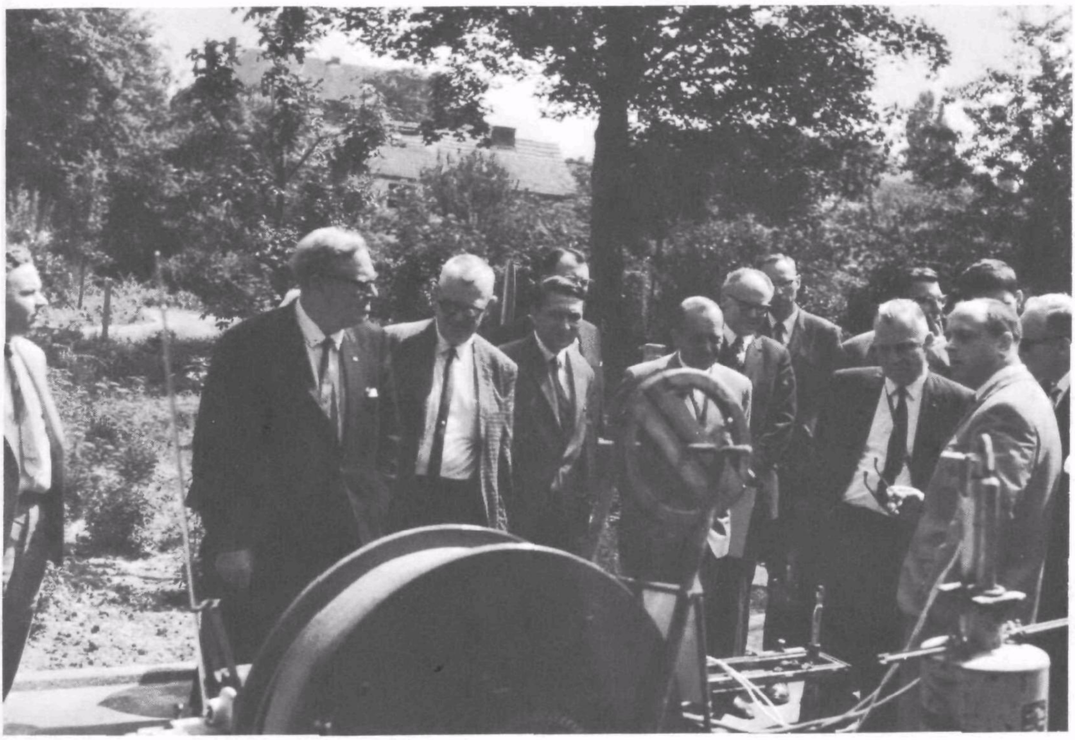
SOLID WASTES MANAGEMENT IN GERMANY

REPORT OF THE U.S. SOLID WASTES STUDY TEAM VISIT

June 25 – July 8, 1967



DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

Front Cover. Institute for Water, Soil, and Air Hygiene of the Ministry of Health. U. S. Solid Wastes Study Team members with Institute staff observe neutron detector used in landfill groundwater pollution studies — Berlin.

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An Exchange
within the
United States - German Cooperative Program
in Natural Resources, Pollution Control, and
Urban Development

This report (SW-2) was written for the Solid Wastes Program
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University of California

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
NATIONAL CENTER FOR URBAN AND INDUSTRIAL HEALTH
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FOREWORD

The United States Solid Wastes Study Team's visit to Germany provided a valuable opportunity to implement a cooperative U.S. — German effort concerned with natural resources, pollution control, and urban development. Recognized environmental health needs in Germany have catalyzed there a national program involving both controls and research, as in the United States.

With the goal of evaluating the status of solid wastes management in Germany and its application to meet U.S. needs, both present and future, eight American engineers and scientists spent two weeks (June 25 to July 8, 1967) on a waste management study tour in Europe. They first attended the Ninth Congress of the International Association of Public Cleansing in Paris. Then from June 30 to July 8 they toured German solid waste handling and disposal facilities. The Solid Wastes Study Team visited the cities of Berlin, Munich, Rosenheim, Frankfurt, Schweinfurt, Düsseldorf, and Duisburg. Attention was directed to the quantity and characteristics of domestic solid waste, its on-site storage, its collection and transportation, and its disposal by landfilling, incineration, and composting. Dr. Samuel A. Hart, who prepared this report, has also written a separate report on European composting, which will be published in the near future.

The courtesy and assistance shown the Solid Wastes Study Team by officials of the German Federal Republic and of each city visited was helpful, friendly, and warm. The members of the study team felt that their visit was not only a technological success but a step toward the broader goal involving information exchange and closer working relationships with their German counterparts.

RICHARD D. VAUGHAN
Chief, Solid Wastes Program

PREFACE

During the period June 25 to July 8, 1967, the U.S. Public Health Service (National Center for Urban and Industrial Health, Solid Wastes Program) sent an eight-member team of scientists and engineers to study solid wastes management in Europe. They were accompanied by Michael E. Jensen, a staff engineer of the Solid Wastes Program. The group first attended the INTAPUC (International Association of Public Cleansing) conference in Paris, June 26 to 30, then went to Germany for inspection of collection, landfilling, composting, and incineration equipment and practices in that country.

The purpose of the trip was to observe German practices with a view to evaluating immediate and potential application of German technology to U.S. needs, and to foster information exchange and closer future working relationships with German counterparts.

The trip was timed to the INTAPUC congress in Paris. Attendance at that congress was valuable for three reasons. First, the technical sessions (simultaneously translated into English, German, and French) enabled the American Team to learn of present science and technology of solid wastes management in Europe. Secondly, there was a major equipment and machinery exhibit where present-day European solid wastes storage, collection, transporting, and disposal equipment was displayed and demonstrated. Thirdly, a number of German waste authority administrators and scientists attended INTAPUC; it was thus possible to meet more of these experts, and to meet them more informally than was possible while on the tour within Germany.

The study trip in Germany was a part of the exchange program of the United States – German Cooperative Program in Natural Resources, Pollution Control, and Urban Development. That program began with a discussion between President Johnson and then Chancellor Erhardt in 1965. Following this, in 1966, U.S. Secretary of the Interior Udall visited Germany and set up the machinery and objectives of the interchange. Dr. James Slater, Office of the Under Secretary of the Department of the Interior, is U.S. Program Director.

The arrangements for the present trip were made through Dr. Joachim Berg, the Germany Program Director, and D. G. Hösel, German Solid Waste Panel Chairman from the Ministry of Health at Bonn. Cooperating with Dr. Berg was Professor Höffken, Director of the Institute for Water, Soil, and Air Hygiene (a research and public service unit of the Ministry of Health) in Berlin. The Zentralstelle für Abfallbeseitigung (Central Office for Solid Waste Disposal), an arm of the Institute for Water, Soil, and Air Hygiene, was directly involved in setting up the tour. This Office is headed by Dipl.-Ing. M. Ferber. Accompanying the American Team on the tour was Dipl.-Ing. H. J. Seng. The success of the trip was in very large measure due to the excellent arrangements and guidance by all of the above men. In addition, the city officials of the visited cities of Berlin, Munich, Rosenheim, Frankfurt, Schweinfurt, Düsseldorf, and Duisburg were all most helpful and gracious.

LEO WEAVER
Chairman, U.S. Solid Wastes Study Team

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CHARACTERISTICS AND CHANGES IN EUROPEAN SOLID WASTES

The first statement one usually hears regarding solid wastes management in Europe and the United States is that there is a great difference in the quantity, composition, and characteristics of the domestic refuse in the two lands. The U. S. Solid Wastes Study Team paid particular attention to this. German waste disposal authorities figure that 1.3 to 1.5 pounds of domestic refuse* is collected per capita per day. The refuse typically has a unit weight of 450 pounds per cubic yard, measured in the collection vehicle. The equivalent figure for American domestic refuse collection is 2.3 pounds per capita per day, with a unit weight of about 350 pounds per cubic yard. German officials indicated that up to about 5 years ago the winter refuse contained a very large quantity of ash from home heating with lignite, coal, and wood. Gas and oil for individual heating and municipally produced central steam heating are replacing the old systems, and present-day refuse contains less ash than formerly.

The refuse observed by the Study Team at disposal facilities definitely appeared denser and heavier, and smelled "ashier" than American refuse. Waste paper and paper products appeared to be the major volume contributor to the German refuse, the same as in the United States. However, brown-paper grocery bags as garbage sacks were conspicuously absent. There were fewer empty tin cans (beer and soft drink cans have not yet become common in Germany), somewhat fewer bottles, about the same amount of plastic film and plastic bottles, and the typical array of shoes, rags, broken toys, metal, and similar materials. Garbage grinders (kitchen sink disposal units for food wastes) have been prohibited in Germany, so the German refuse contains this waste component, although it is usually wrapped in paper and is not particulary obvious. The German waste management authorities stated that the moisture content of domestic refuse averages 40 to 45 percent (wet weight basis) in summer, and about 30 percent in winter.

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* Domestic refuse is defined herein as that which the homeowner or apartment house dweller customarily puts into his garbage can or into a box alongside it and which is collected regularly by the collection truck. This refuse is the food scraps, cans, bottles, ashes, cartons, old paper, and similar discards of living. Yard and garden trimmings (but not fall-of-the-year tree prunings) as collected from individual homes are also included although the percentage of German families living in individual homes is small. Old furniture and bulky objects only occasionally discarded and requiring special pickup are not included as domestic refuse.

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The calorific value of German domestic refuse ranges from 800 to 2,200 kilocalories per kilogram. This is the "lower heating value," which compensates for water as a product of combustion. This corresponds to 1,450 to 4,000 Btu per pound on the lower heat value basis, or 1,600 to 4,500 Btu on a higher heat value basis. Typical American domestic refuse has a higher heat value, between 3,000 and 5,500 Btu per pound.

It is notable that German authorities are observing that not only is the quantity of refuse per capita increasing, but its characteristics are trending toward that of American domestic refuse.

In both the United States and Germany, domestic refuse has been estimated to comprise only about one-third of the total quantity of solid waste that must be disposed of. The study tour was not directed to industrial wastes, construction-demolition rubble, and agricultural wastes, and relatively limited data on these were obtained. However, authorities in several German cities and German research organizations have sampled and analyzed the various classes of refuse and have published the findings.

DOMESTIC REFUSE STORAGE AND COLLECTION

The standard — almost universal — container for domestic refuse is the 110-liter (about 29-gallon) refuse can designed for dustless collection. An example of this is to be seen in Figure 1.

Formerly these cans were made of very heavy galvanized iron, and in some cities some pre-World War II cans are still in service. Today many of the replacement containers are plastic. The cans are generally owned by the city, and the collection fee reflects this cost of city ownership. The 110-liter size is based on once-a-week pickup of one container per family and is still adequate in most cases.

The size of the container and the dustless collection system design were originally based upon the high ash content of German refuse at the time that the system was standardized (prior to World War II). Today the ash content of German refuse is much reduced (though still greater than in American refuse), and the same criteria may not so rigorously apply. However, there appears to be no inclination to change the concept of the 110-liter dustless style container. In fact, the waste collection equipment seen at the INTAPUC machinery exhibit was aimed at promoting this concept.

Most German families live in apartment houses, and the 110-liter refuse cans are stored at ground level. On collection day the residents (or custodian service) place small refuse containers on the curb of the street to await collection; however, the 110-liter containers are usually carried out and returned by the collectors. This same practice is followed in the new housing divisions of single- and two-family residences, the containers typically being stored in the frontyard behind a wall or shrub.

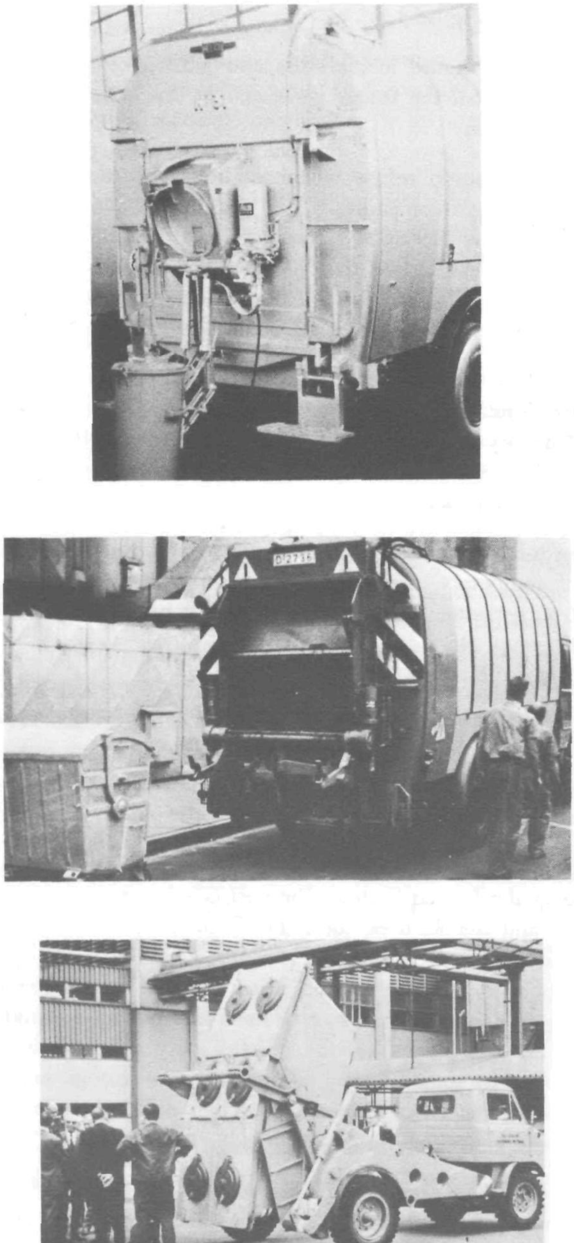

FIG. 1. *Refuse containers and collection equipment.*

Some of the larger apartment and housing units have recently converted to containers that will hold 1.1 and 4 (or even 6) cubic meters; these, too, are shown in the photographs in Figure 1.

On-site apartment house incinerators and garbage-grinding units are scarce or nonexistent. Thus, all the refuse generated by the citizens must be hauled to the central disposal site.

Collection of domestic refuse is almost invariably done by the city rather than by private scavenger companies. The typical collection vehicle has a capacity of 14 to 18 cubic meters (19 to 24 cubic yards). It is usually operated by a crew of one driver and three, four, or five loaders. The loaders roll the containers on the bottom rim over to the back of the truck, actuate the lifting-dumping device, and roll the container back to the curb; containers are not lifted.

There has been a definite trend to twice-a-week pickup of domestic refuse in Germany. It was noted that Monday and Tuesday are "heavy" days (two different routes) and Thursday and Friday are "light" days (end-of-the-week pickup of the same routes). Wednesday is reserved for special (bulky object), park, street-sweeping, and similar pickups.

The Düsseldorf collection system was of particular interest. Its management includes use of computers to analyze data for equipment purchase, route allocation, cost control, personnel assignments, and labor negotiations (determination of incentives, shift setup, etc.).

The fee for refuse collection varies in the cities visited, from Deutschmark (DM) 40 ($10) to DM 140 ($35) per year for picking up one 110-liter container once or twice a week. The DM 102 fee (in Frankfurt) is sufficient to pay all costs of collection and disposal, including equipment amortization; no part of the waste collection is subsidized by other taxes. Details on the other cities were not obtained.

The Study Team observed German concepts of refuse collection with the view of possible use in the United States. The customary use of dustless containers of standard design and the dustless, mechanized dumping of the container into the collection vehicle were very impressive. Because of differences in refuse composition, its wide application in the United States was not considered feasible by the Study Team. In fact, although present German equipment is designed to ease the chore with the 110-liter container, the practicability and economy of the whole system is questioned by some German authorities. The storage and the mechanized dustless collection of the 1.1-cubic-meter container did look impressive; a similar-sized container and collection system is already in operation in the United States.

The German loading crews do a different work than their American counterparts. Refuse is not manually lifted; the machine does this work. The accident rate, especially relative to back injuries, should therefore be much reduced.

LANDFILLING

Landfilling problems in Germany are similar to those in the United States. The Study Team saw many small, uncontrolled, open dumps being used by villages and towns. These are the same blight on the German landscape as they are in America. A concerted effort is being made in Germany to eliminate these small dumps, basically by getting several communities to go together and run a larger, cleaner, and better organized burying facility.

Large, controlled landfills were visited in Berlin and in Frankfurt (Fig. 2). The solid waste disposal problem in West Berlin is extremely interesting. Although an appraisal of the Berlin situation is not yet directly applicable to anything facing American metropolises, it may be suggestive of the future when communities cannot export wastes to the surrounding countryside — because there will be no countryside. West Berlin is an island of 185 square miles (roughly triangular with base and altitude of 20 miles) within the heart of politically opposite East Germany. There is essentially no trade between West Berlin and either East Berlin or East Germany. Almost all food and goods of the viable, modern, western-oriented city of 2.2 million inhabitants must be shipped in from West Germany. The cost of shipping out the wastes is obviously prohibitive, so the domestic, commercial, and industrial refuse, and the construction-demolition debris must be sequestered within the 185 square miles. There are presently five burial sites for refuse. Several of them began as "Trummerberge" or rubble mountains during the early postwar days when the residents were clearing their city of the bombing damage. The largest such Trummerberg is about 250 acres in size, and the back side of it is still being used for some commercial and industrial refuse, plus construction debris. A U.S. radar installation is housed on the top, about 150 feet above the surrounding plain. Most of the mountain is planted with trees and grass and is a recreation site; there is even a bobsled run designed into it.

The Study Team visited Berlin's major landfill site, located in the southwest corner of the city, adjacent to the iron curtain separating the city from East Germany. This site receives all kinds of solid wastes — domestic, commercial, industrial, and construction. Approximately 25 percent of the total volume of West Berlin's solid waste is being buried there. The original site was an abandoned gravel quarry, but it appeared that the landfilling operation had overrun the old quarry. The landfill is surrounded on the West Berlin side by a forested greenbelt. The site has been used for 10 years, and the authorities figure it may suffice for 10 years more without too badly encroaching on the forested recreational area around it.

Except for the height of the refuse above the normal land elevation (about 30 feet), the landfilling operation appeared typical of many American operations. That is, it could not be called a "sanitary landfill" because the refuse was not covered every day, but it was not an open burning dump. Perhaps it can best be described by a rather literal translation of the German term for it — "geordnete Deponie" or "orderly depositing."

FIG. 2. *Controlled landfill — Frankfurt.*

One of the research divisions of the Institute for Water, Soil, and Air Hygiene is conducting research at the Berlin landfill on the effect of compaction of the refuse upon the water regime within the fill. The fill is instrumented to measure temperature, moisture, and specific weight, as well as quantity and quality of leachate. Two-meter layers of domestic refuse are deposited with varying amounts of compaction, covered with earth, additional layers of refuse, and cover. Surface runoff is small, 90-plus percent of the normal 26-inch rainfall infiltrates into the fill or evaporates. The study has been running 3 years. Results to date indicate that maximum leachate occurs with maximum compaction. Temperatures to 180°F have been recorded in the more loosely compacted cells. This research is similar to some of the American research on landfills and groundwater pollution and will be a useful addition to the scientific literature.

The second controlled landfill carefully inspected by the Study Team is at Frankfurt. This landfill started 42 years ago as an open burning dump. Later this was brought under control, and now it is in the final stages of accepting refuse. It is 55 acres in size and the top is 140 feet above the surrounding 11,000-acre nature preserve (mostly fir forest), The landfill is 4 miles south of the heart of the city, on the south side of the Main River.

The Frankfurt landfill is in the process of being abandoned as a disposal site for raw domestic waste. The citizens complained about smoke when the fill caught fire, about odors, and about blowing paper. In the future, Frankfurt's domestic solid wastes will be incinerated, and only a small part of the landfill will be used for the incinerator ash and nonburnable raw wastes.

The completed landfill will actually be an asset to Frankfurt. The slopes are presently being tapered, covered with topsoil, and reforested to match the adjacent land. A luxury restaurant will be built on the summit, where the view overlooking the forest and nearby Frankfurt will be a fine attraction.

The Study Team asked officials of cities with compost plants or refuse incinerators why they did not landfill raw wastes. The usual answer was that there was no land available, or that it was too expensive or reserved for a higher use, and that groundwater pollution was a matter of concern. However, basically the reason often appeared to be political — the residents just did not want a landfill in the neighborhood. The situation at Frankfurt was typical: the whole 11,000-acre forest in which the 55-acre landfill is located is owned by the local, regional, and federal governments. Yet the Frankfurt Public Works Department, itself a local governmental agency, could not get any other branch of the government to release additional land for a landfill.

On the other hand, it was noteworthy that at Berlin, with minimal land availability, landfilling is still considered to be a key part of the solid waste management program. A new incinerator has been built; it will burn one-half of the city's domestic and commercial refuse. There is preliminary planning for an additional incinerator to take most of the remaining burnable wastes. However, it is recognized that a certain amount of landfill will always be required, and it is intended to keep landfilling technology and practice current.

The Study Team thought that the German practice of going "above grade" — higher than the surrounding land level — was a practice that might have application in certain communities in the United States.

COMPOSTING

Because composting has been lauded as the refuse disposal system that "conserves and converts" wastes into something useful, it has received much attention throughout the world. In practice, composting has not been an important method of solid waste disposal in the United States. German composting practice has been somewhat more successful than American experience. It was therefore appropriate that the Study Team spend some of its time learning of the German operations. One team member, on sabbatical leave, had spent 11 months preceding the tour studying compost utilization in Europe.

Nine composting plants have been built in West Germany since World War II, and all nine plants are still in operation. This is in contrast to U.S. activity, where twelve plants have been built in the same period of time, but at this writing only five are operating.

The nine West German composting plants accept and convert only about two-thirds of 1 percent of the German domestic refuse into compost (from 400,000 of the 55 million residents). Thus, composting in Germany, as in the United States, must be regarded as a minor method in the total solid wastes management program.

The composting plants visited at Duisburg (Figs. 3 and 4) and Schweinfurt were excellent examples of typically good German engineering and operation.

The Duisburg composting operation is a two-drum Dano plant built at the Sewage Treatment Plant. This site is already surrounded by housing developments. Domestic refuse from 90,000 of the 400,000 residents of Duisburg is brought to the compost plant. The refuse is elevated, picked over for salvageable bottles, cans, rags, cardboard, etc., sewage sludge is added, and the mixture is put into the slowly rotating drums. Residence time in the drum is 3 to 5 days, on a continuous flow-through basis. The fresh compost from the drum is sieved, and then is piled outside to cure. The noncompostable residue is buried. Most of the finished compost is sold to nearby landscape architects for new garden construction.

The Duisburg plant operation experienced a great deal of trouble with odors from the composting operation. The plant had to be shut down in summer when the incoming refuse was wet and the compost could not be kept aerobic. The problem has been solved by a combination of techniques. Firstly, the sewage sludge is thickened so the minimum amount of excess water is added. (Even with sludge thickening, only one-third of the population equivalent of sludge can be added in summer, and one-half the population equivalent in winter.) Additionally, all the ventilation air of the building and of the Dano drums is scrubbed through a soil filter. This filter consists of a buried perforated pipe covered with earth and cured compost; the filter is approximately 10,000 square feet in size and filters about 7,000 cubic feet of air per minute.

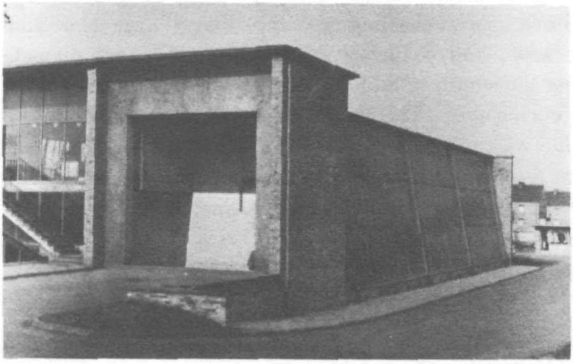

FIG. 3. *Duisburg composting plant. Note proximity of residences behind building.*

FIG. 4. *Duisburg composting plant. Study Team and hosts in front of soil filter.*

The second plant visited was at Schweinfurt (Fig. 5.). The Caspari-Brikollari process is used. This is a new and novel process. Domestic refuse is received, elevated, handpicked, ferrous metals magnetically removed, and the refuse is run into a Dorr-Oliver rasp. The abraded material is ballistically separated to remove inert material and temporarily stored in a hopper. Concurrently, digested sewage sludge is vacuum filtered to dry it from 88 to 70 percent water. Ground refuse and sewage sludge from the same total population are mixed together, and briquettes, formed in a special molding machine (Fig. 6), are approximately 18 inches long, 9 inches wide, and 5 inches deep, with a 1½-inch-diameter semicircular "tunnel" running the length of the under side. The briquettes are stacked on pallets and stored in a curing shed. The temperature within an individual briquette rises to about 140°F, and within 1 to 2 weeks the moisture content drops from the original 50 to 54 percent to about 13 percent. Fungal growths are probably very important in this composting process. After the composting, the blocks are moved outdoors where they are stored in a yard like normal bricks. In the fall when compost can be sold to grape growers, the blocks are run through a grinder and sieve, and the finished compost sold.

At Schweinfurt, the highly mechanized design was motivated by the goal to dispose of sewage sludge with the refuse; thus, a considerable portion of the cost of the composting can be charged to sewage sludge disposal. While Schweinfurt apparently has been successful in getting rid of sewage sludge by composting, other German cities such as Duisburg have been only partially successful.

FIG. 5. *Schweinfurt incinerator and composting plant.*

Some data on composting costs were obtained. Duisburg officials report that composting operations cost DM 8 to 9 (a little over $2) per metric ton of raw refuse accepted, and this includes the cost of accepting the sewage sludge. The finished compost is sold for DM 5 per metric ton. Eight to ten thousand tons of compost are made each year. The city is presently constructing an incinerator for domestic and commercial wastes. The net cost of incinerating a ton of incoming refuse is expected to be about equal to composting it. Therefore, it is planned to continue composting to the extent that it is possible to sell the compost at DM 5 per ton.

In Schweinfurt, the total cost of composting the domestic refuse and the sewage sludge from 60,000 residents is DM 380,000 per year. This includes plant amortization. About 10,000 tons of finished compost is made each year, and sells for an average price of DM 8 per ton; this reduces the cost to the city for waste disposal by DM 80,000.

The Study Team was impressed with both composting operations. The quality of the finished compost observed at both plants was very good, and the plants appeared functional and efficient. The big problem in composting is in marketing the material. Compost is a low-value commodity, and the market for it is very restricted. This is so in Germany as well as in the United States and puts real limitations on composting as a method of domestic waste management. If composting is ever to be a significant avenue of waste processing in Germany or the United States, more satisfactory outlets must be found for the finished compost.

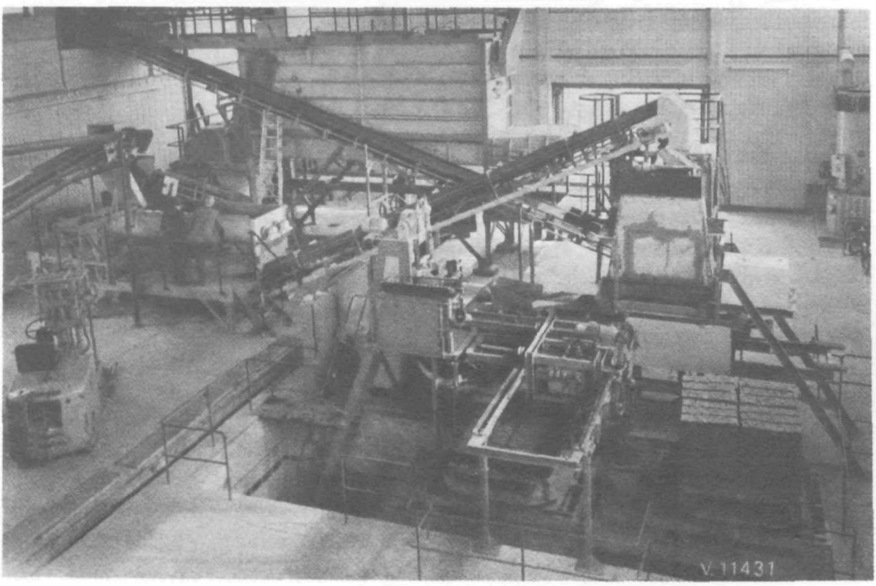

FIG. 6. *View of briquetting equipment — Schweinfurt composting plant.*

INCINERATION

Incineration practice in Germany — and in all Europe — is based on an entirely different set of conditions than in America. The Study Team visited refuse incinerators at Berlin (Fig. 7), Düsseldorf, Frankfurt, Munich, Rosenheim, and Schweinfurt. At every plant except Schweinfurt, either heating steam or electricity from steam was produced from the heat of the refuse burning.

The German decision to produce steam from refuse stems from a compound line of reasoning and conditions. Although German refuse has a lower calorific value than American refuse, the difference in calorific value is less than the difference in fuel costs between the two countries. Thus, the economic potential for energy production from refuse is somewhat more favorable in Germany than in the United States. This alone, however, would not be sufficient to justify all the refuse incinerators with power production facilities. Additionally, because West Germany is so densely populated (8 times the population density of the United States), a high degree of environment management is a necessity. High-quality stack emissions are paramount. To do a good job of cleaning combustion gas, its temperature must be reduced — usually to less than 600°F. One good way of cooling gases is by heat transfer — to absorb the heat by producing steam.

There is also a third factor, which is somewhat more intangible. Conservation and resources management are characteristics of the German people. Because power and utility services are performed by local governments, conservation and waste conversion — the production of energy from municipal refuse — can be more easily practiced, as they are less dependent on profit motivation.

The actual practice of incinerating refuse with steam production takes two basic forms:

1. The primary operation is refuse burning — steam production is incidental, and the quantity of steam so produced and the time of production are not tailored to the community's steam or electric power needs. Rosenheim, Berlin, and Frankfurt operate on this principle. Conventionally fueled boilers must be available to meet the maximum heating or power demand of the community. The refuse boiler merely reduces the quantity of conventional fuel burned.

2. The incinerator is operated primarily to produce steam or electricity in the amount and at the time it is needed — refuse is burned to this schedule, with auxiliary fuel being used to supplement the fuel need. This is the principle followed at Munich and Düsseldorf. Here again, conventionally fueled equipment nearly equal to the maximum steam or power demand must be available, but the fluctuation of the load on this conventionally fueled equipment is much reduced. It was pointed out to the Study Team that there are valid arguments for both systems, and the choice must be tailored to the individual city.

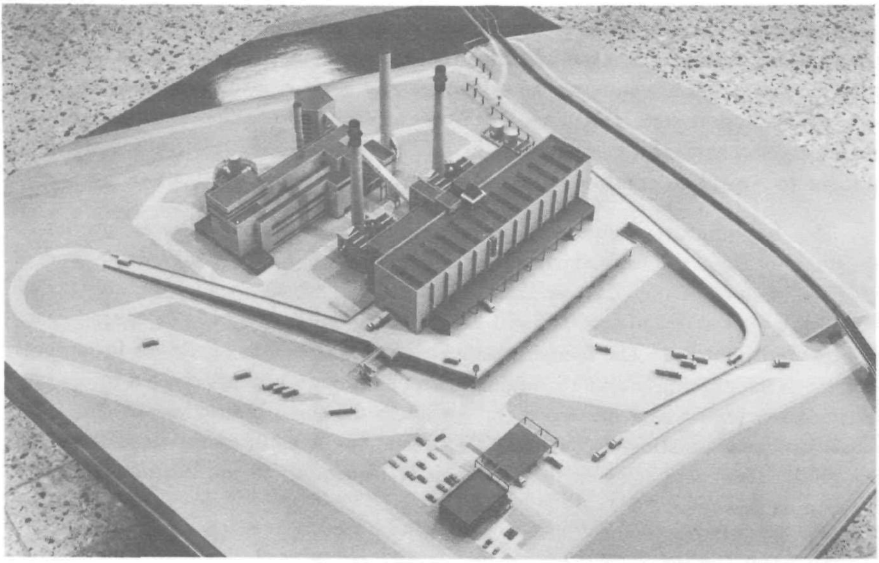

FIG. 7. *Berlin incinerator (model). The sintering plant is in the rear of the large building.*

Other factors include whether the refuse incineration will occur in a separate firebox and boiler, and whether refuse burning and conventional fuel burning will be used with one set of boiler tubes. In addition, it must be decided whether the refuse incinerator will be a simple unit producing low-pressure steam (20 to 50 psi) or will contain a more efficient but more complex and costly high-pressure (400 to 1,300 psi) boiler. The low-pressure steam can be used directly for municipal heating, or can be fed into a high-pressure, conventionally fired boiler.

All German incinerator officials pointed out that steam and power generation from municipal refuse is not a profit-making activity. Refuse is not a "free" source of fuel, because it costs more in equipment, controls, and manpower to burn refuse than it does to burn conventional fuels (lignite, coal, oil, or gas). It was further pointed out that the cost of producing a ton of steam or a kilowatt-hour of electricity from refuse is often expressed in terms of how much more it costs with refuse than with conventional fuel; the extra cost is chargeable to waste disposal for it would cost that amount to burn it without steam generation, or to bury it, or to compost it.

The Study Team members tried hard to obtain meaningful and comparable data on the cost of burning a ton of refuse or of producing a ton of steam from the refuse. The effort was unsuccessful, in part because of technical language difficulties. Some communities include plant amortization in the total cost whereas others include only the refuse burning part, or do not even include plant amortization. Some communities base their calculations only on the refuse burning; others include the power generation, or the ash and slag removal and disposal, and similar variations. The impression was obtained that after reducing the cost by the revenue from the steam, but not counting amortization over what a normal incinerator could be obtained for, it costs DM 6 to 12 ($1.50 to $3.00) to incinerate a metric ton of refuse. A meaningful cost analysis in U.S. terms, useful in relating the German practice to American conditions, would require months of investigation.

The Schweinfurt incinerator does not produce steam. It was primarily designed to burn the industrial wastes from the two ball-bearing plants and a machine manufacturing plant in Schweinfurt. The excessively high heating value of the oily wastes (up to 9,000 Btu/lb) and the metal chips and balls caused grate damage and jamming. The incinerator, which has not been in operation for several months, is undergoing major redesign and reconstruction and is expected to operate satisfactorily with a new grate design. Although the three industries could use the refuse-produced heating steam and the waste has a satisfactory heating value, the Study Team was advised that waste heat utilization is not economic at this location at this time.

This report cannot spell out all the design features of the individual plants. However, a brief discussion of the general components, and their design rationale, does seem appropriate.

Bunkers and Cranes

The Study Team noted the generally very large capacity of both bunkers and cranes. The Düsseldorf bunker (of special design) can hold a 3-day collection of refuse, and because of the 24-hour-per-day, 7-day burning program of the plant, refuse is stored for the weekend when there is no collection. The bunkers are operated with negative pressure ventilation (the air for the incinerators is drawn from the bunker area), and all are fitted with good doors for cleanliness and appearance.

German refuse cranes are larger and slower than are the U.S. cranes. Both polyp (8-fingered orange-peel bucket) and clamshell buckets are used. In some cases, the crane operator sits in a stationary control house and not on the crane trolley. The buckets often have a strain-gauge weighing system incorporated into the hoisting device, and at Düsseldorf a continuous weight record of the amount of waste incinerated is made.

The design of the bunker and crane systems of the large German incinerator plants seems efficient and appropriate.

Grates

The Study Team saw examples of three major designs of grates:

1. The Von Roll shuttle stroke, stepped-deck grate (Frankfurt).

2. The Martin reverse-stroke grate (Munich).

3. The VKM or Düsseldorf drum grate (Düsseldorf, Rosenheim, and Berlin).

All were operating well, and a good burnout of the refuse was observed. (The German standard is 0.3 percent putrescible matter in the residue.)

Walls and Boiler

Water-cooled walls are a typical feature of an incinerator in which steam is produced. Although firebrick is still necessary, the amount of it and the stress to which it is subjected are much reduced. This is one of the plus benefits of producing steam from the heat of incineration.

The water (or steam) tubes do not normally extend all the way down to the grate level. Usually, a three- or four-course liner of abrasion-resistant firebrick is used to line the wall above the grate. The flames, flying ash, and physical movement of the bed of refuse do cause wear on this wall. Additionally, if the refuse burns at too high a temperature on the grate, a slag often builds up on the firebrick wall. This part of incinerator design is still causing some difficulty in Germany, as well as in the United States, but the manufacturers are working on it.

The boiler tubes above the grate and fire are very similiar to those in a conventionally fueled boiler. The choice of low-pressure (and thus lower temperature) versus high-pressure (and temperature) steam production has been referred to previously. Boiler tubes within a refuse incinerator may become fouled, eroded, and corroded more quickly than in a conventionally fueled boiler. Keeping the gas velocity below 25 feet per second and preventing flame impingement on the tubes, however, minimizes these problems. German plant engineers have been concerned about the increasing amount of plastics, especially about the corrosion from the polyvinyl-chloride type that must be burned. Solutions were not obvious from the tour.

Air Cleaning

The most impressive and laudatory feature of German refuse incinerators was the quality of the stack emission (Fig. 8). Fly ash is removed at the turns in the boiler and flue gas passages, and it appeared to be economically and satisfactorily managed in all plants. The fly ash is conveyed to the burned-out incinerator residue (clinker and ash) in the dry state at most plants, but at Frankfurt it is conveyed in a water slurry and settled out in a separate operation.

Large, heavy-duty electrostatic precipitators designed for 98 to 99 percent efficiency are incorporated into all the incinerators except at Schweinfurt. These precipitators are the only gas-cleaning equipment used — no prior scrubbing, centrifuging, or filtering. The electrostatic precipitators are continuous flow-through, with periodic shakedown self-cleaning.

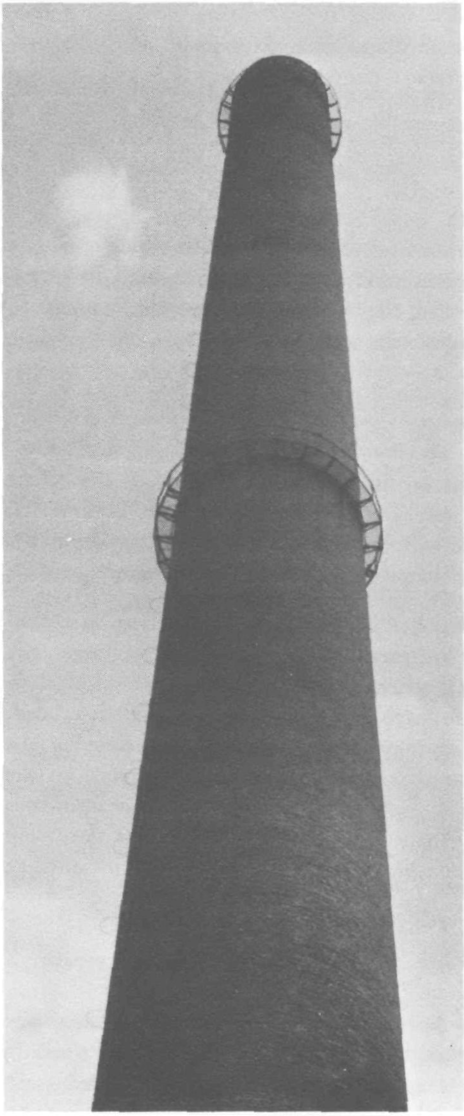

FIG. 8. *Clear incinerator stack — Frankfurt.*

The German air pollution control standards allow a maximum of only 150 milligrams of particulate material per cubic meter of gas cooled to standard condition (760-mm pressure, 60°F). This corresponds to about 0.192 pound of particulates per 1,000 cubic feet of flue gas corrected to 12 percent carbon dioxide. The present U.S. guideline is 0.428 pound of particulate per 1,000 cubic feet. The quality of the German exhaust is thus very good.

The German refuse incinerators are generally equipped with very high (up to 300 feet) chimneys. This provides excellent dispersion of the gases above the city.

Metal Salvage

At most of the plants (including the two composting plants), tin cans, wire, and other ferrous items are magnetically removed from the residue. This metal is baled and then sold to blast furnaces. It is considered worthwhile, both for the monetary return and for the reduction of the volume of residue. (The tin content of such scrap limits its use to cast iron; it cannot be used for steel production.)

Ash Sintering

At Berlin, the Study Team inspected the residue reclamation plant. The incinerator residue is run over a magnet to remove the cans and metal, then crushed as necessary, and sieved. The sieved material is mixed with 1 to 5 percent charcoal and about 40 percent recycled sinter material and passed through a sintering oven. The end product, after resieving, is a lightweight aggregate material used for concrete block construction and for roadbed subbase. It must be pointed out that the situation in Berlin is very special; regular gravel and aggregate must be shipped in across the 140 miles of East Germany, and not only is there the shipping cost, but East Germany collects a toll on its passage. Thus, ash reclamation has a peculiar economic potential in Berlin, which it probably does not have in many other cities.

GENERAL OBSERVATIONS ON INCINERATION

All the German incinerator plants visited by the U. S. Solid Wastes Study Team were well built and clean. They were typical of power plants and appeared to be amply financed. They contained facilities and important details not usually found in American incinerator plants.

The Study Team was particularly concerned with whether the German incineration practice, with steam or electricity production, is applicable to American conditions. The process is technically feasible, but the Study Team had serious questions as to whether present U.S. economic conditions justify its application in the United States. The Team members were impressed with German efforts to meet air pollution control standards and the electrostatic precipitator techniques and equipment used to ensure high-quality incinerator stack discharges. But, even if the same air quality standards were required in the United States, and the same electrostatic precipitators were used, it would not necessarily be economical or appropriate to also produce steam or electricity. Hot incinerator exhaust gas can be cooled by water injection or by excess air, and under American conditions, this might still be more appropriate. As indicated earlier, a comprehensive engineering and economic analysis would be required before a decision could be made.

CONCLUSIONS

Solid waste management in Germany is an impressive operation. The West German federal government and the public works departments of the various cities are doing an excellent job in this difficult area. The public works departments and the officials within these departments have a great deal of initiative and appear to have a relatively high degree of independence. The invention and testing of the Düsseldorf grate is one example; the ash-sintering design at Berlin, another; even the setting of the waste disposal fee, as at Frankfurt, is another. The municipal officials, to whom the public works officials report, appear to have a generous and approving attitude toward waste management costs. Such factors as the architectural appearance of facilities and the safety and welfare of the employees are favorably weighed. Engineering is not done on an absolute minimum cost basis, but rather on an optimum design basis.

Summary of Observations

The U.S. Solid Wastes Study Team found the technology and practice of domestic refuse management in Germany to be of very high caliber. Specific observations were made, which can be summarized as follows:

1. German domestic refuse is quite similar to American domestic refuse; however, it does contain slightly more ash, but fewer cans and bottles, and less paper.
2. The principal storage container for German domestic refuse has been a 110-liter refuse can. This is still common, but larger containers — 1.1, 4, and 6 cubic meters — are becoming more popular.
3. Domestic refuse collection is almost invariably handled by the municipal government. Collection is from curbside, and containers are dumped into the collection vehicle by a mechanized lifting device. The "dustless" dumping originated because of the high ash content.
4. Landfills frequently have the same ill repute as American landfills. Controlled landfills are often built considerably above the surrounding land elevation. No sanitary landfills were observed.
5. Composting is practiced in nine locations in West Germany, but it is not a major refuse disposal process. The economics, especially of marketing the compost, are not favorable.
6. Refuse incineration that produces steam or electricity is common in Germany. Such incinerator plants are models of efficiency and good engineering. However, refuse is not a "free" fuel; it costs more to produce steam or electricity from refuse than from conventional fuels. The additional cost is charged to refuse disposal. Electrostatic precipitators are used on all the power-producing incinerators, and this results in high quality stack discharges.

Special attention was paid to the German practice of steam and electricity production using refuse as a fuel. The Study Team was impressed but concluded that consideration of the significant economic, political, and philosophical differences between the situation in Germany and that in the United States was paramount in evaluating application of this system to any given U.S. community.

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