swavely, D. D. and L. F. Hultgren
"State/Interstate Solid Wastes Planning Grants"
Bureau of Solid Waste Management, U. S. Public Health Service, Rockville, Maryland, Progress Abstracts, Public Health Service Publication No. 1913, January 1969

The present volume is a compilation of abstracts developed from progress reports submitted by state planning agencies in their development of comprehensive statewide programs for the handling and disposal of solid wastes. The publication reflects progress by each state up to 1 July 1968.

The abstracts show at least one common element, namely that the first effort of each grantee has been to survey solid waste practices and problems within its jurisdiction. The abstracts show that the grantees have actively promoted legislation and the appropriate administrative regulations for more effective control of solid wastes activities. They have provided training for agency staffs involved with solid wastes and have coordinated their programs with those of other related state, regional, and local planning units.

"Grant Programs Under the Solid Waste Disposal Act"
Bureau of Solid Waste Management, U. S. Public Health Service, Rockville, Maryland, 1969

This small brochure narrates the background of the Solid Waste Disposal Act and discusses the implications of the act. It delineates the scope of the activity empowered by the act. The brochure describes the steps to be taken in applying for federal support under the act and the review process involved and the time table involved in acting upon requests for such support. Thus are discussed research grants, training grants, demonstration grants, and state and interstate survey, and planning grants. Finally, a list is given of the names and addresses of the various regional representatives.

AUTHOR INDEX

388-400 O - 70 - 30

AUTHOR INDEX (Continued)

AUTHOR INDEX (Continued)

AUTHOR INDEX (Continued)

ORGANIZATION INDEX

ORGANIZATION INDEX (Continued)

ORGANIZATION INDEX (Continued)

SUBJECT INDEX

SUBJECT INDEX (Continued)

SUBJECT INDEX (Continued)

SUBJECT INDEX (Continued)

U. S. GOVERNMENT PRINTING OFFICE : 1970 O - 388-400