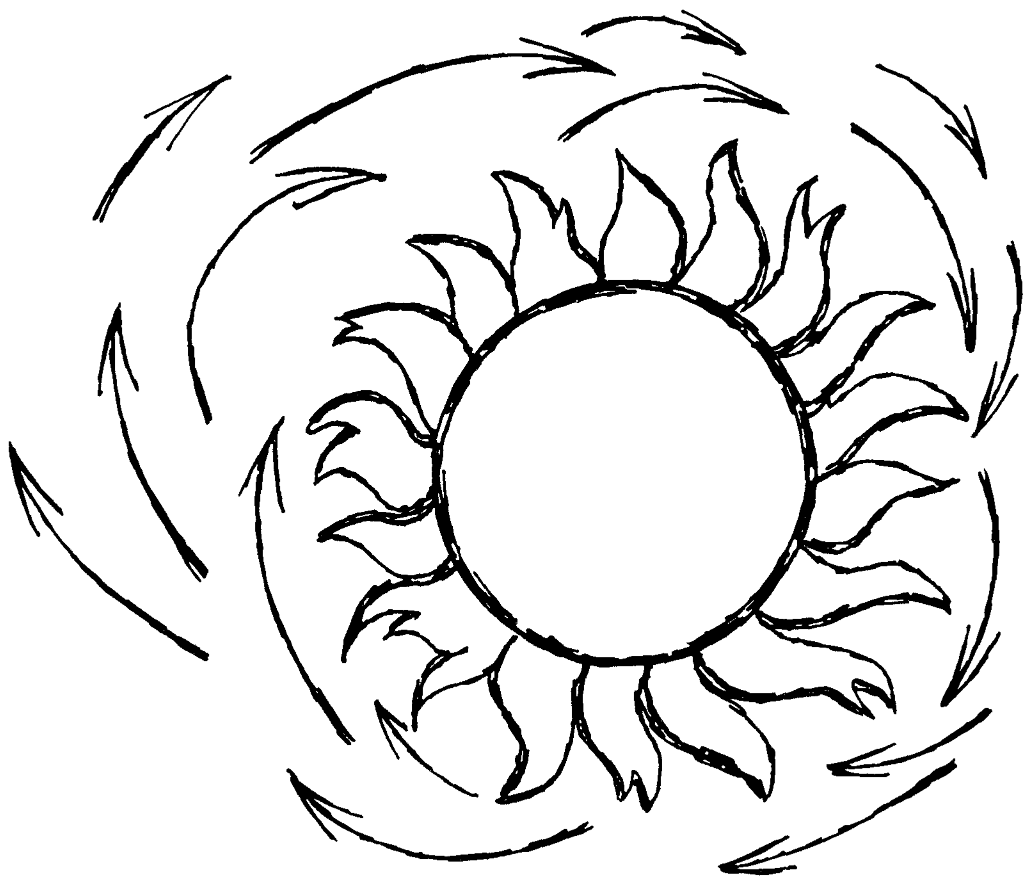
SW-22P

WASTE MANAGEMENT TECHNOLOGY and RESOURCE & ENERGY RECOVERY



PROCEEDINGS
OF THE FIFTH NATIONAL CONGRESS

WASTE MANAGEMENT TECHNOLOGY and RESOURCE & ENERGY RECOVERY

Cosponsored by the National Solid Wastes Management Association
and the U.S. Environmental Protection Agency
Dallas, December 7-9, 1976

U.S. ENVIRONMENTAL PROTECTION AGENCY
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FOREWORD

The U.S. Environmental Protection Agency and the National Solid Wastes Management Association's Institute of Waste Technology and Waste Equipment Manufacturers' Institute co-sponsored the Fifth National Congress on Waste Management Technology and Resource and Energy Recovery in Dallas, Texas, on December 7-9, 1976.

These technical and planning-oriented Congresses have served to advance the awareness of developing technologies and practices and to facilitate their utilization. This Fifth Congress gave particular attention to the three major areas of solid waste management: hazardous and chemical wastes, land disposal and resource recovery. Careful assessment of operating experience in these areas was featured on the program.

The meeting included participants from State and local, as well as the Federal government, waste management and resource recovery firms, universities, research and development companies and the financial community. The wide range of viewpoints included in this volume proved a valuable store of current information and opinion on vital areas of interest in the solid waste management field.

We acknowledge the leadership of NSWMA's Institute of Waste Technology and Waste Equipment Manufacturers' Institute in organizing these discussions. Special acknowledgement is due to Peter Vardy, Vice President, Environmental Management-Technical Services, Waste Management, Inc. who served as Chairman of the NSWMA Institute of Waste Technology and Glenn Park, Vice President-Director of Engineering, Peabody Solid Wastes Management, and Chairman of the NSWMA Waste Equipment Manufacturers' Institute. Recognition is also deserved

,ollowing organizations which lent their support to this conference:

American Public Works Association

American Society of Mechanical Engineers

Association of State and Territorial Solid Waste Management Officials

National Association of Counties

National Association of Regional Councils

National League of Cities/U.S. Conference of Mayors

Sheldon Meyers
Deputy Assistant Administrator for
Solid Waste Management

Eugene J. Wingerter
Executive Director
National Solid Wastes Management Association

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OPENING GENERAL REMARKS

"Opening General Session Remarks"

by

Wayne D. Trewhitt

Vice President - Secretary
Easley and Brassy Corporation

and

Chairman
NSWMA Institute of Waste Technology

Certainly this Fifth National Congress on Waste Management Technology and Resource and Energy Recovery promises to be as revealing and challenging as the previous four. And again we are pleased to acknowledge the co-sponsors of these conferences -- the U.S. Environmental Protection Agency's Office of Solid Waste (formerly Office of Solid Waste Management Programs) and the National Solid Wastes Management Association's Waste Equipment Manufacturers' Institute and Institute of Waste Technology. Additionally, thank you's go to the following associations who have lent their support to this important conference:

American Public Works Association Institute of Solid Waste

American Society of Mechanical Engineers

Association of State and Territorial Solid Waste Management Officials

National Association of Counties

National Association of Regional Councils

National League of Cities/U.S. Conference of Mayors

With the support of fine organizations such as these, this Conference truly reflects the broadest possible perspective on the key issues in a candid and forthright manner - to that end this Congress is directed.

As you are likely aware, the focus of this year's Congress is upon resource recovery, waste processing, landfilling and hazardous waste disposal. Two concurrent forums are planned -- mini-conferences if you will -- each including four sessions - 2 of which are technically-oriented, 2 which are management-oriented. Fewer speakers this year are identified, so as to allow more in-depth presentations, thorough critique and amplification by expert panelists, and ample opportunity for audience participation. For those of you who were in attendance at the Fourth National Congress, you may recall that the audience dialogue often provided the most stimulating, controversial, and provocative discussions. We encourage that response at the sessions this year.

At the Business Luncheon planned for this afternoon from 1:00 to 2:30 p.m. in the Conquistador Room 1 and 2, Peter Vardy, Vice President of Environmental Management, Waste Management, Inc. and Chairman of NSWMA's Institute of Waste Technology will deliver an address in behalf of the Institute and what we have witnessed over the past 2 years.

Most notably at this Congress and following it, we should all strive for cooperative understanding and reasonable implementation of the newly enacted "Resource Conservation and Recovery Act of 1976". This Act is likely to be often referenced and much discussed throughout the next two days. To fully convey the purpose and likely impact of the Act we are pleased to have Mr. Phil Cummings, Staff Counsel, Senate Public Works Commitee, and Mr. Sheldon Meyers, Deputy Assistant Administrator, U.S. EPA with us. Mr. Cummings who played an instrumental role in assuring passage of the Act will be featured as our Luncheon Speaker on Thursday. Mr. Meyers, who this past summer assumed the duties of the Deputy Assistant Administrator's position. He will speak on the topic "To What Extent Is Federal Direction and Regulation Necessary?".

THE RESOURCE CONSERVATION AND RECOVERY ACT OF 1976-- EVERYBODY'S BUSINESS

Sheldon Meyers*

Good Morning. I am pleased to be here and to have this opportunity to participate in the opening session of the Fifth National Congress on Waste Management Technology and Resource and Energy Recovery. My assigned task this morning--which was, of course, formulated many weeks ago--is to answer the question: "To what extent is Federal direction or regulation needed?" On the 21st of October, when the Resource Conservation and Recovery Act of 1976 was signed into law, the answer to this question was provided to all of us. I heard the answer loud and clear and applaud it with vigor.

The Resource Conservation and Recovery Act of 1976 is without doubt one of those kinds of laws which political scientists cite as evidence that the system works. That is to say, it is among those laws which are truly reflective of the will of active public opinion on a given topic at a given historical moment. Built on the foundation of the Solid Waste Disposal Act of 1965 and the Resource Recovery Act of 1970 the Resource Conservation and Recovery Act of 1976 is the evolutionary product of several years of deliberations and hearings held by a number of committees of both houses of the Congress. Whether you fully agree with it or not, whether or not you think that it emphasizes one facet of solid waste

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*Deputy Assistant Administrator, Office of Solid Waste, U.S. Environmental Protection Agency. Presented at the Fifth National Congress on Waste Management Technology and Resource and Energy Recovery, December 8, 1976, Dallas, Texas.

management too much and another too little, you cannot deny that the Congress did its work well. The Act addresses the complete spectrum of problems and opportunities which are so intrinsically a part of the solid waste management issue. It reflects a full awareness of those areas where we have a high level of technical understanding and knowledge as well as those areas of technical uncertainty and relates both to the social and economic ramifications of improved practice.

The Act reflects the fact that all levels of government, industry and a variety of environmental and other public interest groups had full opportunity to be heard. It is no wonder then that both houses of Congress passed it by overwhelming votes.

RCRA integrates the primary thrusts of the two earlier solid waste acts. It acknowledges the interrelation of the resource-use and public health issues associated with land disposal. It mandates a series of actions, requiring effort on the part of all levels of government, industry and the public--over time--to insure that progress in protecting health and the environment will not be inhibited by a failure to move forward in the areas of resource conservation and recovery.

Make no mistake about it. The Congress had a difficult job on its hands. A long hard look at the status of solid waste management reveals that this issue touches the very frontiers of our society's movement toward environmental responsibility. How we deal with solid waste influences, and is, in turn, influenced by, far-reaching social and economic issues. These range from the attitudes of the individual citizen and consumer, through how we extract, manufacture and market products, to such complex issues as depletion allowances and international trade policies. It is no wonder that it took a while and that the Act does not provide immediate, ready-made solutions to all the varied problems and perplexities we have been debating for so many years. Instead, the Act calls for new patterns of interaction among all levels of government, the assumption of key responsibilities by industry on several fronts, and for meaningful public understanding and participation in all the major activities mandated by the Act.

In my opinion, this is as it should be. Particularly if we examine the Resource Conservation and Recovery Act of 1976 in light of the recently passed Toxic Substances Act and the Safe Drinking Water Act it becomes apparent that the Congress is reflecting a new dimension in public understanding of what is required to improve the environment. This new understanding goes far beyond the relatively simplistic attitudes so popular a decade ago, when many seemed to think that placing stoppers on air polluting stacks and water polluting outfall pipes was all that was needed to save us from burgeoning environmental problems we had neglected during two centuries of technological and economic achievement.

Those of us in this room are bound to see this new law, most of the time, from a perspective that narrowly reflects each person's particular area of expertise and interest. This is inevitable. Nevertheless, it is essential that we all draw back from time to time and attempt to see it whole, with all of its many provisions in focus, from the small end of the telescope. That, of course, is what I am doing this morning.

Viewed from such a perspective, I think we can speculate with some degree of certainty on the law's essential meaning. It means that our country is now ready to face the fact that the land is a natural medium which needs to be protected just as air and water do and that resource conservation and recovery are a key element in the process of achieving environmental quality.

The sink of last resort is going to disappear as an inexpensive option for hiding our mistakes and in its place environmentally sound procedures for dealing with wastes will emerge. I believe that all the provisions of the Act are supportive of this goal within which, by no means our only, but certainly our most urgent, necessity is to move rapidly toward controlling the most obviously undesirable portions of the waste stream. Hence, the special, urgent and necessary emphasis on all aspects of hazardous wastes management.

Subtitle C of the new law brings management of hazardous wastes under Federal-State regulatory control. Hazardous waste is defined in the Act as any waste that "because of its quantity, concentration, or physical, chemical, or infectious characteristics" may seriously threaten public health or the environment. EPA is required to identify these wastes, set standards for their management from cradle to grave and issue guidelines for State programs over the next year and a half. The standards go into effect 6 months after their promulgation. States are to establish hazardous waste control programs that will meet Federal requirements and issue permits for treatment, storage, and disposal of such wastes. In those States which choose not to do so, Federal regulations will apply. Civil and criminal penalities are established for noncompliance. To assist States in developing and implementing a hazardous waste program, $25 million in grants is authorized to be appropriated for each of fiscal years '78 and '79. Please note that we do not yet have appropriations under the new law, and therefore do not yet know what sums will actually be available for implementation of the hazardous waste or other provisions of RCRA which require funding.

The new law will increase financial and technical assistance to State, regional, and local agencies for the development of comprehensive programs of environmentally sound disposal, resource recovery, and resource conservation. "Resource conservation" is defined in the Act as "reduction of the amounts of solid waste that are generated, reduction of overall resource consumption, and utilization of recovered resources." EPA will issue guidelines for State solid waste plans. To facilitate regional planning, EPA guidelines will also be issued for identifying regional areas with common solid waste problems. The amount of Federal funds authorized for grants to States for developing and implementing State and regional plans is $30 million for fiscal '78 and $40 million for fiscal '79. In addition, $15 million is authorized for each of those years for grants to regional and local agencies as well as States to implement specific programs that fall within approved State plans.

For a State to be eligible for these grants, its solid waste plan must meet minimum criteria. Among them is inclusion of a requirement that all solid waste be utilized for resource recovery, disposed of in a sanitary landfill, or disposed of in some other environmentally sound manner. The plan must also provide for the closing or upgrading of all existing open dumps.

Criteria for identifying open dumps and for identifying sanitary landfills will be published by EPA no later than October 1977, and the Agency will conduct a national inventory of all open dumps within the 12 months that follow. The Act mandates that all open dumps throughout the country must be closed or upgraded by 1983 and forbids the creation of new dumps. Special grant assistance to help meet these new requirements for land disposal facilities will be available for rural communities. Twenty-five million dollars for FY 78 and 79 is authorized for assistance to rural areas.

Grants to a limited number of "special communities" are also authorized. These are to be communities of less than 25,000 population, most of whose solid waste comes from outside their boundaries, causing serious environmental problems.

Recognizing that States and many local governments will face very difficult problems in meeting the goals and requirements of this legislation, the Act provides for technical assistance teams, called "Resource Recovery and Conservation Panels," which will be available to State and local governments on request. The teams will be prepared to assist in upgrading collection and disposal as well as in developing resource recovery and resource conservation systems. We expect to field these teams from our Regional Offices, where they can gain familiarity with conditions in specific geographic areas.

Wide general authority is conferred by the law for studies, research and development, demonstrations, training, and information activities. The authorization for these functions total $45 million for fiscal '78. The objective is to strengthen and increase the technological base, available expertise, and public understanding that must underlie State and local programs in order for them to succeed.

Demonstrations in resource recovery and improved solid waste disposal facilities are authorized. Studies are required in many specific areas, including sludge management, source separation, agricultural and mining wastes, actions to reduce waste generation, collection methods, incentives for recycling, the imposition of disposal charges on products, and the problems of acquiring land for solid waste management facilities.

In the task of building up the technology for solid waste management, we in the Office of Solid Waste will continue to share responsibility with EPA's Office of Research and Development. In the energy recovery projects, EPA and the Energy Research and Development Administration are required to work out cooperative arrangements.' The commercialization of proven resource recovery technology is assigned by the Act to the Department of Commerce.

A large-scale study of resource conservation will be undertaken by an interagency committee headed by the EPA Administrator. The study will cover the effects of current public policies on resource use and the consequences for the environment and society, and the potential effects of proposed measures, particularly the imposition of disposal charges on products.

In the provisions for information activities, special emphasis is placed on rapid dissemination of information, on public education programs, and a central reference library of solid waste management data and other materials. Efforts are required not only to inform the public but also to promote their participation in the development of Federal and State regulations, guidelines, and programs.

The authorization for EPA for general administration of the programs under this Act is $35 million for fiscal '77--more than double last year's appropriation--$38 million for fiscal '78, and $42 million for fiscal '79. At least 20 percent of this is to be used for the Resource Conservation and Recovery Panels I described earlier and at least 30 percent for carrying out the hazardous waste program.

There, in a rather large nutshell, are the major provisions of the law. It is obvious from the nature and number of specified activities and the increased authorizations for funding that national perceptions of solid waste management issues have undergone major changes.

Perhaps of greatest significance is the heightened concern about threats to health and environment from hazardous wastes and from inadequately controlled land disposal. This concern has developed from damage incidents, from investigations of recent years, and from the realization that pollution controls to protect air, waterways, and oceans are resulting in rapidly mounting loads of residues destined for the land, a heretofore largely unprotected medium. The provisions in the Act for Federal regulation of hazardous wastes and the prohibition of open dumping are the strongest in the Act, and are unprecedented in Federal legislation in the field of solid waste management. The Act clearly provides for State administration and enforcement, with Federal power serving as a necessary backstop where States fail to act. The provisions for assistance to the States for developing programs that meet basic standards make that quite clear.

For the first time, sludges are specifically included in the definition of solid waste in the legislation. Sewage sludge disposal is already a perplexing, expensive problem for many cities, and by 1985, the quantity of sewage sludge generated is expected to double as a result of improved wastewater treatment. Sludge is prominent among those wastes which we believe can be put to work to convert a problem into an environmental asset. Its value as a soil conditioner for non-food-chain use is widely known. Since some sludges contain heavy metals and other contaminants, the use of sludge for food crops requires careful analyses including testing of both the sludge and the soil prior to application. Identifying safe, economic, and acceptable means of sludge disposal and utilization is a matter of high priority for EPA.

Sludge management represents only one of many instances in the field of waste management where, partly in response to environmental problems of disposal, attention has increasingly turned to means of utilizing waste as a resource.

Federal assistance for planning and building resource recovery facilities is available under the Act for State, regional and local solid waste programs, and as demonstration grants. No large financing mechanisms or loan guarantee provisions were included in the Act, but in view of the current level of technology and the unpredictability of markets for recovered products, the emphasis on regional and statewide planning and on demonstrations and evaluations at the Federal level is appropriate. Source separation methods for materials recovery are also cited for support and study, and though lacking the glamour of the large-scale technological systems which depend in large measure on energy recovery for their economic viability, source separation approaches may one day be regarded as the most effective means of recovering materials from the waste stream.

It is noteworthy that waste reduction is clearly recognized in the Act as part of the continuum of processes that make up sound solid waste management. One of the specified objectives of Federal assistance to State and local programs is to encourage resource conservation, and it is a required subject of studies and information dissemination activities. Further development of methods and policies in resource conservation are badly needed. Much of the interest in this area has in the past been concentrated on packaging but there are many other issues, relating to measures of greater and lesser economic scope, that also must be grappled with. The studies mandated in the Act of public policies related to resource use, including the concept of placing disposal charges on products and thereby creating economic incentives to avoid waste, should contribute substantially to a better understanding of the directions in which this country should move to promote optimum resource use.

The new law thus addresses issues in solid waste management that have relatively recently come to the fore in the public consciousness. And, as I have already implied, it also carries forward the continuing emphasis on the State program as a major key to successfully unlocking the opportunities inherent in waste problems. The provisions of the new Act for planning and program grants, technical assistance, research and demonstrations, and information collection and dissemination should all serve to enlarge the capabilities of both States and local governments to fulfill their increased responsibilities.

In the Office of Solid Waste in EPA, we are involved in the complexities of getting the new Act under way. The nature of RCRA demands the involvement in our plans and deliberations of other components of EPA. These include, in addition to air, water, pesticides and toxic substances components, the Office of Planning and Management, the Offices of General Counsel and Enforcement, the Office of Regional and Intergovernmental Operations and several components under the supervision of the Assistant Administrator for Research and Development. The last mentioned is especially important. Major unmet needs in this field depend on a variety of research efforts cited in Subtitle H of the Act.

But of course this is not EPA's Act, it is the public's, and as all of us have had ample opportunity to learn in recent years, the far-ranging issues influenced by solid waste management cannot be properly characterized, let alone resolved, if the only active participants in the process are those of us who regularly read the technical literature and have the professional opportunity to attend meetings such as this. The framers of the Act understood this very well and made it clear that solid waste is everybody's business. Hence they called for rapid information dissemination, public education and public participation programs. The Congress understood that even those represented in the audience today, who have varied positions and interests and sometimes conflicting views, are nevertheless an in-group, and that all in-groups tend to reinforce their own biases.

I assure you that I intend to take the public information and public participation requirements of this legislation very seriously indeed. Our Regional offices will play a major role in this activity, to ensure full State and local governmental involvement and benefit. Next week, on December 16, we are holding our first informal Public Participation Meeting in Washington, to give representatives of major governmental, industrial, environmental and other organizations the opportunity to give us their preliminary views, attitudes, and suggestions on the planning and implementation of the RCRA.

As I implied earlier, the Act takes note of what we know, but just as certainly of what we don't know. Moreover, since scientific knowledge by its very nature is always incomplete, public awareness, understanding, and participation are absolutely essential. Without it, we would have little chance of defining and regulating hazardous wastes, and even less of upgrading land disposal overall, phasing out the use of open dumps, and bringing into existence a new magnitude of activity in the areas of resource recovery and conservation.

Our field is one in which, until quite recently, few of the practitioners really thought of themselves as being governed by the same environmental and public health considerations which have long applied to other environmental problems, such as air pollution. The new Act makes it clear that this is an illusion which we must now cast off. Since this is so, I shall close my remarks today with two quotations from Dr. Leroy E. Burney who was Surgeon General of the U.S. Public Health Service way back in 1958, when the first National Conference on Air Pollution was held, three years after the first Federal Air Pollution Act was passed.

Dr. Burney said, and I quote:

"In law, the suspect is innocent until his guilt has been proved beyond reasonable doubt. In the protection of human health, such absolute proof often comes late. To wait for it is to invite disaster, or at least to suffer unnecessarily through long periods of time.

"Many years ago, before anyone had seen a germ, or positively identified a single causative agent of epidemic diseases, far-sighted leaders observed the association between epidemics and filth. Wherever they had sufficient foresight to act on this circumstantial evidence, they made striking progress. Cleaning up the city filth resulted in better health. Years later, they found out why.

"I suggest that our present position with respect to contemporary problems, especially those relating to the urban environment, may be parallel to that of Pasteur's predecessors."

Later on, in that same address, Dr. Burney made another statement which also seems particularly pertinent to our situation in solid waste management today. He said, and I quote:

"The problems that come as byproducts of our almost unbelievable material progress demand everybody's skills and knowledge. More than that, they demand genuine cooperation. We can no longer ask, Who's going to be in charge? or Who's going to get the credit? We must ask How can we most effectively work together?"

Thank you.

FORECAST OF FUTURE TRENDS FOR LAND DISPOSAL AND RECOVERY OF WASTES

James R. Greco
Technical Director
National Solid Wastes Management Association

Nearly three years ago a market study of the solid waste management field was conducted by a nationally known market analysis firm. The opening paragraph of the summary section concluded that:

> "The solid waste management program in the United States will continue to expand during the decade as Federal and state governments continue to enforce legislation and laws that have been and will be enacted to improve solid waste management practices and to recover either useful materials or energy from the ever-increasing amounts of solid wastes generated".

Certainly, the intent of the Resource Conservation and Recovery Act of 1976 is to improve solid waste management practices and to encourage expanded recovery of useful materials or energy - in addition to the conservation of valuable material and energy resources and the protection of the environment. The Protection of the Environment is perhaps the central and most significant aspect of the new law. It is key to the dual mandate for the prohibition of open dumping and regulating the storage, transportation, treatment, and disposal of hazardous wastes. Certainly, the business environment for land disposal and hazardous waste management will thrive with the promulgation of these provisions - and resultingly, resource recovery programs, likewise. Whether this scenario will unfold, however, is legitimately questionable! One reason being as to whether the law's mandate will be implemented with sufficient funding authorizations and appropriations. Another reason may be the legal morass that can result because of the possibility of citizen suits challenging the effectiveness of the regulations. Nevertheless, let me postulate an example of trends for land disposal and recovery.

By the end of this decade, hazardous wastes will come under a control system. Few hazardous wastes will be indiscriminantly put into or onto the land. Consequently, the "pollution potential" of land disposal sites will be lessened, perhaps dramatically! I believe the prohibition of open dumping will be implemented gradually and slowly. Although by law open dumping should be non-existent by 1983, it may not be economically practicable to meet this deadline much sooner than the early 1980's. Naturally, with the ban on open dumping, more communities will begin to implement resource recovery programs as feasibility and economic viability become attainable. How do I feel about "resource recovery'"? I believe we as an industry have entered a period of "responsible optimism" where solid waste management/resource recovery systems are more realistically considered. Perhaps the most revealing fact which has surfaced during the past year is that resource recovery technology can be part of the solid waste management system and is also viewed firstly as a disposal option and secondly, but importantly, a recovery opportunity. As far as the focus for recovery technology - more emphasis will be placed on materials recovery study, research, and development that was not anticipated last year. Materials recovery not only for recycling glass and metals but also on the production of new process materials and feedstocks for manufacturing processes.

Ironically, the success of the new law and the shape of the future may not be ultimately determined by the Federal government, State governments, local governments, or the private sector - but by the general public. The general public has not seemed to perceive solid waste management. We have failed as an industry to convey to the citizenry our identity as an "environmentally needed" industry. We must also act to do so urgently but responsibly - lest we, as an industry find ourselves in a situation where:

(1) the public focuses on solid waste management problems and a pollution potential perspective rather than pollution abatement:

(2.) the public delays the commencement of environmentally acceptable facilities and sites via the permit process;

(3) the public is unwilling to pay the costs of improved solid waste management practices, environmental protection, resource conservation, and resource recovery;

(4) law suits are filed to challenge the regulations and accelerate the closing of dumps; and

(5) with perhaps a Catch-22 situation arising.

Certainly, we, as responsible governmental officials and private enterprise, must work intensely to build the environmental protection character of our industry in the public's mind. Public law 94-580 can be a step in the right direction and should be.

In the October, 1974 issue of Scouting Magazine, there appeared an article entitled "There's Gold in Your Garbage". I surmised that the magazine's readership were youths who must have been amazed when they read about the "gold" in their garbage. Then I fantasized. Suppose there really was gold in the garbage? Would not the scouts pick it out and extract the monetary value for themselves if they recognized the gold in the garbage? But suppose the scouts did not see this treasure but the refuse collector did. The collector would likely "source separate" to pull the gold before it was mixed in with the trash, provided that the householder (scout) would cooperate. But suppose the collector like the householder failed to perceive that the garbage did contain gold, and the local government suspected some profit from the community's discards (which may be laden literally with gold)? To find that gold and realize its value, perhaps a central plant would be built, mechanized and tuned to pull upon demand the gold from the otherwise valueless stream. But then again, suppose neither the householder, nor the collector, nor the local government thought there was gold in their garbage - or perhaps it was just too difficult to find? Well the gold might then be buried, hidden in the rubbish, with hopes that some day it will be mined to fruition. But if that hope diminishes, the scout - with whom this short story began- might deduce that it makes no sense to search for gold where none may never exist, and he may conclude that in the end it makes no sense to handle vast amounts of wastes when the volumes might somehow be reduced.

The solid waste management industry certainly is experiencing much debate and discussion as to the alternative and perhaps compatible methods for solid waste management, resource recovery and resource conservation. However, whatever the alternative implemented, one must recognize that solid wastes management essentially is a service of need and necessity for the general public. Hence, the central purpose remains to remove the wastes from where they are generated to an ultimate disposal site in a manner consistent with the protection of the general health and welfare of the public in a cost-effective way. Where feasible, recovery of energy and material resources will serve to complement this purpose for the betterment of the populace!

RESOURCE RECOVERY AND WASTE PROCESSING

MARKETING THE OUTPUTS - ENERGY, FUELS, MATERIALS

By

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Resource Recovery Division
Urban Services Group, Inc.

Presented at the Fifth National
Congress on Waste Management
Technology and Resource and
Energy Recovery, Dallas, Texas
December 8, 1976

MARKETING THE OUTPUTS - ENERGY, FUELS MATERIALS

If resource recovery processing is to replace other traditional methods of solid waste disposal, users for the outputs must be identified and secured. The success with which users are developed from the start of project design will be the key to their eventual involvement and the overall economic viability of any forthcoming project. Discussed here are important considerations for the planning process from the start, to the point where actual facility procurement begins.

There are three stages in developing the market: the identification stage; the commitment stage; and, the contractual stage.

Identification Stage

During the first stage, the "Markets Study" is performed. It identifies what users are available for the various energy and material products that are possible to be produced by resource recovery technologies.

The first step is to get a handle on what is in your waste stream, since it constitutes the set of raw materials from which the energy and materials products will be produced. This need not be done through any large-scale sampling program, since the effort required and the statistical validity of such work with respect to the level of accuracy needed at this stage, will most likely not lead to productive results. Also, there is an increasing data base, both on a national level and as examples from specific jurisdictions, on composition of the waste stream. A literature search, looking at such sources as data from the U.S. Department of the Interior's Bureau of Mines facility and from the U.S. EPA's Office of Solid Waste, will provide the basis for applying existing information to your individual circumstances. With this accomplished, you can then feel the rough level of potential products you have, and don't have.

Based on this level of knowledge of the waste stream, the approach with the markets during the identification and commitment stages should be to use your rough estimates of tonnage output for the products in development of commitments to accept: either a product tonnage range with minimum and maximum levels set; or, at least a certain tonnage, with a floor tonnage set upon your best estimate of the minimum amount of available raw wastes that could be turned into a product. Refinements can be made to pin down more precise tonnage levels later on.

The markets investigation should not preclude, a priori, the production of any available energy or material product. To do this may unnecessarily limit the scope of investigations and the eventual viability of the implemented project. Remember--the markets are your disposal mechanism which also play a key role in the economic success of the project. As such, the recovery project should be viewed as a bridge effectively relating the input wastes (the raw product) to the end-users in a viable, long-term manner.

The first contact with possible users is made during this stage, and the dialogue that is developed is important for any future involvement. Often, and especially for certain energy users, development of an appreciation for solid-waste-derived products will be a first. Because of this, a markets education may have to be performed as other background data are gathered.

For energy product users, the data gathered should include: description of energy production facilities, future energy requirements, types and amounts of fuels consumed, availability of on-site space, energy demand curves, value of alternative fuel/energy sources, economics of present energy production, adaptability of integrating the use of either solid fuels, pyrolysis gases, pyrolysis oils, steam and electricity, and overall interest in using new energy sources. Energy users identified include: electrical or steam generating utilities, large industrial facilities, university and hospital complexes, downtown existing steam/cooling loops, new commercial/industrial steam-chilled water loops, and so forth.

Also, remember that your goal in development of markets is to structure a markets situation that can handle all of your projected output of a given product. This need not be done by one single user. For the energy product, which represents the largest single product in terms of percentage product output, it is extremely helpful to secure a single, highly reliable user. The concept of multiple users, however, is worth investigation. We find this concept being used, for instance, in the planned steam-generating facility for Akron, Ohio. With the increased attention being payed to such technologies as the small, modular heat recovery system, jurisdictions may be able to implement such projects as refuse-derived fuel production (RDF) and use by a number of small to medium sized users. Particularly for areas with significant, potential commercial and industrial users with the ability to use relatively small amounts of a facility's RDF output, such a project may even be more desirable than going with one large,but insecure, user. In this way, the impact of eventually losing one user will be lowered.

Once this information is gathered, an evaluation will be required to determine when one or several installations can provide the required consumption levels for the different energy outputs. Once the more preferrable users are identified, future activities should be closely coordinated to ensure a continuing and active market role in future project planning. Establishing a relationship with the likely energy users will make future project coordination and development much easier.

This market role should not be underestimated. Various project development processes have discovered, in fact, that all potential markets are not passive ones. In Lynn, Massachusetts, the General Electric facility is a good example of this. Here, the future energy user took an active role in the development and implementation of the RESCO project. The help of such active future users can be very valuable, with proper consideration given to the specific type and level of involvement they will play.

For materials products, contact is made with likely users for the various products in the waste stream. These users are often more familiar with the use of the recovered product in their industry then energy users. For example, certain industries (e.g., paper, steel, aluminum, glass) have established specifications for secondary products they are interested in purchasing and have experience with using similar products in their manufacturing process. For these reasons, it will be less difficult to assess material product users interest in the recovered product. The actual use by these plants may, however, be on a first-come, first-served basis to those who actually deliver a product, as "commitments" are often made to several projects.

The result of the general identification will be a "Markets Data Base" which states who could be looked toward, for which products, at what tonnages, and for what probably value. With this in hand, it will be possible to decide what generic type of resource recovery processing should be employed to meet the specifications set forth as a result of the survey.

Overall, some estimate whould be made of the potential value of waste-derived products. Generally speaking, the value of the recovered product is tied to some economic indicator. It may be a quoted value in Iron Age Magazine for No. 2 Bundles in New York or in the Federal Power Commission's Monthly Fuel Cost and Quantity bulletin for the cost of a million BTU's in

Illinois. There are almost as many variations to such a formula as there are agreements. Additionally, the price set may be simply fixed. The value of these products per ton of input waste can only be determined by factoring in the process recovery efficiency, fuel/energy product quality and amount, local pricing considerations (energy and materials), and transportation costs to bring the product to the user.

Commitment Stage

With the markets in mind, a closer look at the processing technologies available to meet market specification should be made next. This evaluation will look at technological risk, system capital and operating cost, alternative facility sites, overall system logistics and cost, financial and management alternatives, required legislation/authority farming, budget requests, etc. As this other information is developed, a further refinement of market development should take place prior to decision on project "go/no-go".

The development of more detailed documents such as "Memoranda of Understanding", "Letters of Intent to Bid for the Purchase of Recovered Products", or actual "Invitation of Bid for Recovered Products" should be undertaken. Such instruments should clearly state terms and conditions that each party will place on the other during actual sale of the product over a period of time.

In negotiating prices for energy products*, the guiding principle should be to establish a fair and equitable price for both the producer and the user. This price should provide an incentive to produce the fuel as well as use it. Hence, the price should lie somewhere between the net cost of production and the net value of the fuel to the user.

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* Solid, liquid and gaseous fuels, electricity.

Determination of these values is the next problem. For example, for a refuse-derived fuel (RDF) product to be used in existing boiler installations, the net cost of production would include: (1) the annual capital investment cost; (2) annual operating and maintenance costs; and, (3) the marginal savings/cost of not having to landfill or incinerate that product which was delivered to the user. Questions remain as to how precise each of these factors may be calculated. The life span of these systems are extremely difficult to estimate with a fine degree of accuracy. There is also a problem of apportionment in applying the operating and maintenance costs of the various items when there is more than one output.

For the user of an energy product such as RDF, the net value of the fuel would be the dollar value of the heat content adjusted to account for additional costs. The expenses would include: the capital cost of auxiliary equipment for storing, handling and firing the fuel; operating and maintenance costs; and, changes in boiler effiency. All these are netted against the value of the displaced fuel.

Again, such values cannot be expressed with a great deal of certainty. If the user is an electric utility, there may be "economic dispatch penalty costs" associated with the operation of the boiler designated for RDF use if it is more economical to operate other types of units. Costs may increase when newer and more efficient units enter into the utility system after the utility has installed equipment and contractually obligated itself to accept RDF. The utility must consider this possibility since it is obligated and regulated to supply power to the public at the cheapest possible price. This effect is most pronounced in the case where additional generation capacity flows from newly added nuclear power plants. Incremental costs of generation in these plants are much lower than for those fired by fossil fuels. The success to negotiating an agreement that is attractive to both parties will occur if each party does not try to optimize his benefit at the expense of the other.

For an energy product such as steam, the considerations and experiences are different. Historically, incinerators with steam generating capacities have not had "out of plant" users. While this trend is definitely being reversed by energy recovery facilities across the nation, problems remain to be considered prior to implementing steam energy recovery systems. One of the problems of selling steam to commercial users (based on municipal solid waste as feedstock) is the necessity to vary generation to meet load conditions. In order to do this, a boiler by-pass flue or steam-condensing equipment must be provided. Conversely, when the demand for steam exceeds the supply, auxiliary fuel-firing systems must be included in order to provide an uninterrupted supply.

Unlike fuels derived from solid waste, steam produced from solid waste is indistinguishable from that produced from other energy sources. To be saleable, this steam must meet the specific needs of the users. When designing a solid waste disposal/steam recovery system and pricing the resultant energy product, several factors thus need to be considered. These include:

- proximity to customers - A steam generating facility must have a nearby market because steam cannot be transported economically more than a few miles. In congested areas, expensive pipeline installation may further restrict this distance.
- value - The cost at which the steam is delivered must be competitive with the cost of the customer's alternative energy sources.

- quantity - Price is effected by the ability of the steam plant to supply amounts of steam which are compatible with the customer's needs. If supply is guaranteed to the customer and peak loadings cannot be met entirely by burning refuse alone, then stand-by fossil fuel-fired boilers will be needed and the price correspondingly increased.

- operating schedule - The steam producing facility must set up an operating basis that conforms to the operating schedule of the steam customer. This effects the price of the steam as well as the existence of the market itself.

- steam quality - The temperature and pressure at which the steam is produced must be a function of the limits acceptable to the customer's steam contract. Variations from this norm could seriously effect the price of the steam.

- reliability - If service is to be non-interruptable, contingency plans should be made when the solid waste unit is out of service.

- timing - This aspect can seriously affect the steam plant and the expected revenues. Unanticipated delays in construction of the facility could force the steam customer to secure another source.

Steam can be marketed in two ways: as a guaranteed supply ("uninterruptable service"), or as a limited supply that requires a back-up system ("interruptable service"). The pricing structure will vary in accordance with the type of service offered.

In the first case, the municipality provides a complete and reliable supply of steam, and assumes the responsibility of producing steam from other sources if there should be an interruption in the production of steam from solid waste. If the municipality is supplying steam that the customer does not have the capability of producing, then the municipality must guarantee the reliability of supply. While the municipality's costs go up, so also does the value of the steam it is selling. This steam has a value equivalent to what the customer would have to spend to produce it himself. In the second case, the customer buys all the steam the municipality produces from solid waste, and thereby assumes the burden of producing additional steam in the event that this supply is interrupted or not adequate to meet his demand. In this case, the value of the steam is necessarily lower, in that it is limited to the value of the fuel saved by the customer. At the same time, the municipality assumes less risk and responsibility.

The price of steam delivered to the industrial user is therefore a matter of "marginal cost" vs. "true replacement cost". Fuel shortages and dislocations as well as rapidly rising prices for fossil fuels should accentuate a trend toward the marketability of a reliable steam supply.

For materials products, the "commitment" document should include terms and conditions with respect to floor prices and exchange price formulas, length of commitment, quantity, quality, delivery schedule, and termination provisions.

The longer the period over which material would be pruchased, the better. Five-year periods are often specified, especially in "Letters of Intent." This is adequate, although a ten-year period would be preferrable, since it would be more representative of a project's amortization and operational lifespan.

In general, the decisions on implementing energy and/or materials recovery will follow a few overall guidelines. Not every facility will choose to implement both energy and materials recovery, regardless of the technological development situation. Both, however, are tied to the availability of markets -- without them, the production of the given energy or materials will be meaningless. Somewhere during the "identification" and "commitment" stages, an initial decision must be made on which products to produce. The decision on energy production will be most directly tied to the existing or near-future disposal crisis, since the energy raw materials represent the largest percentage of the waste stream, and also the preponderence of the biodegradable material. Also crucial here are the economic questions of production costs versus energy revenues and disposal credits. With the materials products, however, the economic questions take priority, since any disposal crisis will not be significantly improved by materials recovery.

Contractual Stage

During the "contractual" stage, the "commitment" agreements, which served to solidify the project for purposes of budgetary planning, council approval, etc., need to be made into hard and fast agreements clearly stating all the terms and conditions that will be promulgated into actual purchase orders or purchase agreements. Having such contracts will provide the basis for making the project financable, especially if some sort of bonding mechanism, especially revenue bonding, is to be employed for the intended project. The "contractual" stage is the stage at which signatures are placed on the 'bottom line'. Other key matters must be also made to happen prior to this finalization and confirmation of the marketplace. These include the successful implementation of a "Request for Proposals", in the case of a facility to be privately operated, to the preparation of budget requests and general bond authorizations in the case of a publicly owned/financed facility. In order to get to this stage, other factors including site, management, risks, technology, waste control, etc. will also have to be decided.

From the supplier's point of view, the primary concern of a solid waste processing facility is its ability to dispose of the waste. The establishment of long-term contracts assures the operator of a steady outlet for the recovered products without the need for stockpiling large amounts. Further, long-term contracts avoid dependence on spot markets which are sensitive to local supply and demand factors which can fluctuate widely. The possibility of higher revenues from spot markets whould be sacrificed in order to obtain a guaranteed outlet for the recovered product. As a result, additional overhead costs for storage can be avoided. The long-term market, with a specified floor price, also can provide a basis for the insured revenues necessary to establish the financial foundation for a resource recovery facility.

For the purchaser of the recovered materials, the long-term contract guarantees a steady supply of raw materials at a reasonable price. This also ensures continuous processing. Thus, the buyer can justify a required capital investment in additional handling equipment and the other items necessary to introduce the recovered products into the manufacturing process.

Finalization of signed user contracts will only take place if the user is convinced that the intended project will produce products according to their required specifications. If there is uncertainty in the ability of a process to produce the required output specification, one of two things will occur. The first is that the user will end any negotiations. Secondly, they may still sign for the product, well knowing that start-up period will prove whether or not the facility can meet specifications.

In making contacts with potential buyers, the assumption should be made that purchase orders for the sale of recovered products will go out for bid. This approach, however, often prevents the potential user from offering his best price, since he knows that any signed "Letter of Intent" will become public information and may serve as a minimum target for other bidders. Thus, users can be expected to withhold their best price or pricing structure from the "Letter of Intent", knowing that at the time of bidding they probably will have to bid higher in order to purchase the material. The "Letter of Intent", however, does assure that they will at least bid, and that the price will not be lower than the one stated.

If a formal bid for the sale of a recovered material is to be made with both a floor price and an exchange price mechanism, one of these prices needs to be fixed in advance so that the final bids will be comparable. Thus, when bids are let, the floor price will be specified by the recovery facility and bids will only be based on the need for an exchange price to be established. The current letters provide a basis for designating this floor price.

Those "Letters of Intent" which provide a floor price can be grouped together to calculate a guaranteed minimum revenue, assuming the worst possible market conditions. The results can then be employed to analyze the economic feasibility of the facility. It is worth noting, however, that the floor price incorporates any unforeseen risk the bidder may incur and is generally much lower than any reasonable market price. Such a pegging of the floor price is to be expected when considering: (1) that the operating period may not begin until two to three years hence, and; (2) that it is questionable whether long-term variations in the prices of secondary materials can be predicted. It is important, therefore, that every effort be made to obtain realistic floor prices to provide support for the viability of the facility.

Summary

The considerations necessary for successful market development are numerous and will have their own peculiarities for each situation. As with any essential element of a resource recovery project, they should be well thought out from the start. Much of this work is in the developmental stage, and many people across the nation are putting significant effort into it. With the passage of time, these efforts will lead to a much clearer understanding of how to create the bridge that resource recovery represents.

EPA Technical Assistance Advisor's
Presentation to City Council
on the Initial Steps of Procuring a
Resource Recovery System

NSWMA Conference, Dallas
December 8, 1976

Robert A. Lowe
Chief Technical Assistance Branch
Resource Recovery Division
Office of Solid Waste
U.S. Environmental Protection Agency

(Scenario)

EPA has been invited to meet with the City Council to answer some questions about their plans to implement a resource recovery system. In preliminary conversations, City officials indicated that they have read some of the literature on resource recovery; they have attended several national and regional meetings over the past few years; and they have discussed their situation with a consulting engineer, an investment banker, and several system vendors. They have not yet begun a formal study that is expected to lead toward recycling their solid waste; however, they want to do so now.

Having heard that EPA has given information and advice to other communities, City has asked us to discuss their plans and to answer questions about how they should approach the problem, what should they do first, and what important points should be considered.

EPA's Role

Let me begin by explaining the role of EPA's technical assistance program. Our role is to help provide policy direction to States and communities. We are not a substitute for consultants. Consultants have greater expertise than we have. But consultants usually do not serve their client's needs unless asked the right questions. Many times governments do not have enough experience with resource recovery to ask the right questions. Therefore, EPA's role is to assist local governments in identifying the important questions, and to identify the range of issues and alternative decisions, and the possible consequences of those decisions.

Contrary to common understanding, our knowledge does not come from a Supreme Being; it comes from observing and analyzing the experiences of other cities.

About The City

The City is about the size of New Orleans, St. Louis, or Memphis. Considering City and County together, the metro area compares in size with the New Orleans, Tampa-St. Petersburg, and Portland, Oregon areas. The City generates about 1,000 to 1400 tons per day (depending on per capita waste generation rates, on whether commercial sources are included, and on how many days per week the waste is collected). The County generates an additional 750 to 1050 tons per day.

In view of the short remaining life of the City's landfill and in view of new State and Federal legislation, it is clear that City has a problem; and they cannot afford to waste time.

Solving City's problem is constrained by the debt situation, the new State law on leachate collection, the air pollution situation, and the sludge disposal problem. These are serious, but they can be overcome or accommodated.

There are several important things in the city's favor. City's size and population density means an adequate quantity of solid waste is there; and public collection means that this waste can be directed to source separation and central processing systems. There are also potentially good markets for waste paper and waste derived energy.

<u>What to look at</u>

There are so many aspects of implementing a resource recovery system--it seems that everything must be done first and all at once--that it is easy to become confused. To simplify matters, many cities have started with a technology approach, identifying markets and evaluating technologies.

Unfortunately, we've seen many cities start this way and spend lots of money and lots of time and get no where. They find that they've gone down blind alleys because they did not consider some very important issues.

We want you to avoid these blind alleys. We recommend that you do not take the technology approach. We recommend that you consider resource recovery as a full-scale business enterprise and take a business approach instead.

Of all the issues that must be addressed, four stand out as being of primary importance:

- Markets
- Waste supply
- Financing
- Sites

Markets. I'm sure you are all aware of the importance of securing markets. With me today to discuss these market issues are Harvey Gershman, a management consultant, and Alden Howard, a prospective industrial customer for steam. I defer to them.

Waste Supply. A supply of waste is essential -- waste is the raw material without which revenues cannot be earned. Obtaining a supply of waste should not be taken for granted. Fortunately, because City collects its waste in its own trucks, it has control over its 1000-1400 tons per day and can direct that waste to the system of its choice. But don't make the mistake of assuming that you can build a 2,000 ton per day plant and get the County's waste. More will be said about bringing several jurisdictions into a single system by Steve Lewis, a management consultant with experience in regional systems.

Financing. The third issue, financing, is so important that it must be factored into any city's thinking from the very beginning, especially in your city where, because the City has reached its debt ceiling, general obligation financing cannot be used. The city will probably have to use project financing or some other financing mechanism secured by a source of revenues, such as a special tax assessment, that is earmarked to pay for the project and kept separate from general revenues. Regardless of the mechanssm, the project must be structured in such a way that prospective bondholders will have confidence that their investment is safe. In otherwords, the project must be financeable. Different financing mechanisms have different requirements that can dictate how a project must be structured.

To make sure the project is financeable, the possible financing mechansims and their requirements must be considered from the beginning of the City's study. We will go into more detail on financeability and financing mechansims with two investment bankers, Bob Aldrich and Charlie Ballard.

Sites. Which site is selected depends upon a lot of factors, including proximity and access to waste generators and to customers, which will be identified as your study progresses. But as every elected official knows, siting a solid waste facility is very difficult; and it is never too early to begin acquiring a site.

There are three other major issues:

- Type of system
- Procurement approach
- Legal issues

Type of System The type of systems that are appropriate will be dictated by the markets. We have observed that there is a tendency to limit consideration to central processing facilities and to overlook source separation systems. The enthusiasm for large plants may have something to do with the fact that many companies can make money if a plant is built. But the City can make money--or at least reduce costs--by source separating if you can get long term contracts with floor prices. Therefore, we encourage you to consider source separation as an option. There are many good reasons for this, which will be discussed by John Skinner, Director of the City Planning Agency.

Procurement Approach. There are three basic procurement approaches:

- The A&E approach, where the city hires a professional engineering firm to design a system, develop specifications, and perhaps to monitor construction; then the city purchases the equipment, materials and labor. The City owns and operates the system and is responsible for its performance.

- The turnkey approach, where the city buys the system or the principal components as a package and does not take title until the system has passed a performance test. Then the city owns and operates the facility.

- The full service approach, where the city buys a service from a system vendor who designs, contructs and operates the facility.

These are described in detail in EPA's Resource Recovery Plant Implementation Guide. In my dealings with other cities, I have noticed that their thinking about procurement is made more difficult because of misconceptions about two issues:

- Control and responsibility

- Risk and reward

No company will accept responsibility for something unless it has control over it. For example, no company will guarantee the performance of a system unless it had control over both the design and construction of the facility. In an A&E situation, no one but the city has overall responsibility; and as the Nashville experience shows, it is nearly impossible to assign the blame if something goes wrong.

In a turnkey arrangement, the contractor will accept responsibility until the performance test is over. As an example, with all the problems in Baltimore, there was essentially no question that Monsanto was responsible for everything (within the limit--$4 million-- of their contractual obligation). But once the performance test is over and a second party begins to operate the facility, it would be nearly impossible to hold the contractor responsible if something went wrong because it would be difficult to prove that the problem was caused by the contractor and not by the operator.

In a full service arrangement, the contractor will assume responsibility for the performance of the system under normal conditions. But the contractor has no control over some events such as sabotage, earthquakes, and strikes by suppliers (known as force majeure), and therefore will not pay for losses due to these events.

I mention this control/responsibility relationship so that you may be wary of companies--including designers, equipment manufacturers, and system vendors--that promise--either explicitly or implicitly--that their design will work or their machinery will work. Unless they control the entire system, they cannot guarantee that it will work and will not back up their promises with money.

Regarding risks and rewards, every city wants to minimize costs and maximize benefits. So do private companies (system vendors, product customers, etc.). But every project involves making an investment without knowing for sure how the future will turn out. Companies make such investments every day. So do cities. Making an investment under conditions of uncertainty involves taking a risk. This risk can be bigger or smaller depending on the size of the investment, the strength of the markets, the amount of experience with the technology, the experience of the designers, and other factors.

Companies will take risks if the potential reward (profit) is large enough. The greater the risk, the greater the potential reward that is required to make the investment. Cities frequently make decisions on the same principles, although they generally undertake less risky projects because they are not created to make a profit nor can they suffer the consequences of severe losses.

If costs could be estimated accurately--if the future could be predicted, it would be a lot easier to choose between the A&E and full service approaches. But actual costs (that won't be known until the facility is built and operated) could vary widely, depending upon whether certain conditions are favorable or unfavorable.

Under the best conditions, the actual costs of a project will be low--perhaps lower than the city's original estimates. If the city buys a system under the A&E approach when conditions are favorable, the city is the direct beneficiary through lower costs. If the city buys a system under the full service approach when conditions are favorable, the city will be paying the company a profit. And the cost to the city may be more under full service than under A&E, depending on how efficient the company is.

On the other hand, if conditions are bad, actual project costs will be higher than originally estimated--perhaps much higher. Under the A&E approach, the city would pay dearly; under a full service arrangement, the City would pay the amount originally agreed upon and would be protected from large losses, which the company would have to absorb (unless they default).

Looking back on the projects that have been built, a few have been built within their budget. But most projects end up costing more--sometimes much more--than was budgeted. In view of the risk factors mentioned earlier, actual costs in future projects are more likely to be over budget than under.

Which approach is cheaper? Which one is best? EPA has no preferred procurement approach for all cases; however, in our judgment, when an investment is risky, we think it is prudent for cities to reduce their risk by securing guarantees from industry; and the most meaningful guarantees are secured in a full-service contract. This approach is frequently criticized as being too costly, but we think that a full service arrangement can be less costly in many cases. In the long run, the only system that is too costly is the system that doesn't work.

One final word on procurement. The number of qualified resource recovery companies is limited. They can bid on only a few projects at a time. Consequently, they must be very selective about which jobs they bid on. What this means for cities is that they cannot expect the good companies to come beating down their doors. Cities must make an effort to attract bidders, to demonstrate that they offer a viable business opportunity.

This, companies have told us, means that cities should do their homework before they come to the bargaining table. For example, they should select a procurement approach <u>before</u> a request for proposals is issued. They should also resolve some important legal questions, such as:

Is negotiated procurement allowed?
Can the community enter into a put-or pay contract?
Can the community lease or sell land to industry?
Can the community enter into a long-term contract?
Can the community enter into revenue-sharing?
Must the community comply with split-bidding laws?
What are States salvage laws?

Don't let yourself get into the position--that some cities have found themselves--of issuing a request for proposals without having answered these questions.

How to Proceed

Before the other consultants talk more about these issues, I'd like to make a few observations about how cities go about planning and implementing a project. If you look at the projects that have succeeded, you'll see that they have several traits in common:

- Project Manager--Each success had one person who kept the project moving, followed up on all details, and did a lot of work. Committees don't do work; individuals do. But not department heads: they're too busy with other things.

- Executive Support--Each success had department heads, council members and chief executives who were committed to the project and used their power to get the project approved and moving.

- Coordination--Each success received gudiance and public support from an advisory task force of some kind. In addition, each success was the result of cooperation between many city, state, industry, and citizen groups and departments.

- Realistic schedule--Every project that we know of has taken at least 3 to 5 years to get from the first planning steps to plant operation. Although every elected official would like to have an operating plant to impress the voters before the next election, it is not realistic to expect that a project can be completed in a short time.

- Team of consultants--Each success hired not just engineers, but financial, legal, and management consultants as well. Some cities did not hire legal and financial consultants in the early stages of their planning when they could have done the most good. But they did hire them eventually.

- Minimize conflict of interests--A conflict of interest may exist whenever any consultant, advisory task force member, or anyone else involved in the decision-making process stands to profit from particular options that could be recommended. Such conflicts can be minimized by disqualifying these individuals or firms from follow-on business. Not all conflicts can be eliminated; in such cases, public recognition of the conflict can help protect the public interest.

- Planning expenditures--Each success spent a lot of money, for feasibility studies, for market research, for evaluation of proposals, and for negotiations of contracts. Some tried to skimp in the early phases and ended up paying more for lawyers and other consultants later. It does not make sense to quibble about $50,000 wehn $50 million is at stake.

One way or another, projects can be built without hiring the proper consultants; but they always seem to take longer. And these delays are costly. At present rates of inflation, a $50 million project will cost about $10,000 more for each day the project is delayed, just because of inflation.

We are encouraged by the prospects for a successful implementation in the City, and we look forward to working with you.

Finance - Ability of Resource Recovery Facilities

Robert H. Aldrich, Vice President

White, Weld & Co. Incorporated

There are two measures of the success of a financing: the first, that the necessary capital is raised; and second, that the cost of capital is reasonable in comparison to the money market and considering the risks associated with a particular financing. The ultimate measure of success, of course, is that the project itself meets its objectives and the investors are fully and properly compensated.

Financing of solid waste resource recovery facilities is rapidly developing into a specialized field, due primarily to unique features of the business and the need of the investment banker to have an in-depth knowledge of the industry. It is unique because, by its very nature, resource recovery requires the combined resources of both the public and private sectors.

A community looks to resource recovery to provide a reliable and economic means of disposing of solid waste in an environmentally sound manner. The main resource the public provides is a continuous supply of solid waste, and a mechanism by which to pay for the service of disposal. The private sector, on the other hand, looks to resource recovery as a natural extension of its engineering and manufacturing technology, and a means of generating profit by providing a basic service to a community and marketing or utilizing the resources contained in the waste stream.

Federal and state laws and regulations controlling the financing of resource recovery facilities have recognized the need and desire for joint public/private participation in resource recovery and have provided for the investment community financing mechanisms which are unusual and quite attractive. The main features of the financing mechanisms are that the facility can be privately owned and operated and that the owner of the facility can take tax advantages of ownership including investment tax credit, accelerated depreciation, and deductions for interest expenses -- and yet the facility can be financed using tax-exempt municipal bonds, where the interest income on the bonds is exempt from state and Federal taxes. This combination of benefits -- tax ownership available only to the private sector, and the low interest costs of tax-exempt municipal bonds normally restricted to public debt, provides to resource recovery projects the opportunity to obtain a comparatively favorable net cost of capital.

However, whereas the financing mechanisms and alternatives appear attractive, and they are, the finance-ability of resource recovery projects is still dependent upon the underlying strength of the project, and the security features structured into the financing package. Risks must be identified, and the financing structured so as to minimize these risks and to assign responsibilities to the appropriate parties, generally through contractual relationships.

What the Investment Community Looks to in a Resource Recovery Financing

This presentation assumes that the facility is to be financed as a project financing using revenue bonds, equity, etc., and not secured by a general obligation of a community, state, or private corporation.

Resource recovery facilities must compete for funds in the marketplace. In general, resource recovery facilities are competing in a specific market -- the long term municipal bond market, against state and local general obligation or revenue bond issues for school construction, housing, hospitals, sewage plants, etc. In 1976, the total bonds sold into this market will be approximately $30-billion. While the cumulative to-date dollar value of solid waste bonds has been low (less than $200M), the size of the individual solid waste bond issues have been comparatively large and growing, and the annual requirements are expected to rise over $1 billion per year.

In resource recovery projects, we look to the following in analyzing the finance-ability:

- The need of the community, as measured in terms of available solid waste and its alternative method and economics of disposal.
- The ability and the proposed mechanism by which the community will pay for the disposal service -- the "tipping fee".
- The state of the technology to be utilized -- including the history of operation; the strength of the contractors; and the form and substance of the guarantee of the contractors to convert solid waste into saleable resources in a reliable and economic manner over the term of the financing.

- The availability of reliable long term markets for the recovered resources and the nature of the purchase contracts.
- An economic analysis of the project, by a reliable independent engineering firm, to determine that the facility will be able to operate at the projected costs and generate the required revenues.
- And finally, the security features built into the financing itself including: reserve funds, payment schedules, guarantees, and coverage ratios.

The investment community is positive in their reaction toward resource recovery projects, recognizing the basic need of such facilities to communities as well as recognizing the quality of the private sector companies participating in this industry. From time to time, in our natural competitive fervor, we tend to criticize our competitors' systems and services, seeking to gain some competitive advantage for ourselves. Let me state here and now, that this form of competitive activity is counter-productive to the development of our industry and can only do more harm than good since the investment community is not in the position to judge the relative merits of rumors, and will, unless this trend is checked, be to the detriment of all resource recovery projects. This could have costly consequences to our industry.

Roles of the Community

The decision by a community on whether or not to undertake a resource recovery project is generally based upon an evaluation of comparative economics -- comparing the cost of landfill with the alternative of implementing a resource recovery program.

The finance-ability of the facility is greatly strengthened if the community has limited access to alternative disposal sites. Where land-fills are running out of capacity, and/or where state laws or policies are restricting the use or increasing the cost of land-fill, resource recovery projects look most attractive.

The ability of the community to control the flow of solid waste to the facility and to pay for the service is critical to the financing package. At times the ability to pay for such service is questionable in certain financially troubled urban areas. However, it is our opinion that because of the critical nature of reliable solid waste disposal in such areas combined with strong control over the flow of solid waste, the project financing can be equal or superior to general obligation bonds of those urban areas.

The Roles of the Contractor & Operator

The private sector participant should obligate itself to construct the facility to meet predefined performance specifications at a price which allows for inflation and a reasonable contingency. Further, the contractor, or an operator if not the same, should enter into firm contracts over the full term of the financing to provide the essential services of reliably disposing of the solid waste and providing specification grade by-products for sale.

The finance-ability of the project is directly related to the financial strength and commitment of the private sector participants. Of most importance, is that the technology to be used be one that has been demonstrated to the point where the investors and community are satisfied that the facility will perform its function reliably and economically over the term of the bonds. The technical competence of the private sector participants is a further measure of the quality of the project.

Importance of the Market for Recovered Resources

In order to provide adequate revenues to the project, firm long term take or pay contracts must be negotiated for substantially all of the resources recovered in the operation of the facility. Since energy is a major source of revenue it is most important that the energy purchasers not only commit to purchase the output of the facility, but that the investor be satisfied that the purchasers are financially sound and that the intended market will exist for the term of the bonds.

The contracts negotiated should provide for escalation of prices, generally tied to alternative energy costs to the user.

The Use of an Economic Analysis

An economic analysis of the project over the term of the bonds must be included in the basic financing package. Included in analysis should be a complete breakdown of the projected cash flow of the project analyzing the anticipated revenues and costs (a profit and loss statement) as well as projected balance sheets on the project itself. The report should include a sensitivity analysis measuring the impact of various levels of operating, maintenance and replacement costs, projected revenues, and financing assumptions.

In addition, the economic analysis should provide to the investor the coverage ratios (a measure of the availability of funds to repay principal and interest) expected under various operating conditions. This coverage ratio should be sufficient to satisfy the investor that he will be properly compensated.

Additional Security Features

The additional security features built into a resource recovery financing should include:

1) A reasonable (one year) reserve fund to pay principal and interest on the debt.

2) A reasonable reserve fund for maintenance of the facility, as well planned replacement of certain key components of the facility.

3) An equity contribution to the project by the private sector, not only assures the investor of the level of commitment by the operator, but reduces the level of annual debt service.

4) A "gross tipping fee" concept may be used. Under this concept the community obligates itself to pay a gross tipping fee adequate to provide the pavment of debt service and operation and maintenance costs. Through predetermined sharing formulas revenue derived from the sales of energy and recovered materials is then rebated to the community providing the "net tipping fee". A contract between the community and the operator can provide for a guaranteed rebate to the community from the operator if revenues are not sufficient.

5) A land-fill must be available to dispose of the residual waste from the facility as well as to provide a stand-by for periods in which the facility is inoperable.

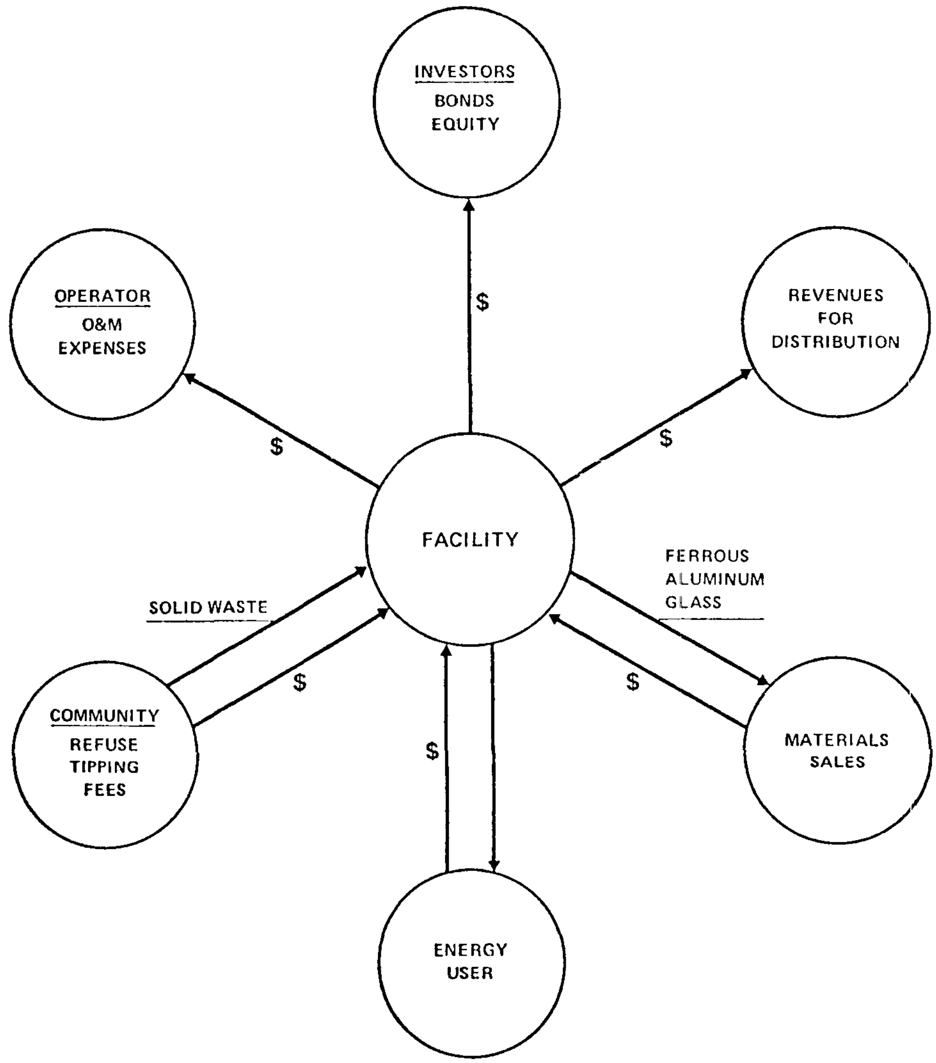
While the above comments deal in general with project financing using a combination of revenue bonds and equity, it is, of course, possible to provide additional security to the financing in the form of guarantees by the community, the state, the Federal government or the private sector participants. These guarantees can take several forms including: general obligations, special tax revenue bonds, moral obligations, price supports, or some limited guarantees. An example of the limited guarantee is the case in Saugus, Massachusetts where the private participants guaranteed to provide additional capital to the facility up to the total tax benefits they derived as owners of the facility.

The various contractual and security elements discussed throughout this paper are representative of the requirements for a successful resource recovery project financing. However, due to various constraints and obstacles, the ideal is seldom achieved. Certain security deficiencies or risks can be accepted by the investor at a cost to the project, but there are limits to the extent that deficiencies may exist and a financing be accomplished.

This paper, due to time constraints, did not attempt to deal with the legal questions involving the issuance of debt or forms of procurement. Nor did it deal with the critical problems associated with keeping the debt off the balance sheet of the private participant (a key element in a financing program), or with the constraints imposed by law or policy on the community of having the debt included in its debt limit, thus impairing its future borrowing capacity.

In conclusion, financing of resource recovery facilities can be successfully accomplished through project financing without the use of general obligation or special tax bonds. The key factor is structuring a financing which properly assigns risks and rewards, and which is secured not only by strong contracts between financially and technically reliable entities, but also by strong commitments on the part of the communities and the private sector participants.

Project Interrelationships



Financing Options for Resource Recovery

Charles A. Ballard
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Thank you. Any discussion concerning financing options for solid waste disposal/resource recovery systems must be viewed objectively. We are, after all, discussing a new industry - one, in fact, so new that the historical lack of meaningful investment, by definition, precludes widely accepted financial precedents. Nevertheless, some patterns are beginning to emerge, albeit far more slowly than might be considered in the Nation's best interest.

The financing of solid waste disposal/resource recovery systems should not be viewed as unique. Financial alternatives must address operating objectives, and often these objectives cannot be set in concrete, but rather are subjective and result from preconceived bias, past experience, or local circumstance.

I felt it might be helpful to review the approaches that four other cities are employing to finance solid waste disposal facilities. Each of these cities has embraced one of a series of options, specifically:

- the issuance of General Obligation Bonds;
- the issuance of Special Revenue Bonds;
- the issuance of Industrial Development Revenue Bonds;
- financing from the private sector; or
- combinations of the above.

Reviewing each option briefly, General Obligation Bonds commit the full faith and credit of a municipality to the repayment of the principal of, and interest on, borrowed funds.

Special Revenue Bonds may take numerous forms, but essentially, a stream of municipal revenues is pledged to secure the repayment of bonds issued. These revenues may be from a special taxation district, an unrelated revenue district, the financed project, or from some other source.

Industrial Development Revenue Bonds may be employed to the extent that the financed project meets certain requisite conditions of the Internal Revenue Code.

These first three options generally involve tax exempt financing, i.e., the interest payable to bondholders is exempt from Federal income tax under the appropriate provisions of Section 103 (c) of the Internal Revenue Code.

Private Sector Financing involves, either directly or indirectly, a pledge of the credit of a participating corporation.

Additionally, each of the preceding four options may be combined to obtain necessary funding.

Perhaps the case-by-case review of four actual examples may bring into better focus the application of the financing options described. (Insert Slide 2).

As may be expected, each of the subject cities - and I have been, or am currently, involved with each, - have varying populations, characteristics and objectives.

City A has a service area population of approximately 250,000. The stated characteristics of City A regarding its solid waste disposal/resource recovery facility include the following:

1) the City desired no ownership of the subject facility;
2) the City desired no direct management responsibility for the operation of the facility;
3) the City had no credit support that it could offer to the facility's financing; and,
4) the City desired no participation in facility profits.

Simply, City A's Facility objectives included the dependable and environmentally sound disposal of solid wastes, and partial recovery of these solid wastes.

City B has a service area population of approximately 850,000. It desired no direct facility ownership or management responsibility for a twenty year period. It had no credit support to offer, but it did desire a meaningful profit participation. As with City A, City B desired dependable and environmentally sound disposal of solid wastes but it had as an additional objective, total resource recovery.

City C has a service area population of approximately 550,000 people. City C desired immediate ownership of the facility, a limited management responsibility, was able to afford limited credit support and was interested in a profit participation. Its Facility objectives were otherwise similar to those of City B.

City D has a service area population of approximately 1,300,000, it desired ownership of the facility upon its completion, limited management responsibility, and through State Bonding, had strong credit support available. Its profit participation desires and other Facility objectives were similar to Cities B and C.

City A's solution was not an overly complex one, but often simplicity rules the day in meeting objectives. City A entered into a disposal contract with a private sector operator for the disposal of its solid wastes. The contract provided for hauling services as well as for disposal services. Through the powers granted to the City under its State laws, the City was authorized to issue Industrial Development Revenue Bonds for the acquisition or construction of facilities which inure to the benefit of the City, the State, or its citizens. The City could issue such bonds, limiting bondholders' resource to those revenues pledged to secure the bonds.

To generate such revenues the City entered into a twenty-year lease with the operator for the use of the facility, and issued its limited recourse bonds in an amount sufficient to construct the facility. These bonds were secured by the pledge and assignment of the lease payments receivable from the project operator. The proceeds of the bond issue were placed in trust and construction contractors were paid as delivery progressed. The operator gave its guarantee of lease payments to Bondholders and, further entered into contracts with certain by-product purchasers for the purchase of recovered items. The financing has been completed; the project has been completed; and the City and the operator have each achieved its stated objectives. Through the City's auspices the operator was able to receive lower cost tax exempt financing, but was required to pledge its direct credit to secure such financing. In this example, the credit of a private sector corporation was combined with a city's authority to issue tax exempt industrial development bonds to finance the solid waste disposal facility.

City B had a more complex problem. The cost of a full resource recovery operation servicing the needs of 850,000 people was substantially in excess of that experienced by City A. Few corporations are capable of, or, if capable, desire to employ their credit in such manner. Nevertheless, the funding problem was solved by the structure shown. Tracing first the contract flow, City B entered into a twenty-year contract with a private sector operator to provide for the disposal of certain minimum amounts of solid waste on a monthly basis. If the City did not deliver such minimum, it would nevertheless be required to pay for the disposal of the minimum. Although the price per ton for disposal was established, it was to be adjusted to reflect escalation as determined by certain independent price indices. The operator then entered into a twenty-year agreement with a principal energy purchaser under which the energy purchaser agreed to purchase any and all energy delivered at a price based upon its alternative fuel costs; such price however, could not fall below a stated minimum. Simultaneously, the operator entered into long-term purchase contracts with other by-product purchasers. Each of these latter contracts contained minimum "take or pay provisions", providing that by-products would be purchased at prices based upon market conditions, but in no event would such prices be below stated minimums.

As with City A, City B had authority under its State laws to issue, through an industrial development authority, industrial development revenue bonds. The operator entered into an agreement with the industrial development authority to lease the completed facility for twenty years at annual payments sufficient to amortize the debt issued. The operator secured its obligation to make lease payments with a pledge of the disposal contract with the City, a pledge of the energy purchase contract, and a pledge of the contracts with other by-product purchasers. To complete this "circle of obligations" the operator's parent company extended a performance guaranty to both the City and the Bondholders which assured that the project would be completed in a timely fashion and would operate in accord with performance specifications.

City B's financing has been completed, and the facility is currently under construction. The issuance of industrial development bonds combined with the City's contractual obligation and several forms of private sector credit made the financing feasible.

City C, as you remember, desired immediate ownership of the facility and had limited credit support available, but its other objectives and characteristics were similar to those of City B. As with City B, the capital cost of City C's plant is to be significant. In general, these objectives and characteristics dictated an even more complex solution to the financing problem.

Let's again look at the contract flow. While the service area population of City C was 550,000, nearly half of that population resided in the County surrounding the City's corporate limits. The facility, when completed, would inure to the benefit not only of the City residents, but also to those of the County. Accordingly, negotiations were held with the County, and the County ultimately agreed that it would lend direct support to the to-be constructed plant. A Cooperative Agreement was executed by the City and the County, each agreeing thereunder to make available its general funds in the cumulative amount of approximately 30 percent of the facility's installed cost. A bond trustee, acting on behalf of the Bondholders, was made a beneficiary of this agreement.

City C then entered into numerous 25-year agreements with energy purchasers providing for the long-term purchase of energy at prices to be adjusted to reflect the plant's actual operating and capital costs. No profit margins were included. The City further entered into contracts with independent construction companies for the construction of the subject facility.

Because City C desired only limited responsibility for the facility's operation, a contract was entered into with a member of the private sector for the supervision of the project's construction and initial operating phases.

The trustee was, by assignment, made a beneficiary of all of these agreements. based on this security afforded by these contracts, other ordinances and legal action taken by the City and the County, the trustee should be in a position to issue revenue bonds for the remaining facility cost. Revenue bondholders would have first claim on all project revenues, such claim being prior to repayment of the general funds advanced by the City and County.

This financing is currently under negotiation. Under such a structure, General Obligation Bonds, Industrial Development Revenue Bonds, and private sector financing, through the assignment of "take or pay" energy contracts, are being combined to accomplish the project's funding.

City D's objectives were similar to those of City C except in one particular regard. Strong credit support is available, through State auspices, once the project is constructed and in operation.

Accordingly, City D has two stages to its financing plan, one occurring during the construction stage, the second during the operating stage.

First - the construction phase - and again, let's follow the contract flow. Because the County government has direct responsibility for the disposal of solid wastes, that political sub division is to be employed in preference to the City. The County will enter into an agreement with the State to provide for the facility's permanent funding on completion. The County further will enter into agreements with a private sector member for the construction and operation of the subject facility. The construction phase includes a "turn-key" price. The major energy purchaser will agree to purchase the facility's energy by-products for a twenty year period. Because the private sector operator will be involved during the operating period, it also will be party to this agreement.

Based upon this agreement with the County and the energy user, the contractor may enter into the construction contracts for the Facility's construction.

To finance the construction phase several additional agreements were required. The funding agreement between the County and the State provides that the State will make its funds available prior to the commencement of construction, which funds will be held in escrow by trustee B until completion of construction. Such agreement addresses the concerns of a changing State legislature, administration, etc. Trustee B, having funds on deposit with it, may then enter into a funding agreement with Trustee A, providing that upon "completion" such funds would be transfered to trustee A. Trustee A, armed with trustee B's agreement, a construction loan agreement with the operator, and an agreement with the operator's parent company guaranteeing timely completion, may issue notes, secured by such agreements, to short-term lenders to fund construction requirements.

When construction is completed and operations commence, the structure changes slightly. Instead of a construction performance guarantee the contractor's parent company will have a continuing operating performance guarantee, assuring both the County and the energy purchaser that the facility will perform in accordance with design specifications. The State funds, heretofore being held by trustee B, will be transferred to trustee A who will then repay construction lenders, and other contract funds advanced by the contractor on behalf of the County. Energy payments from the energy purchaser and operating payments from the County will be sufficient to pay operating and maintenance expenses of the contract, and hopefully, allow some cash flow to accrue to the County's benefit.

Under this structure, General Obligation Bonds and Private Sector capital will be jointly employed to fund the project's completion and capital costs. There, of course, are other options including leveraged leasing, and other combinations, which may, in your particular instance, address particular objectives and area characteristics. Each must be examined carefully with competent financial and legal counsel to assure the best possible financial result. Thank you.

CONTROLLED-AIR INCINERATION —
KEY TO
PRACTICAL PRODUCTION OF ENERGY FROM WASTES

by

ROSS E. HOFMANN

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For the past seven years, *Ross Hofmann, Associates* has been intimately involved with the development of the small waste energy production systems using controlled-air incineration, believing that they offer a major economic and technical solution to our fossil fuel shortfall.

It is estimated that at least 425,000 tons of residential and commercial solid waste is generated daily by American communities. A considerable additional amount of combustible solid waste is generated by thousands of factories and institutions within these same urban areas. The municipal segment alone apparently contains a daily potential energy content of over four trillion, 250 billion Btu.

This much energy is too valuable a resource to be buried in landfills or destroyed by a simple combustion process. In one year, the municipal and privately generated solid wastes in these communities can produce energy equivalent to over 1.5 trillion cubic feet of natural gas — more than the shortfall estimated to exist. Alternatively, it can produce the energy equivalent of over 10 billion gallons of oil currently firing thousands of boilers throughout the nation. It is capable of producing over 900 billion pounds of high pressure steam annually, either for electrical production, or for direct process and heating use in thousands of factories and critical institutions, such as hospitals.

There is nothing new about "resource recovery" from solid waste. A few demonstration projects, both federally and privately financed, have been going on for five years. Some projects have attempted to remove and sell the metals, glass, and paper products from the waste stream, with varying success due to the vagaries of the scrap markets. Others have looked at the potential for extracting the energy in waste, ranging from complicated and expensive chemical processes, such as pyrolysis, to direct energy production through incineration. Three direct energy processes have emerged for the production of steam from some sort of boiler. Milled combustibles, or refuse derived fuel (RDF), in the solid waste stream have been used to augment coal in utility company boilers for the production of electricity; or have been used to fire boilers as the sole fuel source. Other energy production plants have attempted to use "water-wall" incinerators, lining the primary chamber of a conventional, large-scale, municipal incinerator with boiler tubes for the direct production of steam and/or turbine-produced electricity. The third approach has concentrated on small, "controlled-air" incinerators, with matching separate boilers, installed in identical modules to produce steam for immediate process or heating use. This third approach may prove the most dramatic o all, the successes to date, both ... and economically, continue.

Most on-going demonstrations of resource recovery processes seem to concentrate on a mass production approach. This has carried over into those that utilize solid waste for energy production. It is usually envisioned that waste from large cities and their surrounding suburbs will be transported to a central processing plant, with a capacity of up to 1,000 tons daily or more, to take advantage of the economies of scale.

This ignores some simple economics when dealing with solid waste management. The most expensive aspect is the cost of transportation. The greater the mass production, the wider the area that must be covered to obtain the waste and haul it to a central point, and the higher the overall cost. This has been dramatically pointed out in analysis of sanitary landfill total costs which have risen considerably as available sites have involved longer and longer hauls from original pick up areas. For example, a half hour one way trip is estimated to cost $2.[illegible] per ton hauled, while a two hour trip is estimated to cost $7.30 per ton hauled, to which must be added transfer station costs of from $1.20 to $1.50 per ton. To date, the design and construction costs of the mass production plants have been so high, compared to product net revenue, that a reasonable payout period appears difficult to attain. Further, there is almost a direct correlation between the locations that generate waste. the quantities they generate, and a direct demand for process or heating steam on a short haul basis. The economics appear to lead to modular, strategically located, small installations. A large proportion of pot ntial users need energy to survive, but in relatively small qua tities that match closely the amounts available from local wastes.

BASIC CRITERIA

For any energy production system to be practical, it must meet several basic criteria. It must be environmentally acceptable in present day America. With incineration, this means air emissions must pass stringent codes. It should be economically feasible. If inflation is to be halted, total ownership costs of design, construction, and operation must be kept to a minimum. It must be safe to operate, both in the mind of the public and in reality. Technically, it must be sound, and capable of technological up-grading at reasonable cost as engineering advances take place. It obviously should deliver far more energy than it consumes (hopefully, in ratios of at least 20 to 1 or better). The energy should be saleable, immediately, in a competitive market. This latter point is particularly applicable to waste heat, as it is difficult to store and is normally used as generated.

Large municipal incinerators, when converted to steam production units, have experienced problems in meeting these criteria. Emission rates have been high unless expensive and rather sophisticated air pollution control devices are installed. Conventional incinerators have produced a rather contaminated gas which coats and corrodes boiler tubes. Costs of operation and total ownership have been high enough to affect the feasibility of the process.

The "small" incinerators available today are mass produced in a factory and shipped, either completely assembled or in large sections, to the site, resulting in low capital cost. To achieve a given capacity, they are normally installed in identical modules, capable of any amount of desired expansion as needed. They utilize entirely different engineering principles from the large conventional incinerators. As a result, they have solved the emission problems and the economic problems that have plagued incineration for so many years. After automatic air treatment within the unit, they produce a relatively uncontaminated gas from the burning waste. This high temperature gas is passed through a specially designed packaged boiler, or air mixer, as the fuel from which the energy is extracted.

END USES OF THE ENERGY PRODUCED

In an effort to achieve maximum efficiency, the energy of the waste heat gases has been used in a variety of ways. In general, these are directly related to the needs of the institution, industry, or municipality considering the purchase. The most common method is to produce steam or hot water directly in a close-coupled boiler for process, comfort, or sanitary use. In institutional and dwelling or office complexes, as well as factories, the heating of air for comfort conditioning is being investigated, utilizing multi-tube heat exchangers mounted in the exhaust system with or without blowers. Direct conversion of the heat exchanger can also be made for heating water for process or sanitary use. This system can be sophisticated by the use of a thermal fluid heat exchanger for more efficient recovery of the available heat and in situations where high temperature process heating media is useful. Another heat recovery system is to mix ambient air with the exhaust gases for process drying, curing operations, or conveying air to maintain materials at elevated temperatures. Many plants and towns are now investigating the use of low pressure steam turbines both for mechanical drives and for generation of electricity.

With the steam production systems, the efficiency of the boilers is in the range of 60% to 75%, depending on the design. Emissions in the stack gases, under normal operating conditions, have been proven to be as low as 0.03 grains of particulate matter per cubic foot of dry flue gas corrected to 12% CO_2. Net savings of fossil fuel consumption are as high as 95% over a direct-fired boiler of equivalent efficiency. Steam sales revenues are recapturing all total ownership costs in many installations and permitting an operating profit in waste disposal.

CONSTRAINTS OF SOLID WASTE AS A FUEL

Obviously, solid waste is not as efficient a fuel as any of the fossil fuels. It has a lower Btu output per pound in its average "as received" condition; greater weights must be burned to produce the energy equivalent of oil, coal, or gas. The heat output of solid wastes "as received" averages from 3,000 to 9,000 Btu/lb. The majority is one-half to one-third that of coal. A pound of #2 oil releases four times the enrgy of the equivalent weight of solid waste. Waste has not the compactness of fossil fuel, and far greater volumes must be burned to reach equivalent energy output. Oil measures 31 to 35 cubic feet per ton; coal measures 45 to 50 cubic feet per ton; solid waste usually ranges in density, in its "as received" condition, from 130 to 400 cubic feet per ton. However, it also contains, by weight, up to 30% moisture and up to 30% non-combustibles, neither of which contribute to the release of energy. The combustible portion has densities as low as 650 cubic feet per ton.

Hence, the fuel required in the average 70% efficient direct-fired boiler to produce 1,000 lbs. of steam would be approximately 1,440 cubic feet of natural gas or 10 gallons of #2 diesel oil, compared to from 250 to 500 lbs. of waste in a waste heat boiler. Designers of waste heat recovery systems accept these ratios. The materials handling equipment and the engineering of combustion systems provide for the lower densities and larger volumes of fuel (solid waste) that must be charged to produce satisfactory energy recovery.

POLITICAL CONSIDERATIONS

Solid waste as a potential fuel is becoming increasingly valuable. This has led to political discussions on federal, state, and local levels, concerning the ownership of waste and what should be done with it. The battle is shaping up between regional control, with mass production, multi million dollar, solid waste resource recovery systems, and the small controlled air systems that are being promoted on a satellite basis for large cities, or for use in the smaller towns, or in-house for factories and institutions. With solid waste at last being regarded as a practical fuel for the production of usable energy on a profitable basis, we feel that this battle will intensify during the coming years.

In 1975, Public Service Commissions entered the picture because controlled-air incinerators normally required allocations of fossil fuel to at least start the combustion process. Some states, such as Arkansas, have already handed down landmark decisions concerning the allocation of natural gas to the plants that are producing energy from solid waste. In summary, they have stated that such plants produce up to 90% more energy than they consume in fossil fuels, and, therefore, should be granted a high priority in the allocation of fossil fuels such as natural gas. The implications of such a decision are considerable for any town planning to install a municipal plant for the burning of its waste and the selling of the energy to nearby factories.

ECONOMIC REALITIES

During the past 18 months our firm has performed feasibility studies on controlled-air incineration — waste heat recovery systems in a large number of communities ranging in population from 25,000 to 250,000. A primary goal of these evaluations was to determine whether there was an adequate match between the generation of energy from solid waste and the energy requirements of commercial buyers. In all studies the concentration has been on the "bottom line" of a profit and loss statement and on comparisons between the "regional" and the "local" approach.

Most engineers and accountants have known that the cost per ton of design capacity of the small energy production systems is considerably under the per ton cost of the large mass production resource recovery systems. The small systems range in installed cost from $12,000 to $14,000 per ton design capacity, as against capital costs per ton that are four to five times larger for the mass production systems.

A surprising result of the audits of the small systems was the low operating cost we found. Americans have always been led to believe that with mass production, operating costs fall off drastically. Promoters of the large systems have inferred that their labor costs per processed ton would be extremely low. Intensive auditing of the figures by our firm and the other engineering concerns has revealed that this is not the case. Recent audits have revealed that total operating costs of small municipal plants (with outputs as low as 100 tons per day) have been less than $6.25 per ton. None of the mass production plants have apparently been able to approach this low a figure.

These are gross operating costs from which must be deducted the income from the sale of energy. When the income figure is applied, all of the existing small plants appear to be generating a profit for their municipalities.

Table 1A shows the capital costs for plant and equipment of a typical 120 ton per day municipal plant, with a cost per ton of design capacity of $12,417. This figure is average for plants in this size range in 1976.

Table 1B shows the annual operating costs. Without interest and depreciation they amount to $7.76 per ton. When commercial interest at 9% is added and the plant and equipment are completely depreciated over a relatively short time period, the total ownership costs increase to $14.74 per ton.

In this particular plant tipping fees are charged on a basis equivalent to what the municipality figured were the real costs of operating (and charging for) its sanitary landfill. The steam sales contract that was negotiated with a local industrial plant is tied into the going price of fossil fuel and the steam is sold at a price approximately 15% lower than the industry can produce it in its own boilers. Table 1C shows the "bottom line" that is currently being realized by the municipality on the operation of the plant under commercial accounting methods with rapid depreciation and full commercial interest being charged against the venture. Over the life of the plant total profit on the $1½ million investment would be $4,566,000. If fossil fuel prices rise steam revenues and hence profit will rise accordingly.

In addition to the approximately 100 municipal plants that are installed, under design or being seriously considered at present, several hundred institutions such as hospitals and universities, and an even larger number of factories have either installed or committed to these same heat recovery systems for in-house use, to virtually eliminate hauling fees, and to reduce fossil fuel costs by producing energy from their own wastes.

Installed capital costs of these installations usually range from $100,000 to $170,000. The return on investment is proving extremely attractive. Table 2 shows the operational savings being experienced by typical hospitals — an average pay back of from 27 to 38 months. Factories are finding even more rapid pay backs, in some cases as low as 19 months. When one realizes that a medium sized factory generates 20 tons or more daily of high Btu waste, this is not surprising.

Futurists predict that, within 30 years, all resources will become more limited for western civilization, that there will be less and less waste generated, and the fuel for waste energy production will gradually disappear. In the meantime, each of us still produces almost five pounds of such waste daily. It can be put to practical use immediately.

Equally important, compared to all other processes being offered as an alternate to fossil fuels where higher temperature energy is desired, the solid waste direct energy production systems appear to offer the greatest net energy return or gain against the energy required to operate these processes. This is based on the studies made to date on solid waste as a resource, as well as current designs of other alternate energy processes.

The importance of the waste energy recovery process is that it works — and it works now. It is not a theory that requires 10 more years of development. It is not a cure-all, but it can make a tremendous impact on the present energy shortfall.

TABLE 1A

CAPITAL INVESTMENT

MUNICIPAL SOLID WASTE ENERGY PRODUCTION PLANT
(120 tons per day design capacity)

Engineering, Construction Management, Legal Fees, Permits and Emission Testing	$ 128,800
Land Acquisition, Site Preparation, Sewer System, Roads, Landscaping, Fencing and Signs	[illegible],300
Building Construction	[illegible]19,000
Incineration - Steam Boiler System, with Support Equipment, Instrumentation and Steam Delivery Lines, Installed and Tested	940,400
Truck Scale	1[illegible],500
TOTAL CAPITAL COST	$1,490,000

Cost per Ton of Design Capacity: $12,417

MOBILE EQUIPMENT

Front Loading Tractors	$ 22,000
Pick-up Truck	3,900
Furniture and Supply Storage Facility	3,800
Residue and Waste Containers	7,000
TOTAL	$ 36,700

TABLE 1B

ANNUAL OPERATING COSTS
120 TON PER DAY PLANT
(34,320 tons per year)

Labor, Plant and Office	$ 104,570
Fringe Benefits..................................	15,7[illegible]
Operating Supplies:	
Auxiliary Fuel (#2 Oil)......................	35,[illegible]
Boiler Treatment..............................	9,[illegible]
Utilities - Water, Electricity, Phone...........	10,9[illegible]
Plant, Vehicle and Office Supplies.............	[illegible],800
Vehicle Fuel..................................	1,400
Insurance..	15,700
Maintenance Fund.................................	40,300
Residue Disposal (Net Cost)........................	28,600
TOTAL OPERATING COSTS	$ 266,370

Cost Per Ton of Waste: $7.76

Interest on Investment @ 9%........................	$ 134,900
Depreciation on Buildings and Plant (Straight Line 15 Years)......................	99,333
Depreciation on Vehicles (5 Years)..................	5,180
TOTAL COSTS	$ 505,783

Cost Per Ton of Waste: $14.74

TABLE 1C

INCOME STATEMENT
120 TON PER DAY PLANT

SALES REVENUE	
Tipping Fees	
34,320 Tons @ $5.30	$ 181,896
Steam Sales	
206,000,000 lbs. @ $3.05/1,000 lbs.	628,300
TOTAL SALES	$ 810,196
EXPENSES..................................	505,783
NET INCOME................................	$ 304,413

- TABLE 2 -

ANNUAL OPERATING COST SAVINGS

IN GENERAL HOSPITALS

Census Size	Fuel Savings (Oil)	Compacting & Hauling Savings	Total Savings
300	$22,648	$13,450	$36,098
400	30,198	16,800	46,998
500	37,201	20,600	57,801
600	43,986	25,900	69,886
700	50,549	30,600	81,249

EXPLOSION PROTECTION IN REFUSE SHREDDING

By

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ABSTRACT

There have been over 100 reported refuse shredder explosions in the last few years. It is virtually impossible to eliminate all shredder explosions because of the wide assortment of potentially explosible materials, i.e., flammable vapors, gas, and dusts and chemical explosives, that can be present in municipal refuse. The responsible material was not identified in the majority of shredder explosions, but flammable vapors have been identified in many others. Commercial explosives, notably dynamite, which have occasionally been involved, are the most difficult to protect against. Explosion venting, explosion suppression systems, and continuous waterspray in the shredder appear to be effective damage control measures for deflagration type explosions caused by most flammable gases and vapors. Although venting has been the measure most often employed, the majority of shredder vent designs have not utilized current explosion venting design technology.

INTRODUCTION

The use of shredders to process solid waste has increased remarkably during the past five years. According to the recent Waste Age surveys[1,2] of shredding operations in the United States and Canada, the number of reported refuse shredding installations has multiplied approximately fivefold from 27 reported shredding plants in 1971 to 144 in 1976. Many of these installations shred prior to landfilling, since the Environmental Protection Agency considers that landfilling of shredded refuse can be an environmentally acceptable disposal method that reduces the need for daily soil cover and increases site life.[3] Several other installations shred in order to obtain a relatively homogeneous waste stream more amenable to automated material handling and other processes associated with resource recovery, incineration, or the preparation of refuse-derived fuels.

This increased shredding activity has been accompanied by increased anxiety about an inherent hazard in municipal refuse shredding. The heterogeneous municipal solid waste mixture entering the shredder occasionally includes potentially explosible materials such as flammable vapors, combustible dusts, and commercial or military explosives. These materials can be ignited by impact sparks or hot spots occurring during the hammering or grinding operations within the shredders. The resulting explosion may cause injuries or equipment damage unless appropriate explosion protection measures are implemented.

Factory Mutual Research Corporation (FMRC) recently conducted a refuse shredder explosion hazard assessment for the Energy Research and Development Administration. The hazard assessment included a survey of explosions that have already occurred at refuse shredding plants, and an analysis of alternative explosion protection techniques available to shredder manufacturers and/or operators. The results of that study are summarized in this paper. The complete report[4] can be obtained from the National Technical Information Service.

The FMRC survey of shredder explosions was primarily concerned with the conventional hammermills and grinders commonly employed in municipal solid waste (MSW) plants. Rogers and Hitte[3] and Robinson[5] have recently presented comprehensive descriptions of hammermills and grinders, as well as other, less common, refuse shredders. The shredder explosions documented in the FMRC survey were those that either caused damage or required the activation of a protection system (e.g., explosion vents) to avoid damage. Thus, we excluded minor "pops" due to aerosol cans and other materials that are more a nuisance than bona fide explosions. The only exceptions to this definition were a few cases in which explosions were included that did not cause any physical damage, but whose blast caused severe vibration of the building and shakeup of the plant operators.

A total of 95 explosions in mixed MSW shredders were reported during the course of the FMRC survey. (Since the survey was completed, this author has learned of several other shredder explosions, putting the current total at well above 100.) The distribution of reported explosions among the three major types of shredders is listed in Table I. It is apparent that grinders, horizontal shaft hammermills, and vertical shaft hammermills have each experienced a significant number of explosions that is consistent with the relative populations of shredder types in operation.

Although shredder explosions are numerous, the damage and injury potential from any single explosion is limited by the structural integrity of the shredder. Only three of the reported explosions have resulted in any personal injuries and those three involved plant personnel in the immediate vicinity of the shredder. Damage within the plant is usually associated with peripheral equipment such as ducts or conveyors, which are not as explosion resistant as the sturdy shredders. Figures 1 and 2 show the damage incurred by a conveyor following one of the more severe shredder explosions. Only five (5.3 percent) of the reported explosions have resulted in more than $25,000 property damage or caused the shredder to be inoperable for more than a week.

The reported intervals between shredder explosions were also documented in the FMRC survey in terms of both time and solid waste throughout. The average reported throughout between explosions was 85,000 tons. However, the newer MSW plants that had shredded less than 50,000 tons (and, therefore, had better recall of explosions occurring) reported an average interval of 20,000 tons processed between explosions. It is clear from these numbers that operators of large MSW shredding installations can expect to encounter several explosions during the lifetime of the plant. The types and quantities of materials that are responsible for these explosions are discussed in the following section.

TABLE I

DOCUMENTED EXPLOSIONS IN DIFFERENT TYPES OF SHREDDERS

Shredder Type	Number of Locations	Number of Shredders	Number of Explosions
Vertical Grinder	8	11	24
Horizontal Hammermill	24	38	47
Vertical Hammermill	15	17	24
Total	47	66	95

TABLE II

MATERIALS RESPONSIBLE FOR REPORTED SHREDDER EXPLOSIONS

	Flammable Vapors & Gases	Commercial or Military Explosives	Undetermined	Total
Number of Explosions	30	11	54	95

FIGURE 1 DAMAGED CONVEYOR FOLLOWING SHREDDER EXPLOSION

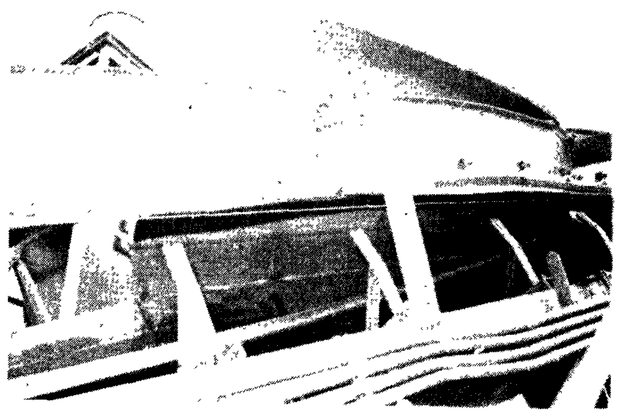


FIGURE 2 CLOSE-UP OF DAMAGED CONVEYOR

POTENTIALLY EXPLOSIBLE MSW MATERIALS

Common sense dictates that explosives such as dynamite, TNT and gunpowder, should not be shredded because of the obvious explosion hazard. However, even if these materials can be completely removed from the shredded waste stream, there are a variety of flammable liquids, gases, and dusts which will invariably be present in refuse shredders.

Table II is a compilation of the different types of materials responsible for the shredder explosions reported during the FMRC survey. Only 11.6 percent of the reported explosions were attributed to identifiable commercial or military explosives. The large majority of explosions were either attributed to flammable vapors/gases or were of undetermined origin. Since many common flammable vapors may not be recognized by shredder operators as explosible materials, many of the explosions of undetermined origin may also have been due to flammable vapors.

Flammable Vapors and Gases

Table III contains representative explosibility data for ten common flammable gases and vapors that may occasionally appear in MSW shredders. The flash points listed in Table III are the minimum temperatures at which enough vapor is evolved to form a flammable mixture within the shredder. Since temperatures in an operating shredder are probably higher than 100°F, all of the vapors in Table III are capable of forming explosible gas-air mixtures* in the shredder.

The vapor concentration at the flash point is the lower flammable limit - also listed in Table III. The other end of the flammability range is the upper flammable limit - defined as the maximum vapor concentration capable of sustaining flame propagation through gas-air mixture. Although any vapor concentration between the lower and upper flammable limits corresponds to an explosible mixture, the most violent explosions are usually associated with nearly stoichiometric mixtures. A stoichiometric mixture is defined as one in which there is just enough air and fuel for the combustion reaction to be completed with no

*Even if the liquid temperature is below the flash point, flammable liquids dispersed in the form of a fine mist or spray can undergo explosions.

TABLE III

EXPLOSIVE PROPERTIES OF COMMON FLAMMABLE VAPORS AND GASES

Gas/Vapor	Common Household Uses/Products	Flash Point* (°F)	Flammable Limits (vol %)** Lower - Upper	P_{max}** (psig)	K_G** (psi-ft-sec^{-1})
Acetone	Paint Solvent	0	2.6 - 13	83	1410
Benzene	Paint Thinner	12	1.3 - 7.9	97	1625
Ethyl Alcohol	Liquor, Cologne	55	3.3 - 19	99	1770
Gasoline (100 octane)	Motor/Lawn-mower Fuel	-45	1.4 - 7.4	-	-
Isopropyl Alcohol	Rubbing Alcohol	53	2.2 -	92	1340
Methane	Refuse Decomposition Gas	Gas	5.0 - 15	-	-
Naphtha	Lighter Fluid Charcoal Fluid	28-85	0.9 - 6.7	94	1770
Propane	Fuel Gas	Gas	2.1 - 9.5	96	1770
Toluene	Paint Thinner	40	1.2 - 7.1	92	1700
Turpentine	Paint Cleaner	95	0.7 -	-	-

* from reference 6

** from reference 7

*** from Table 3 in reference 8

remaining gaseous fuel or oxidant. The stoichiometric concentrations of the vapors listed in Table III are equal to approximately twice the lower flammable limit concentrations.

The other two parameters in Table III, P_{max} and K_G, refer to explosions of approximately stoichiometric gas-air mixtures in closed vessels. P_{max} is the maximum pressure developed in the explosion, and K_G is defined to be

$$K_G = \left(\frac{dP}{dt}\right)_{max} V^{1/3} \qquad (1)$$

where $\left(\frac{dP}{dt}\right)_{max}$ is the maximum rate of pressure rise and V is the vessel volume. The values of P_{max} and K_G lie in relatively narrow ranges for the flammable gases and vapors listed in Table III. Two gases with significantly larger values of P_{max} and K_G are acetylene and hydrogen. They were not included in Table III because they are not as likely to appear in municipal refuse. However, should they get into a shredder (acetylene was suspected in one reported shredder explosion) they are capable of producing more violent explosions.

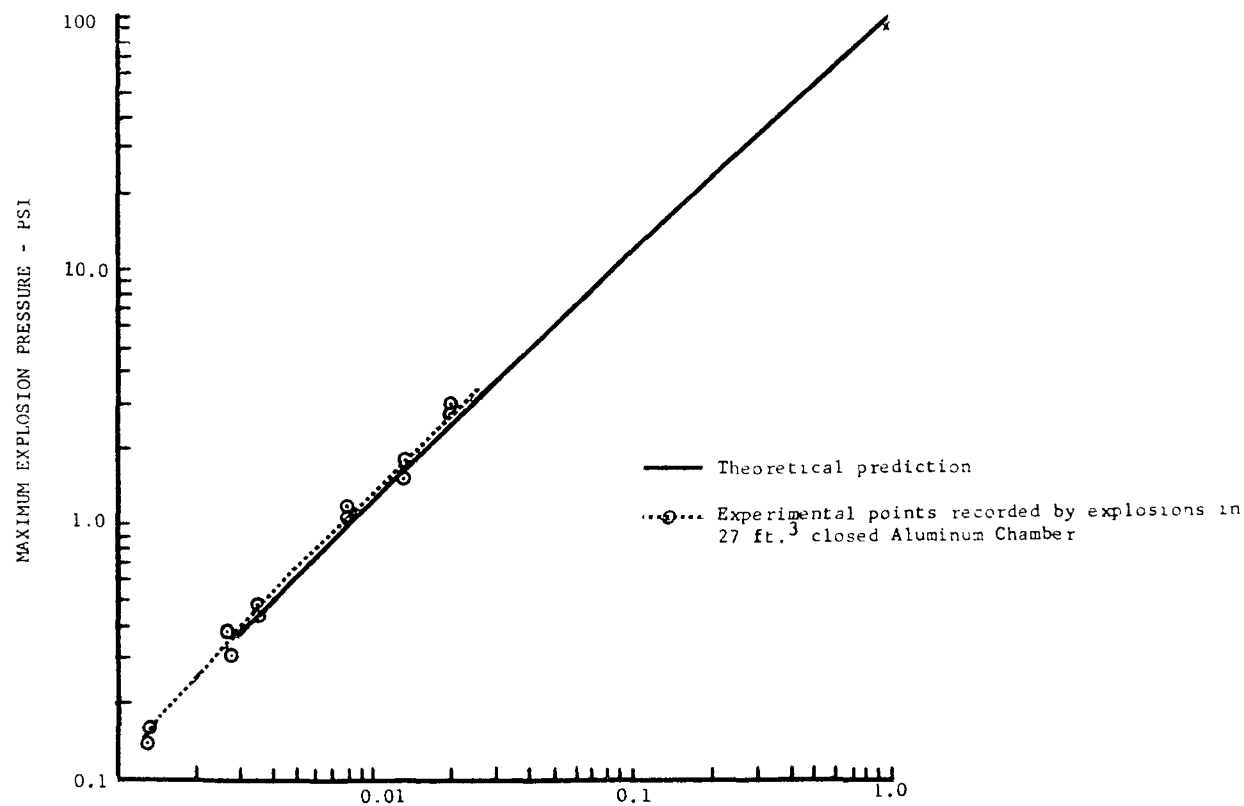
The maximum pressures and rates of pressure rise indicated in Table III refer to deflagration type explosions. The flame propagates through the unburned gas-air mixture at subsonic velocities (of the order of 1-10 ft/sec) in a deflagration, whereas it propagates supersonically in a detonation. The distinction is important since during a detonation the pressure rises virtually instantaneously (as soon as the shock wave arrives at a given location) and there is no time to take corrective action before the explosion is consummated. Most shredder explosions involving the flammable gases or vapors in Table III are probably deflagrations because detonations require either explosive ignition sources or a tubular (or ductlike) geometry.

Most MSW shredders would be damaged beyond repair when subjected to the peak pressures shown in Table III (83-99 psig). These pressures refer to a closed vessel completely filled with an optimum gas-air mixture. For a typical shredder volume of 1600 ft^3 (including inlet hood), a stoichiometric mixture would require about 1.7 gallons of gasoline to be vaporized and mixed with the air in the shredder. Comparable volumes would be required for the other volatile liquids listed in Table III. Vapor volumes and mixtures of that size are certainly possible but a more likely scenario is for only a portion of the shredder to be occupied by a flammable mixture at ignition.

Figure 3 can be used to estimate the maximum pressure developed in an explosion involving a local pocket of flammable gas/air mixture of approximately stoichiometric proportions. The data and theoretical curve in Figure 3 refer to a propane/air mixture. According to the theoretical model[9] of the adiabatic compression of a perfect gas, the results in Figure 3 should be applicable to all gas mixtures having the same value of the ratio $(M_u T_b)/(M_b T_u)$. The symbols M and T denote mixture molecular weight and temperature, and the subscripts u and b refer to unburned and burned gas, respectively. This ratio is also equal to the theoretical ratio of the maximum pressure to initial pressure for a deflagration in a completely filled vessel[9]. Since the values of P_{max} for the fuels, including propane in Table III do not differ by much ($P_{max} = 91 \pm 8$ psig), we expect the curve in Figure 3 to also be approximately valid for all of these fuels.

Since the pressures in Table III and in Figure 3 pertain to closed vessels, they provide conservative estimates of the pressures developed in partially vented shredders. A quantitative discussion, of the relief provided by venting is presented in the discussion of alternate protection measures. Nevertheless, it is interesting to use the data in Figure 3 to estimate the amount of flammable gas/vapor required to produce significantly high pressures in a structure the size of a typical shredder.

According to Figure 3, flammable mixture volumes equal to 10 percent of the shredder volume are capable of producing overpressures of about 10 psi in a completely enclosed hammermill. Based on damage estimates from some of the explosion reports, it appears that pressures of 7-10 psi will initiate major damage to discharge hoods, door latches, and other peripheral equipment. Thus, damaging explosions can result from as small a volume as 0.17 gal of gasoline completely vaporized and mixed in stoichiometric proportion with 10 percent of the air in a 1600 ft^3 shredder. Discarded containers containing at least that quantity of gasoline, paint thinner, charcoal lighter fluid, etc. must appear often in MSW shredder input streams. It is no wonder that a large fraction of the reported shredder explosions were due to such flammable vapors and gases.



$$\frac{V_u(o)}{V} = \frac{\text{Balloon Volume}}{\text{Explosion Chamber Volume}}$$

FIGURE 3. CORRELATION OF LOCALIZED (BALLOON) EXPLOSION DATA (From Yao et al[9])

Commercial and Military Explosives

Carelessly or surreptitiously discarded explosives, such as gunpowder, dynamite, and military ordnance, occasionally appear in MSW shredding plants. Many of these explosives can be triggered by impact, friction, sparks, or hot spots present during shredding. Shredder explosions caused by these materials are more difficult to control than flammable vapor explosions because 1) explosives contain their own oxidant and need not vaporize and mix with air to form an explosive mixture, and 2) the resulting explosion is often a detonation rather than a deflagration.

Laboratory tests to determine explosive sensitivity have been conducted for the more common explosive materials. Interpretation of this test data, indicates TNT, will also detonate when triggered by the lead azide primer, which is particularly impact sensitive. The sensitivity of smokeless gunpowder is strongly influenced by its moisture content.

Reports of the shredder explosions due to dynamite and military ordnance indicate that blast waves, characteristic of detonations, occurred. There has been one documented shredder explosion caused by smokeless gunpowder, but it was not one of the more violent explosions. This is probably because gunpowder is a low-order explosive, tending to produce deflagrations. The explosive yield and TNT equivalence of various explosives in Table IV can be found, for example, in Baker's text.[10]

Combustible Dusts and Hybrid Dust/Gas Mixtures

Although none of the reported shredder explosions were unequivocally attributed to combustible dusts, there is speculation that some of the explosions of "undetermined cause" may have actually been caused by a combustible dust cloud. If some explosions at shredding plants are indeed caused by dust, they are more likely to originate in dust collecting equipment rather than the shredder itself. This is because a bona fide dust explosion can only occur if the dust particle size is small enough to be classified as a powder, i.e., much smaller than 1 mm. Thus, Palmer, in discussing the explosion hazard of grinding machines (Reference 11, p. 300), states that "the explosion risk is low for those crushers delivering product of a few centimeters (1 in.) diameter," which is a typical average particle size for MSW shredder output. Palmer warns, however, that precautions should be taken to prevent the small proportion of powder produced in the crushing process from accumulating in a confined area.

Palmer's speculation and admonition is consistent with the results of the FMRC survey of shredder explosions. In the one report[12] where there was any real evidence of a dust explosion, the explosion originated in a small separate structure through which the shredded refuse was conveyed. Apparently, dust was allowed to accumulate in the conveyor house, and a friction spark set off the explosion which destroyed the concrete structure. Photographs illustrating the damage incurred in this incident are shown in Figures 4 and 5.

It is very likely that, upon occasion, combustible dust and flammable gas or vapor will be present simultaneously in a refuse shredder. These so-called hybrid mixtures are particularly hazardous because they can be explosive even when the individual gas/air and dust/air constituent mixtures are not explosible.[13] For example[14], a methane concentration of 1 vol percent in air is below the lower flammable limit, and PVC dust consisting of particles with a diameter of 100 microns will not explode in any concentration. However, when the two are combined, an explosible hybrid mixture results that can develop a maximum pressure of about 8 bars (118 psi) at a PVC concentration of 100 gm/m^3.

It is particularly noteworthy that small quantities of methane can contribute to explosible hybrid mixtures. The refuse decomposition process which produces methane is a relatively slow one (landfills require about six months to generate collectible quantities of methane), probably too slow to produce enough methane to form a flammable methane/air mixture in a shredder. However, it may be possible for small quantities of methane to combine with accumulations of fine combustible dust to form an explosible hybrid mixture in the shredder.

FIGURE 4 EXPLOSION AT VOLUME REDUCTION PLANT. SHREDDER BUILDING AT RIGHT. COMPACTOR BUILDING AT LEFT. (Reference 12)

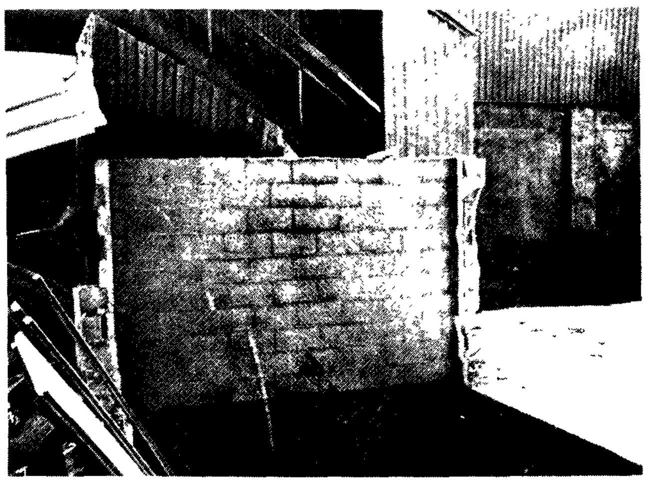


FIGURE 5 REMAINDER OF REAR WALL OF CONVEYOR BUILDING NEAREST TO SHREDDER PLANT (Reference 12)

EXPLOSION PROTECTION MEASURES

Explosion protection consists of preventive measures and damage control techniques. Although prevention is preferable to damage control, it is unrealistic to expect currently available preventive measures to eliminate all, or even most, shredder explosions. Manual and automatic shredder input screening and other preventive measures are discussed in this section, but primary emphasis is placed on damage control measures.

In assessing the potential effectiveness of damage control techniques, it is important to differentiate between detonations and deflagrations. The local overpressurization in a detonation occurs instantaneously via shock wave propagation, but the overpressurization in a deflagration occurs over a time interval on the order of 0.1 - 1.0 sec in a typical size shredder. Most of the protective measures discussed herein should be effective for incipient deflagrations, but cannot be expected to provide much protection for detonations. The two exceptions are isolation and blast resistant construction. Since most shredder explosions are deflagrations, all of the protection measures are worthy of consideration.

Preventive Measures

To prevent an explosion, either the ignition source, the explosive material, or, (for combustion type explosions) the oxidant must be removed. In hammermills and grinders, ignition sources include impact sparks, friction sparks and local hot spots. These sparks and hot spots are inevitable with the metal hammers and grinder rings used today. Some radically different hammer/grinder material or coating would be required to eliminate all ignition sources, and no such development seems to be imminent.

Inerting to reduce the oxygen content does not appear any more promising. Refuse shredding operations currently are continuous processes involving large openings to the atmospheric at the inlet and outlet. Inerting would require either completely closing the shredder openings or else providing a continuous source of inert gas. Neither technique appears to be economically feasible.

The other preventive measure, removal of explosible material, involves either manual or automatic screening of shredder input materials or continuous purging of explosible material in the shredder. Manual screening is already a common practice. Obviously explosive materials, as well as difficult-to-shred items, such as rolled-up carpets, cables, and large tree limbs, are removed from the tipping floor or the shredder input conveyor. Manual screening is necessary but cannot be relied upon to remove the entire gamut of potentially explosible items. A possible improvement in manual screening efficiency might be achieved by indoctrinating refuse plant and collection personnel in the potential explosion hazards of the seemingly innocuous flammable vapors discussed previously.

The use of automatic detectors to screen various explosive materials is possible in principle, but its feasibility is questionable. Vapor detectors placed upstream of the shredder would have to be extremely sensitive to detect the presence of flammable vapors or explosives still contained in their package. Vapor detectors placed within the shredder would only be useful if they triggered some active suppression or inerting system, since most shredders require several minutes to come to a halt. In either case, the detector would have to be invulnerable to false alarms caused by a variety of non-explosible vapors, and would also have to resist deterioration in a rugged, dirty environment. Currently available commercial detectors do not meet these stringent constraints (reference 4, pp 51-52). Thus, automatic screening of potentially explosive materials is not a realistic alternative in the near future.

Continuous purging of explosible materials by utilizing large air flow ventilation rates has also been considered. To be effective, the air flow rate must be large enough to dilute or remove the flammable vapor (or dust) before it mixes with air and encounters an ignition source. Vapor mixing and spark ignition sources, i.e., hammer impacts, are both related to shredder shaft rotation, so the characteristic time for these processes is the reciprocal of shaft RPM, Ω. The characteristic time for diluting/removing the vapor in the shredder is V/Q, where V is the shredder volume (ft^3) and Q is the air flow rate (cfm). Thus, if the vapor is to be swept out before it forms a flammable mixture and ignites, the ratio $Q/V\Omega$ should be larger than unity. However, for the typical values, Q = 10,000 cfm, V = 1,000 ft^3, Ω = 1,000 RPM, this ratio is 10^{-2}, two orders of magnitude too small to rely on continuous purging as a preventive measure. We conclude that purging, like the other preventive measures, may be helpful, but does not provide a foolproof safeguard against explosions.

Explosion Venting

The basic concept of an explosion venting system is that the maximum pressure developed in a deflagration can be greatly reduced if the burned and unburned gases are allowed to escape from the confining structure before the combustion process is completed. This can be achieved by providing vent doors, blow-off panels, rupture discs, etc., on the equipment or building containing the explosion. To be effective, the vent area, inertia, release pressure, and proximity to the ignition source must be adequate to allow the gases to escape before damaging overpressures are generated. Furthermore, any ducting employed to channel the gases out of the surrounding building must avoid a recompression of the gases on their way out.

Most refuse shredders currently in use do not have adequate explosion venting provisions. Those shredders that are outfitted with explosion vents usually have undersized vents (according to the guidelines discussed in this section) that are often located too far from the ignition source, i. ., the hammers, to be effective. This is particularly true when inlet and discharge openings and reject chutes are relied upon for venting. These openings are usually too obstructed with refuse and debris to provide a large enough outflow rate for the vented combustion gases.

During the past few years, several different quantitative explosion venting guidelines have been proposed for gas and dust explosions in process equipment. These guidelines, which are prescribed in references 8,9 and 13-17 describe how a vent system can be designed for a given combination of fuel/oxidant mixture, ignition source, and restraining vessel. Most of these guidelines have been developed from tests in spherical, cubical, cylindrical, or other simple shaped vessels of various sizes ranging from laboratory scale to 60 m^3. They have not been verified for equipment as complicated in shape and contents as a refuse shredder. In particular, internal equipment and refuse within the shredder are likely to obstruct the flow of vented gases and thus produce significantly higher pressures than are measured in similar sized vessels free of obstructions. Furthermore, there are sometimes large discrepancies between the various venting recommendations.

Since none of the quantitative explosion venting guidelines have been verified by tests simulating shredder explosions caused by flammable gases or vapors, no single guideline can be decreed to be most applicable for shredder explosions. The general procedure for using the guidelines for gas explosions will be reviewed here and a comparison of predicted vent areas for three different shredders will be presented. The guidelines will be applied for a worst-case, near stoichiometric propane-air mixture, since propane is representative of the flammable gases expected in a refuse shredder (Table III), and much of the available venting data was obtained with propane.

An essential parameter in all of the recent guidelines is the quantity ΔP_{max}, which is the maximum tolerable overpressure for the equipment (including ducts, hoods, etc.) containing the deflagration. The appropriate value of ΔP_{max} should be specified by the equipment manufacturers on the basis of testing or structural analysis. Inquiries to shredder manufacturers, however, have indicated that they are unaware of what the value of ΔP_{max}, should be for their equipment. Therefore, observations and measurements[18] of damage incurred during several shredder explosions will be used as the basis for estimating ΔP_{max}. These observations indicate that appreciable damage to peripheral equipment occurred at overpressures of about 5-7 psig. The recommendations presented here (Table IV) correspond to ΔP_{max} = 4.4, which was a convenient figure to use in one of the guidelines, and also provides a small measure of conservatism, i.e., safety.

Another parameter in the venting guidelines is P_v, the pressure at which the vent is opened. P_v should be considerably less than ΔP_{max} because 1) the maximum pressure in a vented deflagration is often larger than the vent release pressure, and 2) most industrial buildings containing, or adjacent to, shredders will fail at overpressures well under 5-7 psig. In the following examples, P_v is set equal to 1.45 psig because this is the lowest value of P_v in some of the venting correlations.

The turbulence level* in the vessel is still another pertinent factor in the explosion venting guidelines. In some guidelines(8,14) the turbulence level is an on-versus-off factor, i.e., agitated gas versus quiescent gas, while in other guidelines(9,16) the turbulence level is specified as some multiple of the fundamental laminar burning velocity of the gas-air mixture. In both cases, the required vent area to achieve a specified peak pressure is larger for a turbulent gas mixture, such as would be expected in a shredder, than for an initially quiescent mixture in which laminar flow prevails throughout the venting process.

Once the combination of shredder volume, maximum tolerable overpressure, worst-expected-case fuel/air mixture, desired vent release pressure, and turbulence level have been ascertained, the explosion venting correlations in references 2,9, and 13-17 can be utilized to determine the required vent area. This has been performed for the three representative shredders listed in Table IV. The recommended vent areas shown in Table IV are slightly larger than the values originally given in Table XII of reference 4, because the values shown in Table IV were calculated using new data(19-21) on turbulence effects that have become available since the report was written. The new data indicate 1) that the most appropriate value for the ratio turbulent/laminar burning velocity factor appearing in the Yao correlation is $x=4$ and 2) that the turbulent value of K_G (defined in eq (1)) for propane appearing in Bartknecht's nomograms is 5.5 times the laminar value indicated in Table III.

Although there have not been any shredder explosion tests with gaseous fuels to verify the validity of the vent areas recommended in the various guidelines, Scholl(18) has recently conducted some dust explosion tests. The tests were conducted in an older version of a HAZEMAG horizontal hammermill and were primarily sponsored by HAZEMAG Germany. Most of Scholl's tests were designed to evaluate various explosion suppression configurations, but he also conducted some explosion venting tests.

Figure 6 is a schematic illustration of the dust dispersion arrangement and instrumentation employed by Scholl. Four different dusts (coal dust,

*Turbulence level here refers to both the pre-ignition state of the gas and to the turbulence developed by the vented gases.

TABLE IV

COMPARISON OF RECOMMENDED VENT AREA

CORRELATIONS APPLIED TO THREE HAMMERMILLS

	Recommended Vent Area (ft^2)		
Shredder	NFPA 68*	Yao**	Bartknecht***
Williams Model 680* (Horiz. Hammermill + Inlet Hood, Volume ~1500 ft^3 L/D ≃ 3)	49	45	58.1
Modified Hazemag** (Horiz. Hammermill, Volume ~1800 ft^3 L/D ≃ 2)	57.8	50.8	73.2
Heil Model 42D Vertical Hammermill, Volume ~150 ft^3 L/D ≃ 2)	12.3	9.7	11.8

* Based on Table 2, pp 68-36, reference 8

** from Figure 11 of reference 16, for x=4

*** from Figure 10 of reference 14, adjusted to account for turbulent value of K_G

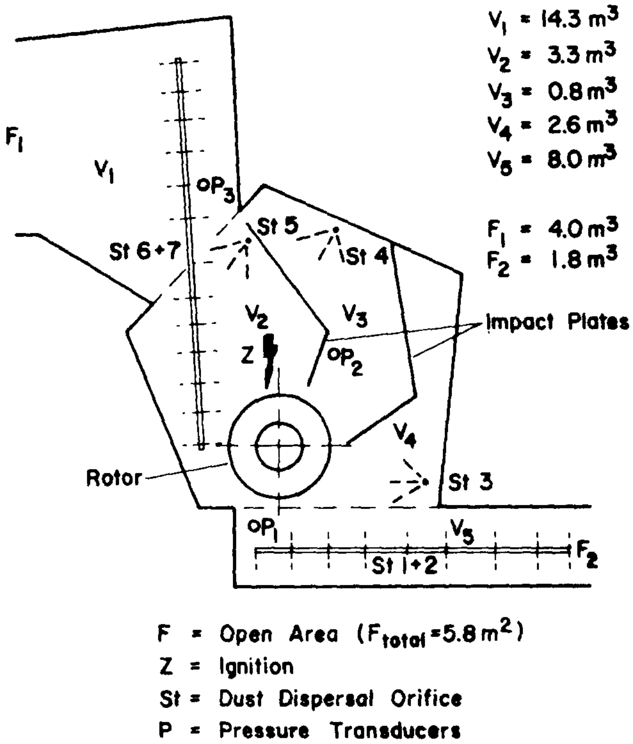


FIGURE 6 SCHEMATIC DRAWING OF HORIZONTAL HAMMERMILL USED IN SCHOLL'S DUST EXPLOSION TESTS; TOTAL VOLUME = 29 m^3. (From Reference 18 , Figure 5)

polyester, "Hexa", and "Sirona") were tested with a spark ignition located near the rotor. Pressures were measured in the mill and in the inlet and discharge hoods. The objective of the tests was to find some suppression and/or venting arrangement that would keep the pressures within tolerable levels and also prevent flame propagation through the inlet and discharge hoppers.

In order to obtain an adequate vent area in the vicinity of the ignition source, i.e., the rotor, Scholl eventually modified the hammermill as shown in Figure 7. The results obtained with the modified vented hammermill are shown in Table V. When the vent area was increased from 10.8 ft^2 to 64.6 ft^2, the mill pressure was reduced from 3.7 psig to 0.7 psig in the test series with Sirona dust. A significant reduction in pressure was also obtained with Hexa dust when the vent area was increased from 21.6 ft^2 to 64.6 ft^2.

The flame duration times indicated in Table V indicate that venting alone cannot be expected to prevent flame propagation into and through the shredder inlet and outlet areas. Therefore, the vented gases should not be discharged into a space containing personnel or unprotected equipment. If the shredder is located inside a building, it is often necessary to provide a vent duct to channel the vented gases out of the building.

If a vent duct is employed, the vent must be designed to prevent a recompression of the vented gases and a possible escalation of the deflagration into a detonation. Bartknecht[14] recommends that the vent duct for typical granulators be less than 6 m (19 ft), and, if its length is in the range 3-6 m, the maximum pressure can be increased substantially over the equivalent unducted situation. The NFPA guidelines [8] suggest that, if any appreciable duct length is required, the cross-sectional area of the duct should be at least twice that of the vent device. Furthermore, the duct should not have any bends including the junction with the shredder.

Several refuse shredder installations already employ vented ducts and/or blow off panels on the walls of the shredder building. Figure 8 shows such an installation in which one vent duct attached to the shredder led to two heavy hinged doors on the roof of the building. Unfortunately, the doors were too heavy to open fast enough, and were blown off their hinges as a result of the explosion. The ducting and roof vent have since been replaced with a diverging duct and a lighter roof vent.

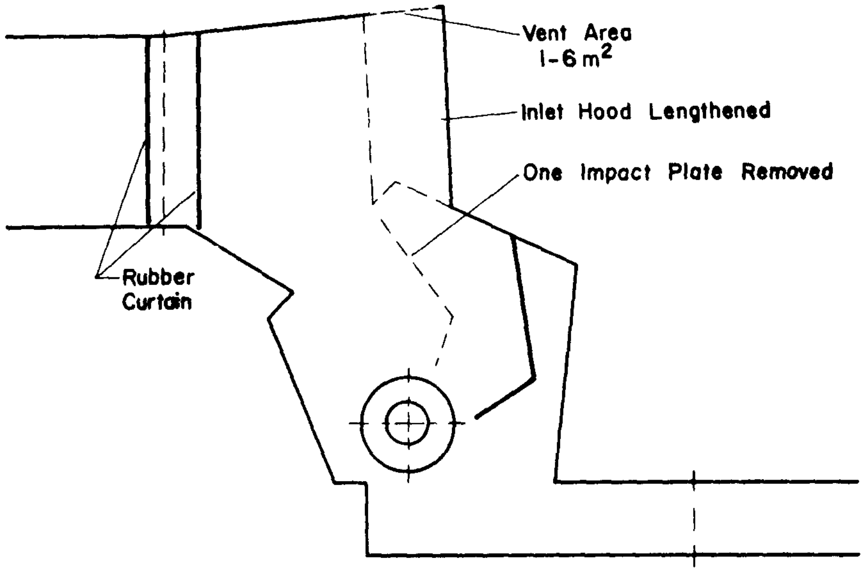


FIGURE 7 MODIFIED HAMMERMILL USED IN SCHOLL'S EXPLOSION VENTING; TOTAL VOLUME = 51 m^3. (From Reference 18, Figure 34)

TABLE V

SCHOLL'S DUST EXPLOSION VENTING TEST RESULTS

(from Reference 18)

Dust Type	Vent Area (ft^2)	P_{max} (psig)	Flame Duration (sec)
Sirona	10.8	3.7	1.4
"	21.6	2.6	3.2
"	64.6	0.7	0.7
Hexa	21.6	2.8	8.6
"	64.6	1.6	4.7

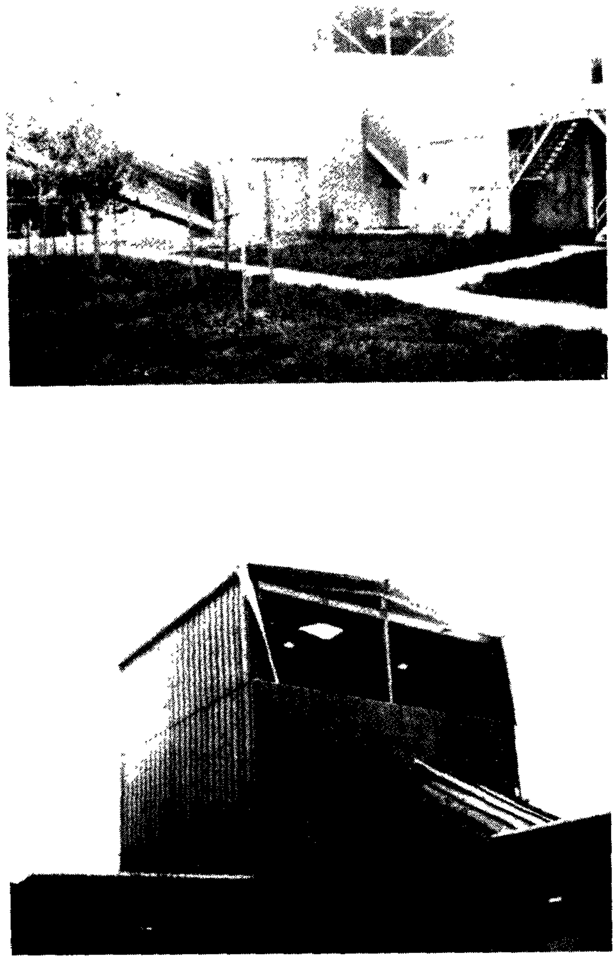


FIGURE 8 SHREDDER BUILDING FOLLOWING EXPLOSION

Several other damaging explosions in inadequately vented shredders have demonstrated the need for improved venting guidelines applicable to shredder operations. A test program similar to the one conducted by Scholl, but employing flammable gases, would be extremely useful in generating the data required for such improved guidelines.

Explosion Suppression System

The basic premise of an explosion suppression system is that the maximum pressure and flame propagation can be reduced to tolerable levels if a suitable extinguishing agent is injected quickly enough into an incipient confined gas or dust deflagration. An inherent advantage of a successful suppression system over an explosion venting system is that the flame will be extinguished in the shredder, so that the post explosion fire hazard is eliminated.

Various types of explosion detection devices (ultraviolet, infrared, thermal, and pressure) can be employed to actuate the suppression system, but the one usually employed in the dirty, obstructed shredder environment is a fast-response pressure transducer. The actuation pressure of the detector must be low enough to allow for early introduction of the extinguishing agent, but high enough to avoid false alarms due to slight pressure transients under normal operation. For shredders, the actuation pressure is usually in the range 0.5 - 1.5 psig depending on the extinguishing agent used.

The explosion suppression agents most commonly employed in the United States are the halogenated hydrocarbons (Halons). The Halons are believed to chemically inhibit the combustion process. The Halons used for explosion suppression applications are bromochloromethane (Halon 1011, CB), Halon 1301 (CF_3Br), and Halon 2402 ($C_2F_4Br_2$). Fenwal, Inc., which is the only American manufacturer of commercial explosion suppression systems, recommends Halon 1011 for use in hammermills and grinders. The concentration of CB recommended by Fenwal is 25 liquid cc's per ft^3 of vessel volume.[22]

The explosion suppression agents favored in Germany are the chemical extinguishing powders, ammonium phosphate and sodium bicarbonate. Tests conducted by Bartknecht[13,14] indicate that these powders are effective even at relatively high actuation pressures, i.e., when the deflagration process is well underway. Thus, powder suppression systems seem to be less susceptible to false alarms than are Halon systems. Bartknecht provides recommended concentrations of extinguishing powder for various combustible gases and dusts and for different actuation pressures in references 13 and 14. Results of recent Coast Guard tests[19] in large obstructed enclosures also indicate that the minimum required agent concentrations (mass of agent per unit enclosure volume) for successful suppression are lower for dry chemical powders (Purple K) than for Halons.

No matter which agent is deployed, the effectiveness of an explosion suppression system is limited by both the detection time and the travel time for dispersing the agent into the unburned fuel/air mixture. Thus, fuel/air mixtures with exceptionally fast burning velocities and rates of pressure rise cannot be extinguished early enough to provide proper protection. For successful suppression of propane/air mixtures, the Coast Guard tests[19] indicated that Halon agents must be completely dispersed within 150 millisec after ignition. Fuels with faster burning rates (or larger values of K_G), e.g., acetylene, would require shorter detection/dispersal times*.

Although there have been no shredder explosion tests with gaseous fuels, Scholl's explosion suppression tests[18] have recently provided a quantitative measure of the effectiveness of the German suppression system for dust explosions. The hammermill used in Scholl's first series of suppression tests is the one shown in Figure 6. The results obtained by Scholl for polyester dust explosions with and without a suppression system are given in Table VI. The suppression system arrangement used in this test series consisted of 14 agent containers uniformly distributed throughout the hammermill. It is clear from Table VI that the suppression system reduced the peak pressures significantly below the corresponding unsuppressed case. Furthermore, the flame duration times in the shredder inlet and outlet were reduced by an order of magnitude with the suppression system.

*The critical detection/disposal time also depends upon shredder volume, V, since the time at which a given overpressure is developed is proportional to $V^{1/3}$ (reference 13).

TABLE VI

SCHOLL'S DUST EXPLOSION SUPPRESSION TESTS

(from Reference 18)

Polyester Dust Concentration (gm/m^3)	P_{max} (psig)	Flame Duration (sec)	Suppression System
250	5.9*	4.8	No
500	8.1*	>6.1	No
250	3.7	0.25	Yes**
500	5.1	0.35	Yes**

* Outlet hood was bent and rubber curtain at inlet blew away in these tests.

** The suppression system used in these tests consisted of 14 kg bottles of dry chemical suppression agent installed throughout the mill and activated at an overpressure of 1.5 psi.

Scholl also made two significant observations about the disadvantages of using a suppression system with an actuation pressure of 1.5 psig: 1) he observed that relatively mild deflagrations, such as were obtained using coal dust, produced maximum pressures below the actuation pressure. Therefore, the agents were never discharged and flames propagated through the hammermill; 2) the same result occurred when a large vent area was used in conjunction with the suppression system to minimize overpressures. Thus, venting and suppression are incompatible unless the vent relief pressure is significantly higher than the suppression actuation pressure.

Fenwal suppression systems with Halon 1011 agent actuated by pressure transducers triggering at 0.5 psig and at 1.5 psig have been installed during the past year at several shredding plants. There have been several successful actuations and suppressions. There has also been one incident in which some damage was incurred, but the material causing that explosion was not determined.

Water Spray

A continuous water spray is used in several refuse and automobile shredders primarily to reduce the suspended dust level. These shredders have experienced significantly fewer damaging explosions than shredders operating dry.

A fine water spray or mist can prevent or mitigate explosions through the following mechanisms: 1) the water droplets can quench, or at least decelerate, the incipient flame; 2) air entrained into the water spray may dilute the flammable mixture more efficiently than forced ventilation; 3) the water vapor represents an inerting agent slowing down the combustion reaction; and 4) some flammable gas may be removed by adsorption onto the water droplets.

Our current understanding of these mechanisms is not sufficient to specify the water flow rates and drop sizes needed for successful suppression/prevention. One shredder installation that has experienced some success* with a water spray, utilizes a flow rate of 4 gal/min for four shredders and ducting with a total volume of 18,000 cu ft.[23] Although large water flow rates are desirable for explosion mitigation, they can cause such deleterious side effects as corrosion,

*The water spray seems to have reduced both the frequency and severity of explosions in this plant.

increased particle size of shredder output, and high moisture content in shredder output. More testing and operating experience is needed before the optimum combination of water flow rate and drop size, i.e., nozzle type and pressure, can be determined.

Miscellaneous Protection Measures

One of the simplest and most effective injury prevention techniques is isolation. Plant personnel should not be near the shredder while it is operating. One of the injuries reported in the shredder explosion survey occurred in a plant where the control room is only about 10 ft from the shredder. In plants where the control room is immediately adjacent to the shredder, it is important to use high-strength glass (> 3 psig fracture pressure) in the control room window.

If personnel or valuable equipment must be located near the shredder, the use of barricades or blast mats should be considered. The barricades should be designed to deflect an impinging blast wave and also prevent penetration by missiles (fragments) caused by the explosion.

CONCLUSIONS

There have been over 100 reported refuse shredder explosions in which some damage was incurred or which caused the activation of some explosion protection measure. 76 percent of the shredding installations surveyed, have experienced at least one explosion. Although the responsible material was not identified in the majority of explosions, flammable gases and vapors are often involved. Damaging overpressures can be produced from as little as 1/4 gal of gasoline, paint thinner, etc. in a shredder of typical size. Commercial and military explosives such as dynamite and gunpowder have also been responsible for some explosions.

Because of the wide assortment of potentially explosible material in mixed municipal refuse, preventive measures such as manual or automatic screening of shredder input cannot be expected to eliminate explosions entirely. Instead, emphasis should be placed on damage control measures. Explosion venting, explosion suppression systems, and water spray all show promise for mitigating the effects of deflagration-type explosions associated with most flammable vapors. However, tests and additional operating experience are needed to determine whether existing design guidelines for these systems are applicable to the complicated shredder environment. For detonation-type explosions caused by most commercial and military explosives, isolation of the shredder and the use of blast mats or barricade appear to be the only feasible damage/injury control measures.

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USE OF REFUSE-DERIVED SOLID FUEL

IN ELECTRIC UTILITY BOILERS

by Stephen A. Lingle and J. Robert Holloway*

Summary

Processing of municipal solid waste to produce products which can be used as supplemental fuels is one of the major alternatives for simultaneous disposal of solid waste and recovery of energy. This technology involves physical or chemical processing of municipal solid waste to produce solid, liquid, or gaseous products called refuse-derived fuels. Most of the attention to date has been on refuse-derived solid fuels, commonly called RDF. Solid RDF can be produced by physically processing solid waste through size reduction and density classification. The RDF can then be sold to users who have existing boilers for use as a supplement to fossil fuels to generate steam or electricity.

Since successful demonstration of this concept by the City of St. Louis, the Union Electric Company and the U.S. Environmental Protection Agency, it has been met by a rush of interest and enthusiasm by cities. By the end of this year, a total of four commercial facilities will have been constructed, and at least four more are considered committed. Many other cities are involved in feasibility studies.

Although actual operating experience is very limited, there seems to be a feeling that questions and problems relating to production of RDF can be worked out. However, cities may face a significant problem in obtaining firm, long-term markets for the RDF with guaranteed minimum revenues. Thus, the ability to market RDF appears to be the most critical issue affecting the future of this recovery approach.

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* Stephen A. Lingle, Chief, Technology & Markets Branch, Resource Recovery Division, Office of Solid Waste Management Programs, U.S. Environmental Protection Agency, presented this paper at the Fifth National Congress on Waste Management Technology and Resource Recovery sponsored by the National Solid Waste Management Association. Dallas, Texas, December 9, 1976.

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Four key points can be made regarding markets for RDF as a supplemental fuel:

1) Electric utilities dominate market potential: In examining the markets for RDF, one fact which clearly stands out is the importance of the electric utility industry. Without use by this industry with its abundance of large, coal fired boilers, it is questionable that solid refuse-derived fuel can be marketed on a broad scale. Industrial boilers have significant potential as a market. However, though large in number, most industrial boilers are not large enough in size to accomodate the RDF which would be produced from plants of 500 tons-per-day or greater scale. Marketing to multiple users could partially solve this problem, but introduces other problems of its own. Thus, electric utilities deserve a special examination.

2) Technical uncertainties reduce user interest. In a demonstration project, RDF has been burned successfully in a coal-fired suspension boiler. However, experience is extremely limited and technological uncertainties remain. A principle concern is the possibility of increased air emissions. Also, some aspects of boiler performance, such as corrosion and ash handling, are not yet satisfactorily resolved. Many utilities, though cautious toward these technical issues, do not see them as major, insurmountable barriers. However, costs may be experienced in addressing them which would have to be considered in determining a price for the RDF. Furthermore, many utilities are waiting for satisfactory resolution of these technical issues before signing agreements or contracts to purchase RDF.

3) RDF use may not be advantageous to electric utilities. Utilities have shown a significant interest in possible purchase of waste-derived fuels, prompted largely by a desire to be socially responsive. However, the electric utilities have a unique set of institutional constraints which question the rationale of their involvement in purchasing and burning a waste-derived fuel. Particularly significant is the fact that profits of electric utilities are regulated. Since fuel savings must generally be passed through to customers, there are not strong profit incentives for using waste-based fuels. In addition, the primary objective of electric utilities is to provide reliable service. New, unproven fuels are inconsistent with that objective. In view of these institutional factors, even small technical uncertainties take on added significance. In short, why take any chances?

4) Costs incurred in using RDF can reduce its value significantly. Some of the major costs involved in using RDF can include (1) receiving, storage and firing, (2) modifications required (if any) for air emissions control, ash handling, or additional boiler maintenance, (3) economic dispatch penalty, i.e., the increase in electric generating cost which might result from operating boilers equipped to fire RDF instead of operating more efficient boilers.

The magnitude of these costs will vary from case-to-case. There is not yet sufficient experience to reasonably estimate some of them. However, those which can be estimated, such as storage and firing costs, are clearly not minor. These costs could range from $2.00 to $6.00 per ton of RDF even if the RDF processing plant is located adjacent to the power plant and transportation costs are eliminated. Transportation could add $3.00 to $4.00 of additional cost. By comparison, RDF might have a gross value (based on heat content alone) on the order of $7.00 to $16.00 per ton. Thus, when estimating costs for RDF supplemental fuel systems, it is important to estimate the net price which can be obtained for the RDF by taking into account these costs.

The above points by no means suggest that electric utilities are not a viable market, or that RDF sold to them would have little or no value. It merely points out that electric utilities do not yet represent an established market for RDF and that until there is more experience, the extent of their interest in RDF or the net price which they will be able to pay are still uncertain. In the meantime, it is appropriate for communities to continue to work with utilities to determine if satisfactory RDF purchase conditions can be negotiated.

Background

What is refuse-derived fuel?

The term refuse-derived fuel can refer to any usable fuel produced by mechanically, thermally, chemically, or biologically processing raw solid waste. For example, a gas or oil product resulting from pyrolysis of solid waste could be a refuse-derived fuel. A refuse-derived fuel may be used either as a supplement to fossil fuels in existing steam generators, or as the sole fuel in a new steam generator designed specifically for waste burning. However, in its common usage, refuse-derived fuel (RDF) has come to represent a solid product produced by mechanically processing municipal solid waste for use as a supplement to fossil fuels in existing steam boilers. This latter concept is the subject of this paper, and the term "RDF" used here refers to solid RDF.

RDF can be produced in three physical forms: "fluff," "dust," and "densified."

- Fluff RDF can be produced by either wet or dry processing. Using dry processing, waste is shredded, usually to 1 to 1 1/2 inch particle size, and then separated in an air classifier into a light fuel fraction (RDF) and a heavy fraction of primarily non-combustibles. Using wet processing, waste is pulped in a device called a hydropulper, the resulting slurry is passed through a cyclone to remove the heavy primarily non-combustible portion, and the remaining organics are dried. Additional screening or other product upgrading steps are often used in either process.

- Dust RDF can be prepared by adding an embrittling chemical to shredded waste and pulverizing it into a powdery material. Currently, dust RDF has been prepared by only one company, which has developed a proprietary process.

- Densified RDF is fluff or dust RDF which has been densified into pellets or briquettes.

Current Experience

There is only limited experience in producing any of these RDF forms or burning them as supplemental fuels. Fluff RDF preparation and burning has been demonstrated at an EPA supported project in St. Louis, Missouri, and implemented commercially at Ames, Iowa. A demonstration facility, partially supported by the Maryland Department of Environmental Service, is operating in Baltimore County, Maryland.

The St. Louis demonstration facility has operated intermittently since 1972. The 45 ton-per-day facility used single stage shredding and vertical chute air classification to recover about 80 percent of the waste as 1 1/2 inch fluff RDF. The RDF was trucked from the City operated processing plant to Union Electric Company's Meramac Power Station where it was pnuematically fired into a 125 megawatt pulverized coal-fired steam generator at heat input rates up to 27 percent. The experimental facility is no longer operating.

The Ames, Iowa project has been operating commercially since November 1975. The plant effectively handles the 150 tons of waste generated daily by the City. The 40 ton-per-hour facility uses two stage shredding, followed by vertical chute air classification to recover about 80 percent of the waste as 1 1/2 inch fluff RDF. The RDF is pnuematically transported to the adjacent City Power Plant where it can be fired into a 33 megawatt pulverized coal fired boiler, and two small spreader stoker boilers.

The Baltimore County, Maryland facility has been operating since January 1976. The plant is currently utilized to shred and landfill solid waste and recover ferrous metals. Test programs to burn a shredded and air classified waste are simultaneously being carried out. Tests have taken place or are planned to burn the RDF in a spreader stoker boiler and cement kiln. Tests in a suspension-fired boiler may be run in the future. The facility has a capacity of 120 tons-per-hour and currently handles about 700 tons-per-day of solid waste. It uses two single stage shredding lines to reduce waste to 1 to 2 inch particle size. This is followed by two-stage verticle chute air classification.

Other cities which have recently completed construction of a facility to produce fluff RDF are Milwaukee, Wisconsin, Chicago, Illinois. In both cases, the fluff RDF is to be utilized in suspension fired electric utility boilers.

Experience with both dust and densified RDF is significantly more limited. A privately-owned dust RDF pilot plant has operated, and a larger facility in E. Bridgewater, Massachusetts is in shakedown. A commercial facility is under construction in Bridgeport, Connecticut. The same proprietary process is involved in all three projects.

Densified RDF has been produced and burned only on a test basis to date. EPA's Office of Research and Development is currently conducting tests of preparing and burning densified RDF at large scale in Washington, D. C.

Thus, there is an interesting dichotomy of limited experience, yet a willingness to proceed. In addition to the cities mentioned above, at least nine other cities are currently involved in design of an RDF system. Numerous other cities have commissioned feasibility studies. This activity suggests a widespread belief that RDF can be successfully produced. There is a sobering question of markets which these cities must face, however. Few if any cities to date have been able to obtain firm, long-term contracts for RDF with well defined product revenues. Some of the possible reasons for this market uncertainty are discussed in this paper.

Markets for RDF

Electric utilities and industrial plants are two basic potential markets for RDF.

Most large electric utilities use primarily "suspension fired" boilers where the fuels are pnuematically fired into the boiler and burn in suspension. Most industrial boilers are relatively small "spreader stoker" fed units that burn part or all of the fuel on a moving grate in the furnace. Fluff or dust RDF can be used in suspension boilers. Fluff and densified RDF can be used in the grate equipped boilers.

Table 1 contains a summary of the capacity of these two markets nationally. Though large in numbers, industrial boilers have only about one-third the total national capacity of electric utility boilers. However, far more significant is the average boiler capacity in the two sectors. Average electric utility boiler capacity is 630 million Btu/hr., while average industrial boiler capacity is only 30 million Btu/hr.

To accommodate waste from large urban areas, large boiler capacities are necessary. For example, a city that generated 500 tons-per-day of refuse would require boiler capacity of at least 500 million Btu/hr to consume the RDF produced.* Most electric utility boilers are above this size. However, only about 55 coal fired industrial boilers are larger than 500 million Btu per hour. These boilers are concentrated primarily in the east-north central area of the United States.

This does not mean that industrial boilers are not an important potential market. Many individual industrial plants have multiple boilers. This would expand the capacity in any one location. Also, several industries in a given area may have boilers. This means that marketing of RDF to multiple users in a given area is a distinct possibility. Nevertheless, from a capacity standpoint, electric utility boilers offer a significantly greater potential than industrial boilers.

Another factor is the stability of the user. Electric utilities offer a more stable long-term market because they are unlikely to cease operations. The same cannot be said for industrial plants. Even very large companies can suspend or cease operation of individual plants.

On the other hand, the gross value of the RDF is likely to be lower when used in an electric utility boiler vs. an industrial boiler. This is because large electric utilities have long-term, high volume fuel purchase contracts that result in lower fuel costs than for most industries. Because a user would buy RDF based on its fuel cost savings, gross revenues could be lower when marketing RDF to electric utilities.

But, all factors considered, the electric utility boiler market appears to have much more potential than the industrial boiler market.

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* This assumes that 350 tons of RDF are produced from the 500 tons of waste, that 40 percent of the boiler heat input is provided by the RDF, that the boiler averages a 70 percent load factor (capacity utilization), and operates 24 hours per day. Using RDF to provide 40 percent of total boiler heat input is considered to be possible in "stoker" boilers. For "suspension" boilers, 20 percent or less is a more likely estimate.

TABLE 1

NATIONAL CAPACITIES
COAL FIRED UTILITY AND
INDUSTRIAL BOILERS

TYPE	NUMBER	TOTAL CAP (billion Btu/hr.)	AVG. CAP. (million Btu/hr.)
Utility	2,200	1,400	630
Industrial	16,600	510	30

Source: Battelle - Columbus Laboratories, INDUSTRIAL BOILER INVENTORY, pp. 13-15, Columbus, Ohio, 1975

Key Factors that influence marketability of RDF, particularly to the electric utility market are discussed below. Included are:

- Technical Factors
    1) Fuel characteristics of RDF
    2) Boiler corrosion
    3) Boiler residue
    4) Boiler emissions
- Institutional Factors Affecting Electric Utilities
- Economic Factors: Determinants of RDF Value

Technical Issues in Marketing RDF

Characteristics as a fuel. Table 2 shows a comparison of certain key characteristics of RDF and coal from the St. Louis and Ames, Iowa projects previously described. One would expect the characteristics of the St. Louis and Ames RDF's to be similar since in both cases approximately 80 percent of air classifier inputs have been recovered as light fraction (RDF). However, the data show some interesting variations. One explanation for the differences may be that the St. Louis data are the average of all measurements made over the life of the project. The Ames data represent a four month average, and thus reflect seasonal influence.

In both cases, the data show the heat content of the RDF's to be about half that of coal, while both ash and moisture are significantly higher. Sulfur, on the other hand, is lower in RDF than coal. The lower sulfur content has been viewed as a potential benefit from an air emissions (SO_x) standpoint. However, the higher concentrations of ash may create ash handling problems, and the higher concentrations of moisture decrease the effective heat value of the RDF.

These RDF characteristics are not representative of what can be achieved by additional processing of waste to produce RDF. For example, additional processing such as screening and drying can reduce both ash and moisture content. Processing into a dust RDF will produce a significantly higher heat content, as well as lower ash and moisture. There is a trade-off between the cost of the processing employed in producing an RDF, and the value of the resulting product. Requirements of the user will determine what specifications the RDF must meet.

Burning experience. There are three primary areas of interest regarding boiler performance when burning RDF: corrosion, bottom ash, and air emissions.

TABLE 2

COMPARISON OF COAL AND
RDF CHARACTERISTICS
(ST. LOUIS, AMES)

Characteristics	Weight Basis			Heat Basis (Per Million Btu)		
	Coal[1]	RDF		Coal	RDF	
		St. Louis	Ames		St. Louis	Ames
Heat Value (Btu/lb.)	11,000	4800	5600			
Moisture	13%	25%	23%	12 lb.	52 lb	41 lb
Ash	7.8%	21%	17%	7.1 lb.	44 lb	30 lb
Sulfur	1.2%	0.18%	0.43%	1.1 lb.	0.37 lb	0.77 lb

[1]Orient No. Coal, Meramac Power Station, St. Louis, MO

Source: U.S. Environmental Protection Agency

Corrosion. Currently there are only limited data on boiler tube corrosion, and all of it is based on short-term burning experience. However, early indications are encouraging. Analysis of critical boiler components at the Union Electric Company indicated no observable increase over coal only firing. However, this was based on intermittent firing of roughly 50,000 tons of RDF over three years, which in total constituted less than 3 percent of total boiler heat input. Thus, these observations cannot be considered the last word. Nevertheless, the willingness of Union Electric to move ahead with a $70 million project to burn 6000 tons of refuse daily is strong testimony to their belief that corrosion would not be a significant problem. Discussions which EPA has held with other electric utility representatives indicate that corrosion is not generally perceived as a prohibitive problem area. Even still, some utilities prefer to take a wait-and-see posture until there has been more operating experience.

Bottom ash. The bulk of existing data on bottom ash are from testing at St. Louis. At 10 percent RDF heat input, bottom ash increased 4 to 7 times over that for coal only firing. This was due both to the fact that RDF has 5 to 6 times as much ash as coal on an equivalent heat value basis, and the fact that not all of the RDF fired into the furnace actually burned. About 10 percent of RDF heat content was lost to bottom ash vs. less than 1 percent for coal.

There is some experience with suspension firing of RDF at Ames, Iowa, although most of Ames' experience to date has been with burning in a spreader stoker boiler. Early observations of bottom ash during suspension boiler firing generally confirm the St. Louis results. Though specific data are not available, it can be said that substantial quantities of RDF did not burn in suspension and added to the bottom ash loading.

Increased bottom ash implies that alterations in boiler ash handling may be required. One notable impact at St. Louis was that ash pond BOD and COD increased with RDF firing to the point where additional treatment would have been required. This treatment can be easily accomplished from a technical standpoint, but naturally involves a cost that would ultimately be charged against the RDF.

However, bottom ash can be reduced by increasing burn-out of the RDF in the boiler. Modifications in method of firing into the boiler -- that is, raising the elevation of RDF firing nozzles to increase retention time of RDF particles in the boiler -- could possibly increase burnout. At Ames, Iowa, a unique method of increasing burnout in the suspension fired boiler is being tried. Combustion air is being injected into the boiler just above the water line in the bottom ash pit to allow the unburned RDF particles to burn as they float on the surface of the water. The effectiveness of this approach has not been fully evaluated due to limited operating experience with the suspension fired boiler.

Another possible means of increasing burnout and reducing bottom ash is to recover a higher quality RDF fraction, that is, one with a lower inorganic content and smaller, less dense particles. This may be possible by recovering a lower fraction of air classifier inputs as light fraction, say 60 or 70 percent, rather than 80. Shredding to a smaller particle size is also an alternative to increase burnout. Furthermore, the RDF could be screened or dried. However, these actions would result in either higher net processing costs or lower product yield.

Air emissions. At St. Louis, data were collected on a wide range of emissions when firing both coal only and combinations of coal and RDF. Measured were particulates, SO_x, NO_x, and trace elements. A more complete discussion of these results is available in another EPA report.[1]

The data did not confirm any increase or decrease in either SO_x or NO_x emissions when firing RDF with coal vs. coal-only firing. A decrease in SO_x had been expected because RDF has a lower sulfur content than coal. Apparently at firing rates of 5 to 20 percent, the impact on SO_x emissions was not great enough to be reflected beyond the scatter of data.

Trace elements were measured even though there are no Federal standards for any of these elements for coal fired steam generators. Emissions were found to increase for most of these elements when firing RDF. For three of the elements measured (lead, berryllium, and mercury), EPA has determined acceptable ambient air levels. Ambient air levels of these elements, estimated from measured stack emissions at St. Louis, were well below these levels when firing both coal-only and coal and RDF.

Particulate emissions were viewed as one of the key issues in RDF firing. At St. Louis, there was no measured increase in controlled particulate emissions up to the boiler design load of 125 megawatts when firing coal and RDF vs. coal only. However, above boiler design load, that is, between 125 and 140 megawatts, the actual maximum boiler load, controlled emissions did increase substantially when RDF was fired with coal.

Measurements of uncontrolled emissions indicated no significant change with coal plus RDF firing vs. coal only firing at any boiler load. Thus, a decrease in electrostatic precipitator (ESP) efficiency was the apparent cause of the increases measured in the controlled stack emissions. A number of possible changes brought about by burning RDF which could have caused the efficiency decrease were investigated. Although no totally satisfactory answer was found, an increase in gas flow rate through the ESP was identified as the primary cause of the loss in efficiency. The increased flow rate resulted from the higher moisture content of the RDF compared with coal.

The St. Louis emissions results should be useful in determining the feasibility of future RDF projects. However, caution should be exercised in drawing generalized conclusions from these results.

Emissions in other situations will depend on a number of site-specific factors including boiler and ESP design, type of RDF, and type of coal. It is important that these factors be examined prior to decisions to proceed with an RDF project.

It is possible that particulate emissions, even if they do increase, can be reduced by changes in RDF firing procedures, ESP operation, or other factors. If such actions are unsuccessful, mechanical modification to the ESP would probably be an effective, although potentially costly, solution. As is the case with the other technical factors discussed, there is a feeling that air emissions, while possibly requiring corrective action in some cases, can be properly controlled. The question is what impact will any necessary adjustments ultimately have on the net value of the RDF.

Institutional Issues in Utility Markets

Electric utilities have been the target of RDF marketing efforts for a variety of reasons. They have large capacity for using RDF and are located in virtually all urban areas where solid waste is generated. They represent a stable market, since individual utilities can be expected to be operating for the duration of long-term contracts.

From the utilities' perspective, purchase of RDF provides an opportunity to assume a good-neighbor role in the community by providing a valuable service. At the same time, a new, though limited, source of fuel can be obtained. In some cases, there may be some opportunity for a profit or lower rates to customers.

However, there are a number of problems with electric utilities as RDF markets:

- The major objective of electric utilities is to provide reliable service . Any technological uncertainties which might be associated with RDF use are inconsistent with that goal.
- Utilities, like many other instutitions, have limited financial capability. Investments for RDF handling compete with investments in new generating capacity.
- Utilities are a profit-regulated industry. This diminishes the economic incentive to use a cheaper fuel such as RDF, which carries with it increased operating risk. For example, any savings in fuel costs would probably have to be passed through to users in lower rates. This makes it difficult to earn a rate of return commensurate with risks in using RDF.

- Utilities, like other industries, are under increasing pressure to meet environmental regulations. Any possibility of increased emissions from burning solid waste could make utilities very cautious about its use.

Recently, the Edison Electric Institute (EEI) surveyed its member utilities to determine their views on use of RDF as a fuel. Here are some of the results:

- Forty nine electric utilities were actively studying the use of municipal solid waste as a part of 62 MSW utilization studies.

- Seventy six percent of these studies (47 of the 62) involve purchasing waste-derived fuels, 15 percent involve purchasing steam, and 3 percent involve electricity purchase.

- Of the 47 studies involving purchase of fuel, 29 involve shredded solid waste; 4 involve incineration of raw solid waste; 3 involve the use of pelletized RDF; 6 involve pulverized (dust) RDF; and 5, the use of a pyrolysis fuel.

Wy would an electric utility want to become involved in such a project? The four reasons most commonly cited in the survey were:

- to make a profit. Despite the regulatory constraints, there may be opportunities, though limited, to increase profit by such ventures. (However, most utilities do not think that the potential for making a profit is very high.)

- to supplement available fuel resources. However, while a new source of fuel would be expected to be a possible benefit to electric utilities, solid waste has been viewed by that industry as not available in sufficiently large, reliable quantities to be a significant new fuel in general. In specific circumstances, it could mean a great deal, however.

- to ensure that a resource recovery project is compatible with the needs of the utility. If a utility believes that a project is going to be built in any case, they may get involved early to ensure that their interests are represented.

- to assist in solving a significant public problem. Utilities tend to place a high value on efforts at civic improvement. Since they are constantly under fire from rate-payers, any actions to improve their community image are looked upon favorably by management.

Over half of the companies involved in studies indicated the last reason, public service, to be their primary motivation. Only 14 percent would insist that participation result in a profit to them.

However, the public service motive can go only so far. The industry realizes that it has no real responsibility to dispose of solid waste. Its primary responsibility is to provide reliable and adequate service at the lowest reasonable cost. H. J. Young, Senior vice president of EEI, testifying before the Congressional Symposium on Resource Conservation and Recovery on April 7, 1976, stated the following: "In order for utilities to consider becoming involved in resource recovery projects, these systems must be developed in such a way that will ensure reliability of service, be cost competitive with other fuels, minimize capital investment risks, comply with environmental regulations, and avoid large increases in operating costs."

It is questionable that operating experience to date is sufficient to definitively address these factors. Thus, there seems to be a tendency toward a "wait-and-see" attitude by many utilities. Utilities which have become involved are requiring contracts which provide an opportunity for them to discontinue their involvement at minimum cost if significant problems develop during a test period. Also, utilities have shown a reluctance to put up "front-end" capital, and naturally expect to reduce the price paid for RDF to cover any incremental costs experienced. This is by no means a criticism. It is simply good business on the part of the utilities.

The widespread interest shown by utilities at this still early stage of resource recovery implementation, when many technical questions remain unanswered, is a strong, favorable indication for the future. However, at the current time, there are still a number of significant constraints facing this market.

RDF Value

The price that a user, particularly an electric utility, will pay for RDF will depend on numerous factors. A starting point would be a simple equation such as the following:

$$Prdf = Pcoal - Crdf$$

Expressing all factors on a per unit of heat basis, Prdf is price received for the RDF, Pcoal is the price paid by the utility for coal, and Crdf is the net incremental costs experienced by the utility as a result of RDF use.

Thus, if $1.00 per million Btu were paid for coal, if RDF had a heat value of 10 million Btu/ton, and if a utility experienced incremental costs totaling $5.00 per ton for each ton of RDF used, then:

Prdf = $1.00 per million Btu - $.50 per million Btu

= $.50 per million Btu

To use this equation accurately requires that the measurement of heat value of the RDF be at the same moisture content as the coal being used, and that any loss of RDF due to incomplete burnout be taken into account. Otherwise, the usable heat of the RDF relative to coal would be overstated.

Another way of looking at the pricing determination substitutes the value of the coal saved (SAVcoal) for the price of coal per million Btu.

Prdf = SAVcoal - Crdf

Using this equation, if one half ton of coal at $14.00 per ton were saved for each ton of RDF burned, and if it cost $5.00 incrementally for each ton of RDF burned then:

Prdf = $7.00 - 5.00

= $2.00 per ton (or $.20 per million Btu)

These are only examples, and the costs used are not intended to represent an actual situation.

The latter formula assures that the user pays only for the usable heat produced by the RDF. By measuring coal actually saved, it automatically takes into consideration factors such as burnout of the RDF, heat lost when vaporizing moisture in the RDF, and other changes in boiler efficiency, such as increased stack heat loss. This approach suffers from the practical problem that it may not be possible for a utility to accurately measure the quantity of coal saved based on the amount of electricity generated. This is because the unit's steam and electricity generating efficiency changes: 1) as the boiler gets older, 2) between maintenance and cleaning cycles, and 3) with changes in boiler loads.

In practice, both of the above equations can lead to the same result in terms of RDF value if sufficient data are available to apply them accurately. Both of these equations assume that the RDF is priced equivalently with coal on a heat value basis (after deducting incremental costs) rather than being priced at a discount. If a utility wanted to discount the RDF price below that paid for equivalent Btu's from other fuels (perhaps to provide an economic incentive) then this discount would also be deducted in calculating the price of the RDF.

The most complicated factor in the above equations is the incremental cost incurred in using RDF. Some of the components of this cost are:

1) Capital and operating cost of RDF storage and firing facilities.

2) Increased boiler operating or maintenance costs due to corrosion, ash handling, air emissions, or other factors.

3) Economic dispatch penalty, i.e., the increase in overall electric generating cost to the electric company, which might result from operating boilers equipped to fire RDF instead of operating more efficient units, such as nuclear or hydro powered.

4) Cost of replacement electricity while unit is out of service for initial modification to fire RDF.

There are also other, possibily less significant, costs which can arise in specific situations.

It is difficult to define in the abstract what value should be placed on any of the factors in this equation, and they will naturally vary from case-to-case. However, it is worth pointing out the order of magnitude of some of the key components of the cost factor (Crdf) in comparison to the gross value of the RDF.

One item is the capital cost of receiving, storage, and handling facilities for RDF at a power plant. Definitive examples of these costs are limited at the present time. But a consideration of available information suggests that we might assume $4 to $8 million as a rough ballpark estimate of the capital investment to handle 1000 tons of RDF per day at a power plant. Amortizing $4 million over 15 years at 6 percent translates to $1.10 per ton of RDF. Amortizing $8 million at 12 percent over 10 years amounts to $3.90 per ton of RDF. (If the storage and handling facilities were owned and financed by a municipality or authority, 6 percent financing and 15 to 20 year amortization might be expected. If the same facilities were owned and financed by the utility or a private firm, 12 percent and 10 years is more likely.)

Operating costs (labor, utilities and maintenance) at the power plant can also be crudely estimated. Two feasibility studies (conducted for the Tennessee Valley Authority and the Delmarva Power and Light Company, Delaware) estimated costs in the range of $0.75 to $1.20 per ton of RDF. Another estimate, obtained from private sources, placed O&M costs at around $2.50 per ton of RDF. Thus, collectively, capital and operating costs amount to on the order of $2.00 to $6.00 per ton of RDF. If the RDF processing plant is not adjacent to the power plant where the RDF is to be burned, then truck or rail transport will be required. One cost estimate for a project now under construction was $3.00 to $4.00 per ton of RDF for an 8 mile track transport. Thus, the cost of handling RDF can be significant.

Other components of the utility RDF cost factor, such as possible costs of emissions or residuals control and economic dispatch penalty, would have to also be subtracted from the gross value. No reasonable estimates can be made of these costs at this time. In specific instances, they could have values ranging from zero to several dollars per ton.

These costs must be subtracted from the gross RDF value to obtain a net price. As a basis for estimating possible gross RDF values, Table 3 shows the average contract price paid for coal in various regions of the United States in June 1976. Based on these data, it appears that RDF might have a gross value of roughly $0.65 to $1.25 per million Btu.

Table 4 combines these ranges of costs and revenues to determine a possible range of net RDF values. The result is net values ranging from a high of over $13.00 per ton to a low of a negative value of nearly $4.00 per ton. Not included in this estimate are any costs relating to pollution control or other additional boiler maintenance costs, or an economic dispatch penalty. There could be no costs for these items, or in some cases significant costs could be experienced.

There are two purposes in pointing out this range of potential values. One is to illustrate the need for municipalities to thoroughly analyze their own situation, rather than depending on suppositions or approximations of RDF value. The other is to point out the significance of the difference between net and gross RDF value. However, the net RDF value is only one component of an overall economic analysis of a plant to prepare RDF and sell it as a fuel. Capital and operating costs of the RDF processing plant and revenues from recovery of any other products must be estimated. Then, this overall system net cost must be compared with costs of alternative disposal and recovery options.

Conclusions

Obviously, markets are a key factor in the viability of any resource recovery technology. However, they take on added significance in the case of a refuse-derived solid fuel (RDF). Some other technologies produce "final" end products, such as steam or electricity, which are not significantly different from the same products produced by other means. Still others produce intermediate products (fuels), such as oil or gas, representing chemically refined solid waste. However, refuse-derived solid fuel (with one notable exception) is physically processed solid waste - essentially size reduced and classified by density. A key aspect of the technical and economic appeal of this technology is its simplicity; there is no chemical processing equipment or thermal conversion equipment employed in producing a solid RDF. However, obviously the product is somewhat more crude than final products such as steam or more refined waste-derived fuels. Thus, the front-end processing simplicity may simply translate into a more difficult marketing task.

TABLE 3

COAL DELIVERIES TO STEAM-ELECTRIC PLANTS

FPC REGION	Quantity (Thousand Tons Coal/ Month, 7/75-6/76)	Percent National Total	Average Contract Price Range, 6/76 ($/$10^6$ Btu)[2]	Average Contract Price, 1/76-6/76 ($Btu6)[3]
New England	70.5	0.2	1.22	1.23
Middle Atlantic	3,738.8	10.0	1.01-1.42	1.02
East North Central	12,349.8	32.9	.81-1.02	0.85
West North Central	4,164.4	11.1	.29- .82	0.63
South Atlantic	7,152.1	19.1	.92-1.21	1.00
East South Central	5,642.8	15.0	.64-1.02	0.84
West South Central	888.5	2.4	.26- .94	0.26
Mountain	3,164.6	8.4	.20- .66	0.34
Pacific	325.0	0.9	.75	0.75
TOTAL[1]	37,496.4	100.0		0.83

1 Regions defined by the Federal Power Commission.

2 Prices vary with location, as well as with quantities of coal purchased.

3 All grades of coal.

Source: Federal Power Commission, FPC News. Washington. June 1976.

TABLE 4

RANGE OF NET RDF VALUES

Revenues	Low	High
Gross RDF Value	$6.50[1]	$16.25[2]
RDF Storage and Handling Costs	Low	High
Capital Costs	$3.90[3]	$1.10[4]
Operating Costs	2.50	.75
Transport Costs	4.00	0
Net RDF Value per Ton	(-$3.90)	$13.40
Other Costs		
Economic Dispath	?	-0-
Pollution Control	?	-0-
Other	?	-0-

[1] Based on 10 million Btu/ton; 65¢ per million Btu

[2] Based on 13 million Btu/ton; $1.25 per million Btu

[3] Based on $8 million amortized over 10 years at 12 percent

[4] Based on $4 million amortized over 15 years at 6 percent

Source: U.S. EPA estimates.

However, there is a tremendous momentum behind this technology. A host of firms are marketing RDF processing plants, many cities are considering implementation of such a system, and many electric utilities are considering involvement as a fuel user.

The primary message which should come from a consideration of both the market uncertainties and the great enthusiam behind this recovery approach should be one of realism. One should not conclude that technical or economic problems will prevent implementation of this technology, nor that all the problems will simply work themselves out. Important marketing questions exist at the present time and should be understood by those considering such a system. But the technology is still in an early stage of development. It is important that industry and government understand both the problems and the opportunities and work together to resolve the uncertainties and build a foundation for future implementations.

References

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THE ENERGY PURCHASERS' STANDPOINT

PITFALLS IN PLANNING

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At the present time, a 1200 TPD solid waste steam generating plant is in operation in Saugus, Massachusetts. The steam output from this plant is piped across the nearby Saugus River to a large industrial plant for use in processing, testing and power generation. The 2 billion pounds (907,100 t) annually to be supplied will reduce the fuel oil requirements of the industrial plant by about 73,000 gallons (276,335 litres) of #6 fuel oil daily.

This paper, while describing the basic features of the plant, will deal primarily with the inception of the idea, the attempts at municipal participation, funding, securing of permits and some of the unusual features of operation due to its integration with the industrial plant's steam system.

The General Electric Company operates its River Works Plant in Lynn, Massachusetts, bordering on the Saugus River. This large industrial complex occupies 278 acres and employs about 13,000 people. Its energy systems are complex and its steam plant capacity is over 1 million pounds per hour (453.5 t/hr) and its power generating capacity is 80 MW. This consists of 60 MW of steam turbine capacity and 20 MW of gas turbine capacity which is part of a combined cycle package of a gas turbine and a heat recovery steam generator.

Steam is used for building heating, processing, and for power generation, but the largest demands on the steam system are from testing operations. The plant manufactures steam turbines and jet engines and large flows of up to 450,000#/hr (204.1 t/hr) are required to meet the conditions of an individual test. Steam ejectors are used for altitude simulation in jet engine testing, and some ejectors can pull in access of 250,000#/hr (113.4 t/hr).

Steam is generated at 2 pressures: 650 and 200 PSIG (4481.8 and 1379.0 kPa). The bulk of the steam is generated at 650 PSIG (4481.8 kPa) and is used directly by some test equipment at that pressure. The rest goes to extraction turbines which make up the bulk of the supply to the 200 PSIG (1379.0 kPa) system. The steam plant consists of 7 boilers, the largest of which is 300,000#/hr (136 t/hr), 650 PSIG (4481.8 kPa) dual-fired, oil or gas unit.

In the late 60's, plans were being made for the normal replacement of two units which were reaching the end of their useful life. At the same time, the City of Lynn was coming to the realization that they would be facing a solid waste crisis within a few years, and as General Electric was the major taxpayer in the community, they would share in any increased cost resulting from the solution of the problem.

It was really at that time the thought of a joint solution became apparent. Why not think of solid waste as an asset, rather than a liability, and examine the possibility of recovering the heat content as fuel? Many years previously, the industrial plant had two small steam generators which were fired by rubbish, but could a unit be built today large enough to replace the two oil-fired units soon to be retired?

City officials were approached to see if they would be interested in providing some form of collection facility on land owned by the company across the Saugus River from the plant. It was originally contemplated that the rubbish would be shredded, then conveyed across the river on an enclosed conveyor, and the residue returned the same way.

It was immediately apparent that if steam were to be generated at the plant's system conditions of 650 PSIG (4481.8 kPa), 825^{o}F (440.5^{o}C), and in quantities between 350,000 to 400.000#/hr (158.7 - 181.4 t/hr), we were dealing in some unknowns. The concern for corrosion in the superheaters and the overall effect of chlorides on boiler surfaces was uppermost. It was felt a feasibility study was necessary to determine if the concept was both technically and economically sound.

Working with the City officials and a major boiler manufacturer, funding was received through H.E.W. and the Office of Solid Waste for the study. The project examined the communities' solid waste quantities and makeup, its chemical content and heating value. The boiler manufacturer examined preliminary design concepts and paid particular attention to corrosion considerations. Concurrently, the study looked at the size of units and the reliability requirements and how steam from an external source could best be integrated into the plant's steam system.

The study indicated, as you would expect, that solid waste could be considered an acceptable low-grade fuel and facilities could be designed to recover the heat value from it. The economics looked particularly attractive, although it should be pointed out these studies preceded any real concern for environmental control requirements which have added significantly to the capital costs of the installation. The study looked at various combinations of equipment and locations. You will recall the collection site was across the river from the industrial plant, and either the steam or the rubbish and residue would have to be transported across the water. The study also evaluated the economics of the entire installation on the plant side and, of course, showed the lowest cost per ton; but, the Company did not have the available land, nor could they stand the traffic congestion of 40 or 50 rubbish trucks a day in the plant, so that was not considered a viable combination.

I mentioned earlier that one plan was collection and shredding on the Saugus side of the river and conveying the rubbish over to a boiler on the Lynn side and returning the residue, utilizing the same conveyor. Another was the entire collection, burning and steam generation, on the Saugus side and transporting the steam across the river on a pipe trestle to the Lynn side. A variation of both of these was the generation of saturated steam on the Saugus side and a separately fired superheater across the river at the plant site. It was felt this might avoid some of the contemplated problems of corrosion which might only be present at the higher temperatures. After careful consideration of all the technical problems, space requirements, and capital cost, the system chosen has the entire rubbish burning steam generating facility on one side of the river and the steam transported over a pipe trestle at the pressure and temperature of the Plant's steam system.

Upon completion of the feasibility study, the actual sizing and costing of the plant was necessary in order to approach the proper municipal authorities for approval of a bond issue. It was evident that the City of Lynn did not generate enough solid waste themselves to produce the quantities of steam required. It had been estimated that in order to meet the steam demands of 225-250,000#/hr (1020-113.4 t/hr) average and peaks of 350,000#/hr (158.7 t/hr), a minimum size plant of 1000 TPD would be required.

Lynn's solid waste load was estimated in the vicinity of 350 TPD, so other communities were solicited and the North Shore Solid Waste Disposal District was formed, with eight communities, under provisions of the General Laws of Massachusetts. The district put together a specification for the proposed plant and solicited proposals from firms we felt had the technical resources to design, construct and operate such a facility.

Throughout this process, which was time-consuming, the industrial plant was facing a deadline due to the replacement schedule of its boilers. Replacement steam was required by the later part of 1975 which meant preliminary design, funding and approvals had to be firmed up in 1972.

Many evening meetings of the North Shore Solid Waste Disposal District were spent listening to firms present their proposals. Throughout this process, the industrial plant was cast in a unique role. As a corporate citizen of one community, they had a vital interest in the proceedings, but had no justification to dictate or rule on the capabilities of the proposers. But as the sole steam user, (and without that steam sale, there would be no justification of such a project) they had a vital concern first to have the assurance the plant would be built, and secondly, that it could succeed. For the first time, they were putting their destiny in the hands of others, and they needed absolute confidence that their steam demands would be met in a timely and economical fashion. If the plan faltered, they had to make plans immediately to install conventional boiler equipment to meet their 1975 replacement schedule.

Initial cost projections indicated a capital expenditure of about 22 million dollars would be required to construct a 1200 TPD plant, and municipal bonds were felt to be the most attractive way of providing that capital. A problem developed in that the solid waste district was made up of both cities and towns, and the town meeting form of government was employed by some. Bond issues had to be approved by town meeting and by city councils or boards of aldermen, depending on the particular charter. It soon became evident that it would be practically impossible to go into a town meeting and ask for that town's share of a 22 million dollar bond issue for a project so radical at that time. In this age of protest and self-styled public-interest experts, long delays could be expected if the necessary capital had to be raised in this manner.

While it was recognized municipal bonds offered the most attractive interest rate, the possibility of industrial bonds at a slightly higher percentage looked attractive. Their use required some legislative changes so that solid waste facilities would qualify along with regular industrial construction. The necessary legislation was obtained and bonding companies contacted, but here again the spector of long-drawn out battles at town meetings loomed again. The bond merchants explained that in order to sell industrial revenue bonds, there must be proof of the ability of the venture to succeed and that took the form of long-term or 20-year rubbish contracts. An investor in a 20-year bond must have the assurance the plant could meet its commitment of its steam sale and, therefore, must be assured of a continuing supply of low cost fuel; namely, solid waste. While the possibility existed that contracts could, in time, be negotiated and approved by the proper authorities, the commitment date to the industrial plant did not allow this.

When it appeared the entire project would falter because of this, it became evident to some that private capital offered the only hope to initiate the project. The cities and towns who made up the solid waste district were presently, with one exception, dumping in a large commercial landfill immediately adjacent to the plant's land in Saugus, where the solid waste facility was to be built. This landfill was receiving the rubbish for some 18 communities in the Greater Boston-North Shore area. The State and local community had tried to close this facility on many occasions, but there was no acceptable alternative, so it was still operating. The owner approached the company and suggested he would like to build the plant, realizing incineration and energy recovery offered a long-range solution with many benefits over operation of a sanitary landfill operation in a hostile environment.

They felt he needed a partner, preferably a company that could bring in the technical resources to assure the plant's success as this concept had never been done in this country. He was put in touch with a major pollution-control manufacturer and engineering firm, who had an association with a Swiss company that had built over 50 rubbish-burning steam generation plants in Europe and Japan, and more recently, one in Montreal, Canada. A joint ventuer was formed, called REFUSE ENERGY SYSTEMS COMPANY(RESCO), and the plant was originally financed by the two partners, and then refinanced with industrial bonds once construction was underway.

A great deal of time went into the negotiation of the contract between the industrial plant and RESCO. A high degree of redundancy was required to assure the company their steam demands could be met at all times, regardless of planned or unplanned boiler outage, or even a prolonged rubbish strike. They have contracted for 2 billion pounds/year (907,100 t/hr) of 650 PSI 825°F (4481.75 kPa 440.5°C) steam which is generated in 2- 750 TPD solid waste furnaces, each capable of 185,000#/hr (83.9 t/h4) on rubbish or on oil firing. The maximum demand will be 350,000#/hr (158.7 t/hr), and this rate of taking is allowed for 1200 hrs/yr. The average demand from RESCO will be about 225-250,000#/hr (102.0-113.4 t/hr). The contract requires a minimum flow of 65,000#/hr (29.5 t/hr) in order to keep the 3,000 ft (914.4 meter) line at temperature.

The cost of steam purchased bears a direct ratio to the cost if they were to generate it in their own plant. A formula was conceived that uses a maintenance factor, depreciation, labor, etc., over the contract period of 14 years, plus factoring in the cost of oil and this equals the cost per 1000# the plant would have incurred if they were forced to put in conventional fossil fired boilers. A fixed percentage of that number determines the final cost/1000# for the contracted steam. The main variable there is the price of oil, so over the length of the contract the purchased price will be affected by any fluctuation in the price of energy.

One of the more interesting features of the contract is the total energy exchange between the two plants. The industrial plant will supply to RESCO, a portion of their condensate, fuel oil and all of their electrical needs on a total energy exchange basis. They have excess turbine generator capacity, and will take RESCO's steam over and above their contracted requirements and convert to kilowatts for them. This will be done on a BTU/KW rate agreed to in the contract. Condensate returned from the plant system and not needed in their own boilers will also be sent to RESCO for a negotiated rate which will cover heat content and pumping costs. Because the plant had large #6 fuel oil storage facilities and were effectively increasing that by the reduced usage in lieu of steam being generated from solid waste, it seemed logical to eliminate the capital cost of providing large fuel oil storage tanks, at the RESCO site. Oil is supplied over the pipe trestle from the plant and is pumped to a 20,000 gal. (75,700 litres) day tank at the RESCO site which provides easy suction for fuel pumps.

It is apparent that the plant running at full capacity burning 1200 TPD of rubbish can generate more steam than is required under the present contract. The existing commercial landfill site could accommodate a future industrial complex which could utilize the steam, and the industrial plant is continuing studies as to the feasibility of increasing steam demands if they were to retire more of their existing boiler equipment. The utility company shows interest in excess power that can be generated and fed to their system.

The design of the solid waste steam generating facility follows closely that of many successful European installations, some of which have been in operation over 20 years.

Trucks will dump mixed refuse into a storage pit of 6700 tons capacity, which is 5.6 days of storage at an average disposal rate of 1200 tons/day (1091 t/day). This large storage capacity will allow the plant capacity to be doubled without the necessity of increasing the pit size.

Refuse will be transferred to the boilers or fragmenter by one of two overhead cranes. One crane will be in continuous use and the other will be a standby.

The facility has two refuse boilers, each will consume an average of 600 tons/day (546 t/day) of refuse and will produce approximately 180,000 lb/hr (68 t/hr) each of 690 PSIG (4758 kPa) and 875°F (468°C).

The refuse boiler units are designed with a three level, inclined reciprocating grate, water wall furnace and a convection heat transfer surface containing a three section superheater, generating section and economizer. Gases leaving each boiler enter an electrostatic precipitator and are then conveyed by the ID fan to the concrete stack.

Backup steaming capacity is provided by fuel oil burners located in each refuse boiler and two 120,000 lb/hr (54.5 t/hr) package boilers designed to burn fuel oil. The backup steaming capacity will not be used under normal circumstances, but is installed to make sure that the industrial plant's steam requirements will always be met.

Each refuse boiler is equipped with an electrostatic precipitator for removal of particulate from the flue gases. Each boiler will discharge a maximum of 200,000 ACFM (5660 M^3/Min) at 430°F (221°C) which is equivalent to 107,000 scfd (3028 M^3). Particulate emissions from the boiler are about 1-2 grains per scfd (35-70 g/M^3) adjusted to 12% CO_2. The precipitator is designed for an efficiency of 97.5% to maintain emissions to the atmosphere within the allowable of .05 grains per scfd (1.77 g/M^3).

Oxides of nitrogen are produced by burning a high nitrogen content fuel with a high efficiency burner that produces flame temperatures about 2800°F (1538°C). Refuse is a low nitrogen and relatively low heat content fuel. The composition of refuse, as fed into the burning zone, and the method of handling the fuel during combustion precludes the generation of high heat zones and high flame temperatures associated with the burning of highly pulverized coal of highly atomized oil in conventional utility type power boilers and therefore eliminates the possibility of generating nitrous oxides.

Refuse is a low sulphur fuel with a sulphur content of less than .3% and usually less than .1%. Fuel oil burned in the plant will be sufficiently low in sulphur content to meet the requirements of the Massachusetts Bureau of Air Quality Control requirements.

The refuse storage pit is located in the refuse handling building which is totally enclosed. The intake for the forced draft fans, which provide combustion air to the refuse boilers, is from this building. This arrangement provides for a slight negative pressure in the building and thereby prevents any odors escaping to the surrounding area. The odors are conveyed by the combustion air to the furnaces where the temperature is sufficiently high to completely destroy them.

Hydrocarbons are formed in the furnace, however, the operating temperature of the furnace is too high and the residence time too long to allow them to escape without being burned. The temperature would have to be below 1000°F (538°C) in order for hydrocarbons such as methane, parafins, olefins, etc., to escape without going through the combustion process and producing CO_2 and water which are harmless.

I commented previously on the difficulties encountered in securing funding through municipal participation, and that private financing with a subsequent conversion to industrial revenue bonds seems a viable approach. While some larger cities would obviously generate sufficient solid waste to power a 1200 TPD plant, the combination of trash quantity and a steam customer large enough to utilize the output of the plant may often be found only in the suburban communities which, therefore, makes the area or regional approach the logical choice. We have come to realize that we can effectively and economically operate water supply and sanitary sewage systems on a regional basis, but most small communities appear to be extremely provincial in their approach to solving their solid waste dilemmas. This is not hard to understand when we recall our solid waste has been buried inexpensively in landfills; and because the pickup and transportation constituted the major cost element, landfill sites were generally found within the towns' borders. A need exists to educate local officials that the solution to solid waste disposal needs to go beyond those borders and economies and an improved system can be achieved on a regional basis.

It is in this area that the states, rather than the federal government must display some leadership and direction through better enforcement of existing regulations governing landfill operations in order to adequately control open dumping which gives properly run sanitary landfills a bad name. The State must also provide incentives for communities to form regional solid waste alliances. Appropriate sites can be secured by state governments through eminent domain takings where no one community could likely have that power for a regional facility.

The greatest contribution state governments can make to the long-range encouragement of energy recovery from our solid waste would be to streamline and simplify the morass of approvals necessary to bring such a plant on line. The ever-increasing regulatory agencies involved in granting approval for construction and operation is frightening and must be simplified. Of course, new concern and control is necessary due to our expanding population and worldwide environmental considerations, but more than often State agencies have conflicting regulations or overlapping approval responsibilities which must be simplified if we are to avoid discouraging and, in fact, preventing many worthwhile projects.

Our present regulatory agencies are structured primarily for the protection of our health and safety and do not respond easily to new techniques or dimensions of scientific advancement. Decisions are often required during the design and construction stages of multi-million dollar projects that state agencies are incapable of responding to in a timely fashion. Because we live in an age of protest, they are sensitive to all objectors which is our democratic way of life, but some means must be found to avoid the unfair delay of projects benefiting many because of the often ill-considered protests of a few. A fair balance must be struck more quickly than is frequently possible at present.

If the granting of permits can be simplified without sacrificing protection for the public, a great deal of needless time and expense can be avoided. To illustrate the point, the utility bridge required to cross the Saugus River to transport the steam to the customer required approval of eight agencies or Government Legislative bodies. The approval process starts with the town or city's conservation commission which must send a favorable recommendation to the town's board of selectmen, or a city's city council or board of aldermen. Their formal approval is required before The State Department of Public Works - Waterway Division - will act on an application for construction. But in the case of the RESCO Bridge, it is a fixed span over a river that has drawn bridges both up stream and down; and, therefore, a special act of The Legislature of The Commonwealth of Massachusetts was required before DPW could act. Upon passage of that special act, they reviewed the request after examining the Environmental Impact Statement which is required for the bridge, as well as the entire project. Once finally approved by DPW, they sent their recommendation to the Corps of Engineers who have final authority. Because it is a navigable waterway, the corps would not take any action until the Coast Guard had sent in their recommendations and approvals which they would not do until after a public hearing was held. This process and the subsequent receipt of the necessary permits consumed over one year of time and numerous hours of testimony time by engineers, lawyers, and officials of the company. When one realizes the entire process could have been stymied by one partime City Park Attendant who was Chairman of the City Conservation Commission, it is apparent our precedures for approval must be modernized if we are to benefit from projects which can improve our environment and preserve our precious resources.

Our present regulations submit a developer to an unreasonable risk in that the Massachusetts Department of Public Health - Division of Air Quality - requires the submission of a complete set of drawings and specifications including detailed operating and maintenance procedures before they will act on the approval of the necessary construction permit. Because of the uniqueness of this project, the department agreed to allow five-phase submissions for approval covering the following subdivisions of design: (a) site work and foundations, (b) substructures, (c) superstructures, (d) machinery, and (e) operational and maintenance procedures. While construction is proceeding on the project, committing many millions of dollars, final approval of the plant design has not yet been received. The state has informed RESCO that no further phased approvals will be permitted by the department on subsequent projects, thereby requiring the expenditure to provide complete drawings and specifications before any approvals are granted. What reasonably prudent investor will take that risk in the future?

There is a need for legislation which will create a centralized state licensing board with the responsibility to protect the public health and safety, but which also has the power to expedite certain regulations or procedures in the overall best interests of the public.

Federal legislation, recently adopted will enable a growing number of communities to plan comprehensive solid waste management programs and investigate resource recovery options available to them. A number of localities have already been involved in planning and procurement activities. From our experiences and theirs we know that the planning process for comprehensive solid waste management services, particularly those built around resource recovery, is often a time consuming and frustrating experience. To facilitate responsible private industry's participation in providing recovery services a number of key issues should first be resolved. It is here that the Resource Conservation and Recovery Act of 1976 can be of assistance in assuming that State and regional plans are responsive to eliminating the many roadblocks hindering development of these facilities. Those state plans must assure a quantity of waste supply sufficient for the scale of the proposed facility. The economics of resource recovery partially depend upon income obtained for the disposal services rendered to the community. There are a number of different approaches to assuring sufficient waste for the resource recovery plant. In Boston, we competed in the open marketplace with landfill and other disposal operations. We feel this to be the best way to secure a long-term waste supply at a reasonable, controlled cost to the public. Other ways are being considered. They include districting, franchising, and otherwise mandating the flow of refuse within an area. In each case a community must make a long-term commitment to supply a certain quantity of refuse necessary to defray the capital and operating costs of the facility. From the communities standpoint, making these assurances will often depend upon whether the disposal services being offered at the resource recovery facility are cost competitive and as reliable as other disposal options. Congress has recognized the importance of long-term waste supply commitments by providing in Sec. 4003(5) of the Resource Conservation and Recovery Act of 1976 that local governments be given the legal authority to enter into long-term supply agreements with the private sector.

A second key issue concerns the nature of energy markets for the combustible fraction of solid waste -- markets for steam or electrical energy of fuel produced by the resource recovery process. As a general rule, income from energy production and dumping fees should meet the capital and operating costs for the resource recovery facility. The availability of long-term, stable energy markets will reduce the need to rely on dumping fees to meet plant costs. In the recently passed legislation, Congress, recognizing the importance of recovery markets to the commercialization of proven resource recovery technology, has mandated the Secretary of Commerce to develop ways to encourage markets for recovered resources.

There are, of course, other issues which are equally important in evaluating the feasibility of establishing resource recovery services. For example, are local governments able to negotiate for such services or are they limited, by law, to procurements made through a competitive bids procedure? Very often it will be difficult for a city to adequately evaluate resource recovery services if it is limited to accepting the lowest bid quoted in terms of a net dumping fee.

Before closing, there is an important observation to make about the potential for solving our solid waste disposal requirements through resource recovery. Even with the most favorable markets for recovered energy and products it is likely that there will be residue from the process which will require land disposal. In addition, most technologies being offered are unable to handle the wide variety of volatile, toxic and otherwise hazardous industrial solid waste materials. Hence, state and local governments should be under no illusion that resource recovery means the end of land disposal for solid waste. These are a necessary adjunct to a totally integrated resource recovery plan.

The RESCO plant demonstrates that an industry can benefit from the energy to be derived from the solutions of our mounting solid waste problem. Regional associations of suburban communities appear to be as logical to solve our solid waste problems as we have found them in serving our other needs, such as water, sewerage, and transportation systems. However, they often lack the means to finance these facilities and by soliciting proposals to design, build and operate the facility, they can make judicious use of private capital, possibly converting to industrial revenue bonds which gives ownership of the facility to the regional group after the amortization period.

The Europeans have been an energy-short society for years, and they have learned to recover the precious energy from solid waste that we bury daily. The technology is not new. It's time we removed the needless bureaucratic roadblocks preventing the use of that technology. To those of us who lived through it, it appears the whole process currently is out of balance, and it is the public -- all of us -- that suffers as a result.

THE IMPACT OF SOURCE SEPARATION AND WASTE REDUCTION ON THE ECONOMICS OF RESOURCE RECOVERY FACILITIES

John H. Skinner*

Background and Introduction

The rising costs and decreased availability of land, energy and raw materials have created pressures for the recovery and reduction of solid waste. In recent years communities across the nation have considered various options to reduce solid waste disposal requirements and simultaneously conserve energy and materials. These options can be grouped into the following three broad categories.

1. Waste reduction is defined as the reduction or prevention of waste at its source, either through the redesign of products or the reduction of product consumption. Examples include the use of reusable products or products with increased durability and longer lifetimes.

2. Source separation is defined as the separation of waste materials at the point of discard followed by separate collection and recycling. Source separation currently accounts for virtually all post-consumer solid waste recycling. Examples include collections by charitable, service and religious organizations, community and industry recycling centers, and municipal separate collection programs.

3. Mixed waste recovery is the processing of mixed municipal waste to recover useful materials or energy. A number of technologies have been developed and are being applied for this purpose. Most of them involve energy recovery through either waterwall combustion, production of solid refuse-derived-fuels or pyrolysis to produce liquid or gaseous fuels. Mixed waste recovery systems also include a number of unit processes to recover metals and glass from mixed refuse.

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* Dr. Skinner, Deputy Director, Resource Recovery Division, Office of Solid Waste Management Programs, U.S. Environmental Protection Agency, presented this paper at the Fifth National Congress on Waste Management Technology and Resource and Energy Recovery sponsored by the National Solid Waste Management Association. Dallas, Texas, December 9, 1976.

In recent years there has developed a debate concerning both the relative importance and the potential conflicts between these three options. Part of this debate has viewed these options from a national perspective and has explored the importance of each in dealing with the national solid waste management problem. Another part of the debate has focused on the choices and conflicts in the implementation of combinations of these options at the local level. This later issue will be the main subject of this paper. However, before proceeding along these lines, a few of EPA's major findings concerning the national policy significance of waste reduction and resource recovery will be stated. This is important to put this subject in the proper perspective because a number of prevalent misconceptions have developed on this issue. One is that large scale mixed waste processing systems can be expected to solve the Nation's solid waste disposal problems in the forseeable future. Another is that the other two options - waste reduction and source separation - are of only nominal or symbolic significance. In this regard EPA has found that:[1,2,3]

- Even with an optimistic increase in the number of cities installing mixed waste recovery systems, the total national solid waste disposed of annually will increase significantly by the mid-1980's.

- Many mixed waste processing technologies are still in the developmental stage. While accelerated implementation is expected in the future, it is not likely that more than 10 to 20 percent of the nation's solid waste will be processed in such plants in the next decade.

- Source separation and waste reduction measures can make quantitatively significant reductions in solid waste disposal requirements. However, there are market and institutional barriers to these options.

- Increased adoption of all three approaches is necessary in order to have a large positive impact on the amounts of solid waste disposed of nationwide. No single approach in itself will yield desired reductions in waste disposal levels.

The basic conclusion on this issue is that from a national perspective there is no choice between the various forms of resource recovery and waste reduction. No single "solution" can "do it all" and all three options taken together will not obviate the need for well-designed land disposal sites.

Turning now to the second issue which has been raised, concerning the potential conflict between the local implementation of the three options. Waste reduction, source separation and mixed waste recovery each offer a number of different benefits to the local decision maker and involve different costs. A few examples will make this clear. Waste reduction and source separation will reduce the requirements for both disposal and collection of solid waste, while mixed waste processing can only reduce disposal requirements. Conversely source separation involves requirements for collection and transportation of separated materials. Source separation is generally less capital intensive than mixed waste recovery, but large scale processing facilities enjoy certain economies of scale. Some waste reduction options, could effect product consumption levels, prices and litter rates, while source separation and mixed recovery may not impact these items at all. Source separation may result in recovering a few materials at higher economic values as compared to mixed waste processing. On the other hand, processing facilities employing energy recovery may result in a higher recovery rate for more of the waste stream. Any decision to locally implement combinations of these programs should be made from a comprehensive analyses considering overall costs and benefits. In fact, the recently passed Resource Conservation and Recovery Act of 1976 recognizes the importance of such analyses and mandates:

> "research and studies concerning the compatability of front-end source separation systems with high-technology resource recovery systems."[4]

This paper will address only one aspect of this subject, the impact of source separation and waste reduction programs on the economics of mixed waste recovery plants. Such programs could cause significant reductions in the quantity of recyclable materials in the waste stream. Since such materials provide a source of supporting revenues for mixed waste recovery facilities, their removal could impact adversely on plant economics, especially if such programs are instituted after a plant has been designed and constructed. This paper will present a preliminary estimate of the order of magnitude of some of these economic impacts and a discussion of their significance and relevance to recovery plant implementation decisions.

In the following sections two types of programs are analyzed:

1. paper recycling programs and their resulting reduction in the heating value, energy content and value of solid waste a fuel, and

2. metal and glass reduction and recycling programs and their resulting decrease in recycled material revenues for mixed waste recovery plants.

It must be re-emphasized that the analysis will not consider the relative costs and benefits of paper separation and container reduction as compared to recovery of these products through mixed waste processing plants. Rather the analysis will consider only the impact of such programs on recovery plant economics. Even if the impact on plant economics is negative it would be beneficial for communities to carry out such programs if the overall system economics is improved or if the benefits exceed the additional costs.

Paper Recovery Through Source Separation

Quantities and Recycling Levels. Wastepaper makes up approximately 32 percent by weight of residential and commercial solid waste* (Table 1). Several grades of wastepaper have significant potential for source separation and recovery (Table 2). Old newspaper represents approximately 20 percent of the wastepaper discarded in solid waste and most of this is generated from residences and households and is easily separated from other wastes. Old corrugated represents approximately 25 percent of wastepaper discards and most of this is generated in commercial and industrial establishments. Corrugated recovery from such sources has been practiced for years. Office papers represent approximately 13 percent of discarded wastepaper. In the past few years a number of office buildings have instituted programs to separate high grade office papers for sale and recycling. The theoretical maximum potential recovery level for all three of these grades has been estimated to be approximately 50 to 60 percent.[1,p.48] However, actual recovery levels that have been experienced have been much lower than this. Municipal separate collection programs (collecting primarily newspapers) have reported recovering from 5 to 20 percent of the total wastepaper available.[5] While individual office buildings have reported paper recycling levels ranging from 10 percent to as high as 70 percent the overall level of office paper recycling in most communities is probably very low.[6] Other wastepapers such as books, magazines and miscellaneous packaging and other papers do not offer significant potential for recycling because of their high contaminant levels, dispersed generation and heterogeneous nature.

Paper Value as a Fiber. A key factor in decisions whether to recover wastepaper as a fiber is the market prices for wastepaper. Wastepaper prices vary with grade, location and time and prices ranging from a few dollars per ton to over $100 per ton have been observed (Table 3). For certain high grade papers such as sorted white ledger (a grade which can be obtained from office paper separation programs) the fiber value is probably high enough to make source separation economically viable under most circumstances. For other grades such as mixed wastepaper, old news and corrugated, the fiber value depends upon local paper markets and could vary significantly as prices change over time. In the periods

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*Throughout this report solid waste composition percentages are defined as national average disposal levels after national average recycling rates have been subtracted. Similarly recycling and recovery percentages are defined as increments over and above present national average recycling levels and expressed as a percent of national average disposal levels.

when paper markets are strong, these grades may be extracted for recycling through increased collections by community groups, private firms or municipalities. At times of low paper prices such papers may be discarded with other municipal wastes. It is these shifts in the price of wastepaper in the local market areas, and the resulting increase or decrease in paper recycling levels that may give rise to some degree of uncertainty in the economics of energy recovery plants.

Impacts on Energy Content. In order to illustrate the impact of paper removal on the energy content of solid waste two situations will be described. The first situtation is for a plant receiving wastes from a service area with a fixed or constant quantity of waste. For example, this would represent a plant serving a fixed population community with a constant per capita waste generation rate. Prior separation and recovery of paper would reduce the total amount of solid waste received by the plant and the energy recovered (and energy revenues) would be reduced in direct proportion to the paper removal. The order of magnitude of this effect is presented for various paper recovery rates on Table 4.

The reduction in energy available from the wastes generated in a fixed service area does decrease significantly (greater than 20 percent) at very high paper recovery rates. However, in the range of actual paper recovery rates experienced (10 to 20 percent paper recovery) the reduction in total energy available is less than 10 percent.

The second situation analyzed is for a plant with an expandable service area, i.e., a plant which can expand its service area in order to fully utilize plant capacity. The fixed-no growth service area is an unlikely situation for most parts of the country. Most plants would have some opportunity to compensate for waste reductions from paper separation by expanding the service area to a larger population. Such reductions would also be offset over time by growth in the per capita waste generation rate. However, even in these situations there would be a reduction in total energy recovered. Since paper has a higher heating value than the average for mixed municipal waste, its removal results in a decrease in the average heating value of the remaining waste. This means that even if plant throughput was not reduced by a paper recovery program, less steam or fuel would be produced for every ton of waste processed. These effects are also shown on Table 4. The reduction in heating value is minimal (less than 10 percent) even for high paper recovery rates. Removal of paper does not result in a significant decrease in the heating value of the remaining waste. Solid waste with some of the paper removed will still burn.

Economic Impact Estimates. In order to illustrate the order of magnitude of economic impacts of paper separation on energy recovery plants, the results of a simple calculation are presented on Table 5. This calculation makes a number of assumptions concerning fuel price, energy recovery efficiency, heating value and processing costs as shown in the table. While these are not the actual figures for any particular plant, they are within the range of values that have been presented for various energy recovery systems. The results are presented in terms of the disposal charge or tipping fee per ton of solid waste that would have to be charged at the plant in order to cover fixed processing costs. Results are presented for both a fixed service area and a service area which can be expanded to maintain plant capacity as paper is removed.

The results show that for the expandable service area the increase in disposal charge is about $.65 per ton for the highest paper recovery rate. For the fixed service area, since the energy recovery decrease is greater and the fixed processing costs must be spread over a smaller tonnage, the disposal cost increase is greater. For the highest paper recovery rate the disposal charge increases about $2.85 per ton. For the range of paper recovery rates that have been experienced in municipal programs (10 to 20 percent) the disposal charge increases by $.70 to $1.35 per ton.

The actual numerical results derived above should be used with caution since they are based upon a number of assumptions which may or may not be valid for other resource recovery plants. However, the results do illustrate several interesting points. Paper separation programs that are instituted in areas where there are existing energy recovery plants may reduce both the capacity utilization and energy revenues of such plants. However, for plants that can expand their service areas to compensate for waste reductions from paper separation, the disposal charge increase is likely to be insignificant (much less than $1 per ton). For plants with fixed service areas, disposal charges could increase several dollars per ton at very high paper recovery rates. However, for "typical" paper recovery rates the disposal charge increase would be much smaller (of the order of $1 per ton) even for fixed service area plants. For plants that are built after the institution of paper separation programs, these impacts can be reduced even further by designing such plants for full capacity utilization. The major negative economic impact occurs for a plant that suffers a precipitous decline in delivered tonnage at a rate that cannot be compensated for by expansion to additional sources of waste. It is this situation that should be of primary concern to owners and operators of mixed waste processing plants.

Metals and Glass Separation or Reduction

Alternatives for Metal and Glass Recovery. Metals and glass make up approximately 20 percent of municipal solid waste by weight. Many mixed waste recovery plants are considering extraction and recovery of some of these fractions. Ferrous metals recovery through magnetic separation is a commercially established technology which will probably be widely used in most recovery plants in the future. However, glass, aluminum and other nonferrous metals recovery is in the developmental and experimental stage. There are a number of uncertainties concerning technologies. Markets for recovered glass and nonferrous metal resources have just begun to be developed. Given this situation any analysis of the impacts of material separation or reduction programs becomes somewhat tentative, because the economics are uncertain on both the cost and revenue side.

There are several types of programs that could effect the recovered materials revenues from mixed waste recovery plants:

1. Glass and metal source separation. While several communities have experimented with programs for the source separation and separate collection of glass and metals this option has not been practiced widely to date.[7]

2. Aluminum can recovery programs. The aluminum industry has instituted a can collection program that has resulted in the recovery of 25 percent of all aluminum cans nationwide and much higher rates in local situations.[8]

3. Beverage container deposit programs. Four States, Oregon, Vermont, Michigan and Maine have passed mandatory beverage container deposit laws. In Oregon and Vermont where the laws have been in place for several years very high return rates (greater than 90 percent) for all beer and soft drink containers have been experienced with similar reductions in container waste generation rates.

For purposes of illustrating the impacts of such programs on the material revenues of mixed waste processing plants, the beverage container deposit case will be used as a model. On the average, beverage containers make up 45 percent of the glass, 38 percent of the aluminum and 15 percent of the ferrous metal in mixed municipal waste (Table 2). It will be assumed that container deposit programs will result in a complete elimination of the beverage container fractions from the waste stream. While this is certainly an exagerated impact it serves to maximize the reductions in recovery plant material revenues.

Impact on Gross Revenues. Estimates of the gross revenue contributions for metals and glass recovered in a mixed waste processing plant are shown on Table 6. Gross revenues represent simply the recovered material sale prices and do not account for the costs of extracting and recovering these commodities. Because of the uncertainties and variations in some of these numbers the estimates are shown as a range rather than a point value. These variations are due to differences in:

1. recovery efficiences which depend upon the technology employed and the quality of the product recovered, and

2. recovered material sale prices which depend upon the markets and the product specifications.

The numbers shown represent the range of efficiencies and prices that have been discussed in the resource recovery literature. The upper range represents pushing the technology to its limits and receiving top prices for the products. The lower range represents minimum efficiencies and relatively poor market conditions. The gross revenues from ferrous metals, glass and aluminum range from $2.75 to $6.00 per ton of solid waste processed. All other things remaining constant, an elimination of the beverage container fraction would reduce these gross revenues by $.70 to $1.60 per ton of waste processed. However, as will be discussed in the following sections, removal of glass and aluminum beverage containers may reduce revenues from other glass and aluminum products. Moreover, conclusions regarding the impact of beverage container policies on the overall economics of mixed waste processing plants must consider the net revenue contributions after processing costs are accounted for.

Impact on Net Revenues. Net revenue calculations are subject to wide margins of uncertainty. There has been very little analysis of the costs of processing specific components of the waste stream. It is very difficult to separate the incremental costs of steel, glass and aluminum recovery from the overall plant cost figures. It is even more difficult to evaluate how these costs might change as a function of changes in the quantity and composition of the wastes processed. Therefore, the cost presented are a very rough first approximation.

The recovery plant considered is a refuse-derived-fuel plant that recovers ferrous metals by magnetic separation and glass and aluminum by a combination of heavy media separation, froth flotation, optical sorting, and electrostatic separation. The approach used is to estimate only the incremental cost of separating the ferrous, glass and aluminum fractions. This means that the basic costs of shredding and air classification have not been allocated among these products. This is the correct approach in determining whether or not materials recovery subsystems should or should not be included in a project--that is in terms of their incremental contributions to processing costs and net revenues. The results are shown on Table 7.

The incremental process costs for ferrous metals recovery have been estimated separately. Glass and aluminum recovery share many of the unit processes in common making it impossible to separate the processing costs for these two materials from each other. These costs estimates include fixed and variable operating costs and capital costs amortized over the plant life.

The incremental process costs of ferrous metals recovery are estimated to be in the range of $.50 to $1.00 per ton of solid waste processed and the costs of glass and aluminum recovery are estimated to be from $1.70 to $2.00 per ton of solid waste processed. These process costs, when subtracted from the high gross revenue estimates derived previously result in net revenue contributions for ferrous metals recovery ranging from $2.20 to $2.70 per ton and for glass and aluminum recovery ranging from $.85 to $1.15 per ton. (It should be noted that for the low gross revenue estimates aluminum and glass recovery is not economical, i.e. the incremental processing cost exceeds the gross revenue contribution).

Removal of 15 percent of the ferrous metals would probably not effect processing costs significantly and recovery of the remaining 85 percent would still be economically feasible. Therefore, the impact of removal of ferrous beverage cans on ferrous metal revenues is roughly equal to the reduction in gross revenues which is about $.50 per ton.

For glass and aluminum recovery the effect of beverage container removal is more complicated to analyze. Many aluminum recovery subsystems are more efficient with respect to recovery of aluminum cans than other aluminum products (such as foils). A given reduction in aluminum cans could result in a much greater reduction in the percentage of total aluminum recovered. In the extreme, removal of the aluminum can could make recovery of the other aluminum fractions unprofitable. Also, the economic feasibility of glass recovery is closely linked to aluminum recovery as many of the processing steps are combined for the two materials.

Therefore, the impact of removal of glass and aluminum containers could range between two extremes. In the best situation net revenues would be reduced only in proportion to the reduction in the container fractions and would range from $.35 to $.45 per ton of solid waste processed. In the worst situation removal of the glass and aluminum container fractions would make other glass and aluminum recovery economically unfeasible and the net revenue loss would be from $.85 to $1.15 per ton of solid waste.

In summary, for plants recovering only ferrous metals, the removal of beverage container materials could reduce net revenues by roughly $.50 per ton of solid waste processed. For plants also recovering aluminum and glass, and receiving high gross revenues for these products, beverage container removal could reduce net revenues by an additional $.35 to $1.15 per ton. As for the paper separation analysis, these results could be extended to estimate the disposal charge impact for both fixed and expandable service areas. It was decided that this further refinement would not be meaningful due to the uncertainties in these numbers in the first place. The net revenue reductions approximate the disposal charge increases.

Conclusions

The previous sections presented estimates of the effect of paper separation programs and beverage container reduction programs on the economics of mixed waste recovery facilities. These estimates are based upon a number of assumptions concerning the composition of the waste stream, technology performance and costs, and recovered material market prices. As was pointed out, there is a certain amount of variability in each of these parameters and the results could be different for plants employing different technologies or for plants located in different parts of the country.

The analysis showed that the impact of paper separation programs on plant disposal charges could range from a few cents per ton to several dollars per ton depending upon the paper recovery rate and the plant capacity utilization. However, considering the paper recovery rates that have been experienced, and considering that many plants should be able to compensate for waste reductions by expansion of service areas; the likely increase in disposal charge for most plants would probably be much less than $1 per ton.

The analysis also showed that beverage container reduction programs could reduce recovery plant net revenues from $.50 per ton to over $1.50 per ton depending upon the technology performance and recovered material market prices. For plants recovering only ferrous metals the impact would be in the lower end of this range. Revenue reductions in the upper range would only occur for plants recovering glass and aluminum as well, and achieving high recovery efficiencies and receiving high market prices. Therefore, for most recovery plants the likely impact of beverage container reduction programs would probably be much less than $1 per ton.

Given the uncertainties that exist in resource recovery technologies and markets, possible cost changes within the range of $1 per ton should not be determining factors in community decisions. Future costs cannot be projected to this degree of accuracy. Small changes in construction costs, interest rates and material and energy prices could produce comparable effects.

Of course, there is the possibility that resource recovery markets and technologies might develop to the point that the impacts of separation and reduction programs could be greater than what is presently considered likely. This raises the question of what actions, if any, should be taken by resource recovery plant operators to guard against such negative economic impacts. Should communities contracting with recovery plants be prohibited from engaging in municipal source separation programs? Should there be penalties if a community (or State) passes a returnable beverage container ordinance? It is believed that such drastic measures are <u>not</u> necessary to protect resource recovery plant investments.

It is important to realize that over the 20 to 25 years lifetime of a mixed waste recovery plant there will probably be a number of changes that would impact on plant economics. Many of these changes will be "uncontrollable" and will be brought about by private sector free market actions. For example, increased use of plastic beverage containers could reduce the metal and glass content of solid waste and produce effects similar to beverage container deposit programs. Private sector paper recycling could produce effects similar to municipal source separation programs. Changes in the prices of fiber and energy could effect the relative economics of paper separation versus energy recovery. Recovery systems that are being built today are going to have to be designed to accomodate such changes.

Mechanisms and institutions need to be developed for managing these uncertainties and share some of the potential risks and benefits between local governments and recovery plant owners and operators. Communities should try to maintain the flexibility to implement new programs that would improve the overall economics and environmental impacts of their solid waste management systems. Contract provisions or agreements that foreclose future improvements are unwise. However, provisions that equitably allocate costs and responsibilities are also a necessity. The potential uncertainties concerning public policies for source separation and waste reduction programs should be handled within such a framework.

Table 1

Material Composition of Residential and Commercial Solid Waste*

Material	Percentage
Paper and Paperboard	32.3
Glass	9.6
Ferrous	8.4
Aluminum	0.8
Other Nonferrous	0.4
Plastics	3.7
Rubber and Leather	2.6
Textiles	1.4
Wood	3.6
Food Waste	16.8
Yard Waste	19.0
Miscellaneous Inorganics	1.4
	100.0

*U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Fourth Report to Congress, Resource Recovery and Waste Reduction. Draft, November 1976.

Note: Estimates on an "as generated" weight basis assuming normal moisture content of material prior to discard.

These are national average disposal levels after national average recycling rates have been subtracted.

Table 2

Selected Product Composition of Residential and Commercial Solid Waste*

Material		Percent of Total Solid Waste
Paper and Paperboard		32.3
Newspaper	6.0	
Office Paper	4.1	
Corrugated	8.2	
Books and Magazines	2.6	
Other Packaging	8.4	
Other Nonpackaging	3.0	
Glass		9.6
Beer and soft drink containers	4.3	
Other containers	4.5	
Other products	.8	
Ferrous		8.4
Beer and soft drink containers	1.2	
Other containers	3.2	
Durable goods and other products	4.0	
Aluminum		0.8
Beer and soft drink containers	0.3	
Foil	0.3	
Other Products	0.2	

*U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Fourth Report to Congress, Resource Recovery and Waste Reduction. Draft, November 1976.

Note: Estimates on an "as generated" weight basis assuming normal moisture content of material prior to discard.

There are national average disposal levels after national average recycling rates have been subtracted.

Table 3

Selected Wastepaper Prices*
($/Ton)

	New York Market		Chicago Market		Los Angeles Market	
	August 1975	October 1976	August 1975	October 1976	August 1975	October 1976
No. 1 Mixed	$5	$5 - $10	$5 - $12	$15 - $18	$8 - $9	$8 - $9
No. 1 News	$10	$30	$18 - $25	$40	$20 - $22	$25 - $27
Corrugated Containers	$0 - $5	$20 - $25	$15 - $20	$40	$22 - $24	$43 - $47
Sorted White Ledger	$70 - $75	$85 - $95	$60 - $70	$90 - $100	$80 - $85	$100 - $110

*Official Board Markets, Magazines for Industry Inc., Chicago, Illinois, Volume 51, No. 32, August 9, 1975 and Volume 52, No. 44, October 30, 1976.

Table 4

The Impact of Paper Recovery on the Energy Content of Solid Waste

Paper Recovery Rate (percent)*	Fixed Service Area Reduction in Energy Available (percent)**	Expandable Service Area Reduction in Energy Available (percent)+
10	5.3	2.2
20	10.8	4.6
30	16.0	7.0
40	21.5	9.9

*Defined increments above present national average recycling rates, as a percent of present national average rate of wastepaper disposal.

**Reduction in energy content of a fixed quantity of waste caused by the removal of paper.

+Reduction in average heating value per unit weight of waste. Calculated from data by Niesson, W. R. and S. H. Chansky, "The Nature of Refuse", Proceedings of 1970 National Incinerator Confernce.

Table 5

Impact of Paper Recovery on the Disposal Charge of an Energy Recovery Plant

	Disposal Charge (per ton of solid waste)	
Paper Recovery Rate*	Expanded Service Area	Fixed Service Area
0	8.50	8.50
10	8.65	9.20
20	8.80	9.85
30	8.95	10.55
40	9.15	11.35

Assumptions:

1. Energy revenues $1.00/million BTU.
2. 65 percent of input waste is converted to energy.
3. Heating value of solid waste with no paper recovery 10 million BTU/ton.
4. Fixed costs (capital costs and fixed operating costs) of $15 per ton of daily plant capacity.
5. Other materials revenues are not included.

*Defined as increments above present national average recycling rates, as a percent of present national average rate of wastepaper disposal.

Table 6

Recovered Metal and Glass Revenues

Recovered Material	Percent of Solid Waste	Recovery Efficiency	Material Sale Price (per ton)	Gross Revenue (per ton of solid waste)
Ferrous Metal	8.4	95	\$20 - \$40	\$1.60 - \$3.20
Glass	9.6	40 - 60	\$5 - \$20	\$.20 - \$1.15
Aluminum	.8	40 - 70	\$300	\$.95 - \$1.70

Table 7

Net Revenues from Metal and Glass Recovery
($/ton of solid waste)

	Ferrous Metals Recovery	Glass and Aluminum Recovery
Gross Revenues (high)	$3.20	$2.85
Incremental Process Cost*	$.50 to $1.00	$1.70 to $2.00
Net Revenue Constribution	$2.20 to $2.70	$.85 to $1.15

*Derived from: Resource recovery engineering and economic feasibility for either a 650 or 1300 ton per day processing facility. National Center for Resource Recovery, Inc. Report prepared for the Metropolitan Washington Waste Management Agency. Washington, D.C., January 1975.

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8. Press Release, The Aluminum Association, New York, May 11, 1976.

REGIONALISM: ITS ROLE IN RESOURCE RECOVERY

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THE ISSUE OF REGIONALIZATION

Over the past three or four years we have learned a few things about planning for resource recovery. First, and most important, we have learned just how difficult it really is to plan and establish a facility that, in reality, is a complex manufacturing plant processing raw materials, solid waste, provided for the most part by local governments. From these raw materials the plant produces energy products for sale such as steam, gas, oil, refuse derived fuel, or electricity, and materials such as ferrous metals, aluminum, or glass. Because of the high cost of these plants, the trend is to finance them through the issuance of revenue bonds supported by financially strong revenue streams under contract. The revenue streams are derived from the sale of energy and materials, and fees for refuse disposal from local governments and private refuse collectors. The job of putting the system together requires selection and negotiation of markets, technologies and capable private firms for design, construction, and operation. It also requires selection of sites and definition of long term commitments to deliver refuse to the facility.

One conclusion from this is that the resource recovery planning process requires skills, time, money, conviction, and political and entrepreneurial strength not possessed by most local governments. Another conclusion is that a long term and reliable energy customer is needed, as well as sites for the processing facility and for disposal of process residues and emergency use. Both the energy customer and the sites must be within the boundaries of the local jurisdiction planning the facility, and most local jurisdictions are hard pressed to come up with these. A final conclusion is that there must be sufficient refuse generated within the jurisdiction to supply the type of facility that is otherwise appropriate for the area, based on energy and materials markets, site locations, and private industry interest.

These conclusions point to the need in a number of cases for local governments to join together in some manner and regionalize so that they can expand the market opportunities, the siting options, or increase the amount of waste available for processing to a level where the capital investment for the facility is warranted. It seems a pity that resource recovery implementation is going to be dependent upon regionalization, since it is such a difficult thing to bring about. On top of the difficult technical and financial planning tasks required for resource recovery itself, in regionalization we must also address what may turn out to be an even more complex political and organizational planning task.

Certainly, there is nothing new about forming regional organizations or cooperative efforts. In water supply, wastewater treatment, delivery of educational services, local purchasing, and even police and fire protection there are numerous experiences to demonstrate that certain government functions or services can best be performed on a broader metro-urban regional basis. But the diversity of local environments makes it unwise to expect that an effective approach for one area will necessarily be applicable to another. It is equally unwise to believe that such new government forms are easy to define and create.

The purpose of this paper is to illustrate why regionalization in solid waste disposal and resource recovery is important, to discuss the approaches that can be used and the problems in achieving them, and to make some general recommendations which will hopefully speed up progress.

THE SOLID WASTE RESPONSIBILITY OF LOCAL GOVERNMENTS

In the United States about 70% of the people are packed into densely populated urban areas. About 30% of these people live in the central city itself while the remainder (40%) live in communities surrounding the central city. For the most part, local units of government are individually small. Although there are almost 2000 cities with a population over 10,000, almost 60% of these are actually smaller than 25,000 people. In total we have more than 30,000 units of local government. It is clear that, by far, the majority of these are extremely small. Individual counties are not much larger, with almost 80% of the 3000 counties having a population of less than 50,000 people.

Although figures are not very good, we have reason to believe that many thousands of local governments are themselves responsible today for their own solid waste disposal, and thus will have a key voice in what their new procedure will be when the current one is no longer available. Estimates indicate that there are over 18,000 land disposal sites in the country, of which some 6000 are state approved*. Almost 4000 of these are publicly owned and operated. Obtaining solid waste disposal capacity is certainly a problem, since in a 1973 survey** local governments ranked the need for disposal sites their number one problem, and 46% of the governments reported they had less than five years of disposal capacity remaining.

In summary, there are thousands of local governments responsible for deciding how to dispose of their solid wastes. Among their decisions is the one to regionalize or to find a solution by themselves.

THE REGIONALIZATION ARGUMENT

The basic argument for regionalization in solid waste disposal and resource recovery is that the function is a capital intensive one that, within a certain size range and in the majority of cases, can be performed at a lower unit cost at larger scales. A second, but no less important argument, is the need to provide both a site or sites for processing as well as disposal of residue and nonprocessable items, and the possible need for close proximity of processing with a secure energy customer, such

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*Waste Age, "Survey of the Nation's Land Disposal Sites", January 1975, p.17.

**National League of Cities-U.S. Conference of Mayors, "Cities and the Nation's Disposal Crisis", March 1973.

as a user of steam or gas. A third and more philosophical argument -- but one which may indeed be the most important -- is that the solid waste management objectives of this nation will not be served be providing resource recovery solutions for only those few local governments who happen to have the right conditions for it within their borders.

The realities of these arguments have been recognized by many:

- National League of Cities, Cities and the Nation's Disposal Crisis, 1973, p.7 - - -"The solutions to [solid waste] problems require: (1) resources and support functions that exceed the internal capability of cities, (2) available land areas for disposal, which many cities increasingly lack within their political boundaries."
- U.S. Environmental Protection Agency, Decision-Makers Guide in Solid Waste Management, 1976, p.95 - - -"Resource recovery systems require large quantities of waste delivered for processing at one site in order to achieve economies of scale . . . plants in the 500 to 2000 ton-per-day range are likely to be the most economical."
- Urban Systems Laboratory, M.I.T., Summer Study on the Management of Solid Wastes, 1968, p.5 - - -"In solid waste management there appears to be overwhelming cost advantages in being big."
- Committee for Economic Development, More Effective Programs for a Cleaner Environment - A Statement on National Policy, April 1974, p.50 - - -"These considerations [community size, availability of land, expertise] lead to the suggestion that regional agencies may be desirable for management of solid waste collection, recovery, and disposal in many areas."

ECONOMIES OF SCALE IN RESOURCE RECOVERY TECHNOLOGIES

There is sufficient data available for most resource recovery technologies to substantiate the statement that, in general, the cost of owning and operating a resource recovery facility decreases as its size or scale increases. In Figure 1 this is illustrated with data on three different technologies (bulk incineration, refuse derived fuel, and pyrolysis) prepared for three separate projects in different areas of the country. Net cost per ton, or the estimated disposal fee in $/ton, is plotted against facility size, and the only conclusions that should be made from the Figure are that net disposal fee can decrease with an increase in facility size, and the value of the decrease varies widely for different technologies, as well as for the same technology when applied in different projects and at different times.

An essential statement to make about interpreting this type of data is that it is virtually useless in predicting the cost of resource recovery elsewhere. Differences in cost of 100% or more for basically the same system can occur for a number of reasons:

- The equipment and construction costs can be substantially different because of differences in the cost of land, site preparation, or the year in which the estimate was prepared.
- The basic technology actually can be quite different in design in terms of redundancy, design for overall availability, or extent of processing. Producing electric power from steam, for example, requires an additional large capital investment for a turbogenerator over the investment required for the production and sale of the steam itself.
- A number of cost elements are frequently left out of estimates, including bond expenses, contingencies, interest during construction, residue disposal, taxes,

SAMPLE DATA
RELATIONSHIP BETWEEN NET COST OF DISPOSAL AND FACILITY SIZE

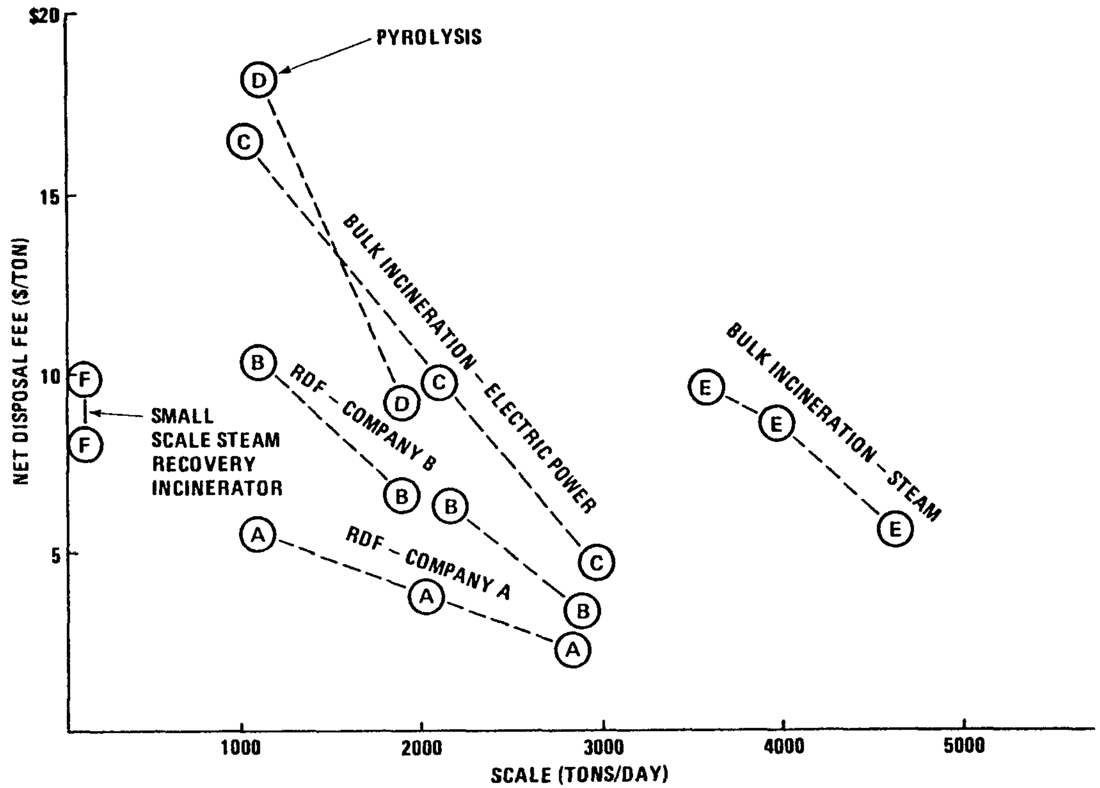

Figure 1

etc. For line E in the Figure, for example, the inclusion of local property taxes alone (which has been left out) adds another $3.50 to the net disposal fee.

Projects have different degrees of risk built into the estimated net disposal fee. The system represented by line A in the Figure was competing against the system represented by line C. One problem was that the expected income from the sale of RDF included in the computations for system A was highly speculative, while that for the sale of electric power from system C was quite firm.

The issue, again, is that it is very difficult to translate cost data, particularly net disposal fee, from one project to another.

Also shown on Figure 1 is an example of a recent estimate for a 50 ton per day (capacity) modular steam recovery incinerator, a so-called small scale system (line F) now in operation in a city of approximately 30,000 people. Steam is currently being sold to a local industry. The lower point shown ($8.00/ton) represents the net disposal fee to be paid by the city when the quantity of steam sold at the contracted price is what it was originally planned to be when the decision was made to construct the system. The upper point ($10.00/ton) is computed from actual experience to date. These data are provided in the Figure to illustrate an actual case in which a local small scale resource recovery system was chosen. Such a small scale system can be installed in communities from 30,000 people up to 150,000-200,000 people, provided there exists a reliable steam customer whose steam requirements are compatible with what the system provides. This is a critical need since without the sale of steam, the net disposal fee would be much higher. For example, the fee for system F (in the Figure) would be about $17.00-$20.00 per input ton without the income from the sale of steam.

It appears at this point in time that small scale technology systems are most likely with steam production, although under investigation now are off-the-shelf small scale turbogenerator systems for waste heat recovery. It is possible that these can convert, at a small scale, solid waste to electricity for sale at competitive prices, and result in a net disposal fee comparable with that realized for the small scale production and sale of steam. The importance of this, of course, is the vast expansion of opportunities because of the marketability of electricity as compared with steam, although matching electric power supply and demand also presents formidable problems. Other small scale system opportunities are possible with materials recovery, perhaps even refuse derived fuel preparation (RDF); however, the problems of marketing small quantities of such materials are well known.

This small scale system case is presented because it must be one of the options to be considered by local decision makers. If it is believed that the net disposal fee for a small scale system (or local landfill) dedicated to the community will be approximately the same as that for a large scale regional system, then many local officials will probably opt for the former. This is because of the difficulties associated with regionalization discussed later. In any event, if that decision is presented to them, they will certainly find it a challenging one!

As a concluding comment, it has to be recognized that the use of small scale systems does not make regionalization unnecessary. Even with small scale systems, communities under 25,000 population probably will find it necessary to team up with other communities in a joint solution. Furthermore, a concept likely to evolve is the use of a group of small scale systems linked together as a network within a region to form a single "system". This system would function as a single unit; it is a regional system in disguise.

THE TRANSPORTATION COST ISSUE

An important cost element in any resource recovery system is the cost involved in transporting the refuse to the facility. This is particularly important in regional systems. In the case of a central city of about 1-1/2 million people the 3000 tons per day generated represents the input for a large scale system, probably without an increase in transportation costs. In fact, transportation costs actually can be reduced since the facility may be more centrally located than existing and planned landfills. The cases we want to focus on, however, involve a smaller central city and its suburbs, or a group of small to medium communities, within an area spanning 50 miles or even greater, who may be able to jointly consider their solid waste disposal problem. Analyses performed recently show that transport of solid waste over distances of 40 miles or more can be "economically feasible", when considering three key questions relating to economic feasibility:

(1) The benefits of the economies of scale in processing achieved by having a larger quantity of solid waste available for processing.

(2) The alternative cost for solid waste disposal by whatever other option is available locally, considering also projections about increases in this cost.

(3) The manner in which the overall regional costs of solid waste transport, processing and disposal is to be apportioned.

We want to illustrate in the next few figures how these questions relate to the overall decisions that must be made about what communities might be included in a regional system project.

Figure 2 illustrates the tradeoff of processing costs with transportation cost as the size of the region increases. Note that an increase in region size is equivalent to an increase in facility scale, which is

RELATIONSHIP OF PROCESSING AND TRANSPORTATION COSTS WITH REGION SIZE (HYPOTHETICAL DATA)

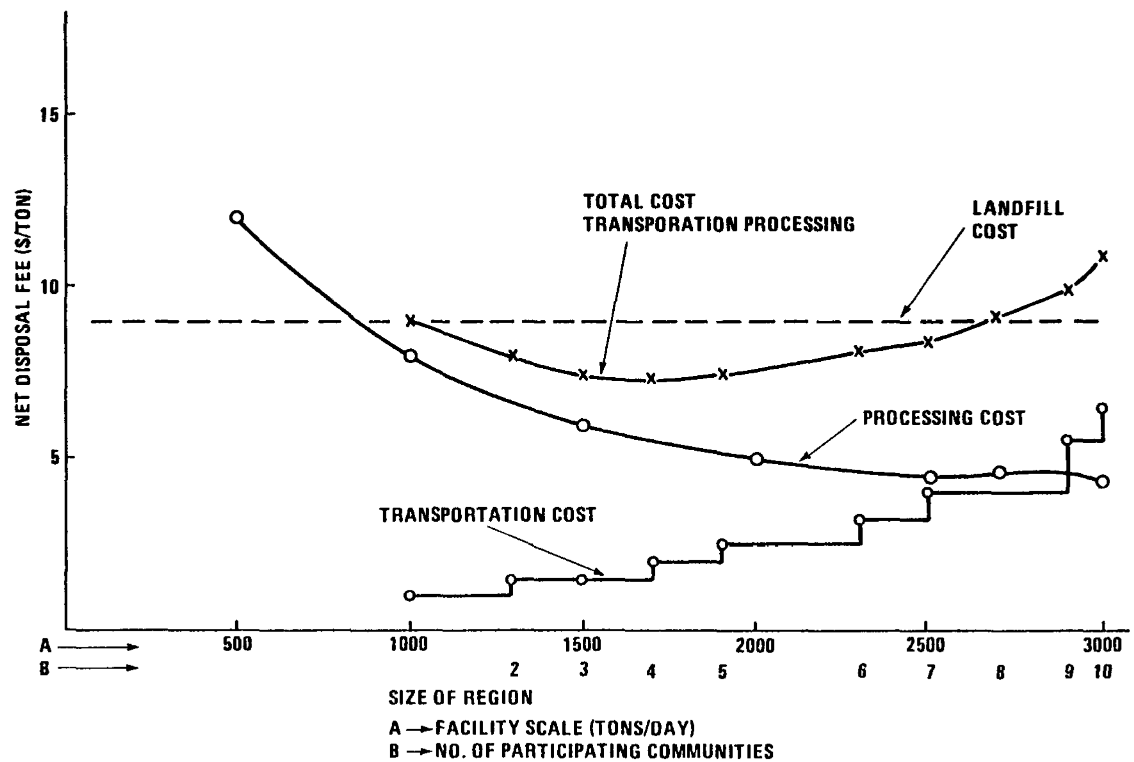

Figure 2

the same as an increase in number of communities which participate, and the same as an increase in the maximum distance over which solid waste is transported. Shown are four curves:

- Processing cost per ton which diminishes with scale. (Note that the processing curve in reality is a set of discrete points representing specific designs at each scale.)
- Transportation cost per ton which increases with scale. This is shown as a step function with steps occurring at the points where each new community enters.
- The sum of processing and transportation costs, which, in this example, diminishes with scale up to about 1700 tons per day (four communities) and then increases.
- An assumed standard landfill (or otherwise whatever alternative disposal system that is available) cost of $9.00 per ton for each community. Actually, each community probably has a different alternative cost based on their landfill, incinerator, or small scale system option and the transport cost associated with that option.

From the figure it appears that the best decision for the region is to scale the facility at 1700 tons/day and plan for participation by the four closest communities; adding the fifth community causes the total average disposal cost to increase. But what if the fifth community -- and possibly others -- are willing to pay more than the minimum disposal plus transportation fee of about $7.00 per ton. This is possible as long as the fee does not exceed the total cost of their alternative disposal system, say landfill at $9.00/ton? In fact, the range between the two figures is a "bargaining range". Under such a transportation cost sharing arrangement, it actually may be better for all participating communities to enlarge the system beyond the point at which the total average cost is a minimum. With this concept in mind, it is possible to define more comprehensively what "economic feasibility" really means in a regional resource recovery system.

The concept of transportation cost sharing is not common in this country. This is because most of the large scale systems that have been implemented have been located in densely populated, urban areas with ample supplies of solid waste. Therefore, it has not been required that outlying communities' tonnage be recruited, or when cost sharing did take place, the arrangement has been such that each community could pay its own transport costs. There are, however, precedents for transportation cost sharing in Europe, specifically in Paris and London, where large scale facilities (or even an "integrated" set of smaller facilities) require the waste contribution of distant municipalities. These two cities have taken the view that part of the cost of refuse transport is related to disposal and hence, a basis for sharing costs has been established. In both cases, the cost sharing formulae are determined by the distance involved in transporting refuse from the end of the collection route to the processing facility. Reductions in disposal fees are granted to those municipalities which have to travel more than a given distance to the processing plant.

In real practice, and when a number of independent local jurisdictions are considering the issue, the overall question of cost sharing is possibly even more complex than has been depicted above. Consider, for example, the overall transportation schematic shown in Figure 3. The lowest cost total regional design involving a number of individual communities may result in different modes of transportation for three groups of communities:

1) Those communities (Group A) that are near the facility and thus may proceed directly to it from the end of their collection route. This is direct packer truck haul.

REGIONAL RESOURCE RECOVERY PROJECT TRANSPORTATION SCHEMATIC

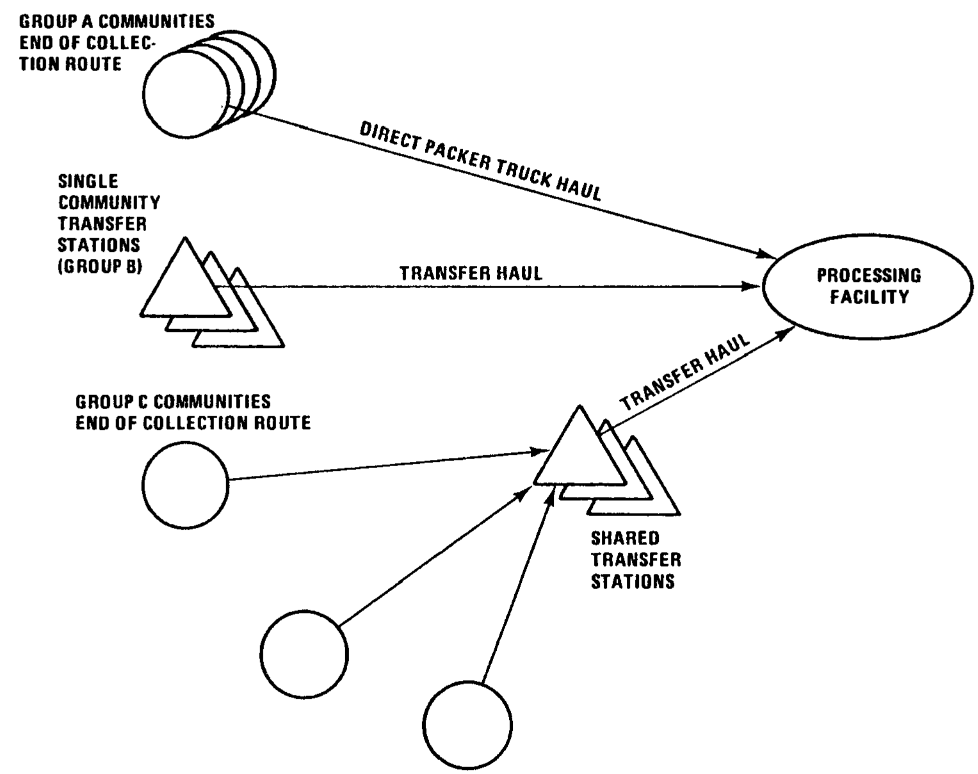

Figure 3

2) Those larger communities (Group B) located more distant from the facility which may be assigned a transfer station and haul system that is dedicated to them. This is termed single community transfer haul.

3) Those smaller communities (Group C) also located more distant from the facility which may share in the use of a transfer station and haul system. This is shared community transfer haul.

Note that in this overall regional transfer system each community, from a local government accounting standpoint, has two types of transportation costs:

1) Those involving the existing packer (collection) trucks, and thus are a part of the current ongoing annual appropriation for refuse collection. In the regional system these costs are probably handled in the normal manner regardless of whether city collection or contract collection is the current practice. In a sense, these costs are relatively invisible.

2) New costs associated with the transfer station and transfer haul. These are paid to the owner-operator of the transfer-haul system, a private contractor or another government agency. These are highly visible costs.

The result of this transportation system is that Group A communities incur no new costs, but may incur a change in the amount of existing collection costs resulting from a change in the distance to be traveled from the end of the collection route to the facility. Group B communities have the new transfer haul cost elements to consider, and possibly some change, most likely a slight reduction, in collection costs because of the more advantageous location of their transfer station. Group C communities incur new transfer-haul costs and possibly added collection costs to deliver solid waste to the shared transfer station.

From all this the important question to raise is -- how should transportation costs be shared and what cost elements should be considered in the sharing arrangement? This is one of the questions that can send the best regional plan into a tailspin. For example, these are a sample of the problems:

- The host community may not want to share transportation costs with outlying communities at all, and yet if it doesn't, the plan is not economically feasible for any community.
- Based on the particular sharing plan and the costs involved, it may appear that certain communities are getting preferential treatment since their new costs, which again are highly visible, may be much lower than that paid by other communities. In fact, the new costs could even be negative resulting from a regional system plan which calls for a particular community to direct haul a much longer distance.
- Based on what it believes it is to pay for the regional disposal service each community must decide if it is to participate. This is done by comparing the cost of regional disposal with the cost of its alternative disposal options. Because of the complexity of the cost elements involved, it is quite possible for the wrong comparison to be made. It is also possible for local officials to make the correct decision, but be unwilling or unable to follow through because of the complexity of the issue and, thus the difficulty of selling it politically.

But perhaps the real issue concerns who is in charge; who is really making the decisions? The answer to that is determined by how the regional thrust is organized and managed.

SOME COMMENTS ON REGIONAL ORGANIZATION

Experience has aptly demonstrated that voters are not moved by the arguments of economies of scale, efficiency, and regionalization. Metropolitan plans have been defeated at the polls time after time. Fragmented metropolitan government is the result of fear of loss of power, prestige, and responsibility, as well as a genuine concern that a regional body may become more concerned about itself than its member units. It is also the result, in large part, to the values and life styles of families which have moved to the suburbs. This is a political fact of life that must be reckoned with; the potential for regionalization, how one goes about it, and what form is to be sought are all tied up in the political situation unique to the area.

The simplest regional mechanism to consider for resource recovery is the intergovernmental agreement in which one jurisdiction agrees to deliver a service to another for a stipulated fee. The advantage to this mechanism is that it bypasses the need for organizational changes. Another version of this arrangement exists when a private company is to own and operate the facility on a full service basis under a franchise arrangement with the host or sponsoring community. Refuse delivery and disposal agreements, with this arrangement, exist between communities and the private operator, not the sponsoring community. Because of a lack of experience with this, communities seem unable to distinguish between the two arrangements. But there is an important difference indeed, since in one case a community must perform, and in the other a private firm must perform!

Other regional arrangements are much more complex than the interlocal agreement or private contract since they involve the creation of authorities, or special districts, or assigning the responsibility to an existing regional body such as a county, Council of Government, or state.

Each regional approach involves a unique assignment of responsibilities and risks. It is important to consider how the issues of siting, contracting, and cost sharing are to be treated under each that is considered so that the arrangement is fair and equitable for all participants.

CONCLUSIONS

There is no doubt that regionalism in resource recovery is important to progress. We certainly cannot afford to conclude that regionalization is too difficult to consider, and thus assume that we will have some 18,000 small scale systems to replace landfills in existence today. Nor is it useful to assume that local governments will somehow be able to decide what is best and act accordingly. We must worry about the piecemeal approach to resource recovery implementation in which a few communities implement projects for themselves leaving the surrounding communities without an economically viable solution. Every community in the nation must have an economic and environmentally sound means for solid waste disposal. States must accept the responsibility to see that this occurs, but they must recognize and cope with the issues discussed in this paper: markets, siting, waste volume, traffic, environmental impacts, and cost apportionment among local jurisdictions. This requires that states engage in rather sophisticated and detailed economic planning to determine which jurisdictions should regionalize. They must begin to understand the economic consequences in total and the impact on each community of various siting and transport options*. Subtitle D of the new Resource Conservation and Recovery Act of 1976 (PL 94-580) recognizes this need and provides guidelines for starting the planning process.

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*In many cases the economic tradeoffs involved in such planning cannot be evaluated intuitively. Computer models are available to aid in such planning.

In each state and in each local situation we eventually must come face to face with the questions about mandatory participation in a regional project. Should the state, or a substate regional body, require communities to transport and deliver their waste according to a plan, or should communities' participation be optional. The answer is not at all clear. States must have strong, well managed programs and the fiscal, institutional, and regulatory tools needed for implementation, but communities that can successfully solve their solid waste problem within their boundaries should be permitted to do so.

It is more important than ever that efficient resource recovery systems at both the large and small scale are available. For many communities regionalization will not be the answer. For others a network of smaller facilities will be preferred over a centralized system.

It is quite clear that there is a much larger role for private industry in resource recovery that in other municipal service areas. The role includes operation of resource recovery facilities, as well as collection and transport operations. Under this arrangement communities must realize that in a regional project they may be contracting with a private firm, not another community, and so the traditional fears of regionalization may not be relevant. They should concern themselves with the wording of the contract and not their long standing dislike and fear of the host community.

DESIGN AND OPERATION OF THE PUROX SYSTEM DEMONSTRATION PLANT

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The PUROX System is a refuse processing plant which converts a low quality, environmentally undesirable material into desirable products. Municipal refuse is converted into a clean burning, low sulfur fuel gas; an inert, glassy aggregate; scrap iron for recycling; and a wastewater stream that has been cleaned to existing discharge standards. This conversion is accomplished by gasifying the organic fraction of the refuse and slagging the inorganic material. Water from the gasification is removed from the gas stream and treated to required standards. The glassy aggregate that is produced is an inert, non-leaching material. The ferrous material in the refuse is removed after shredding by magnetic separation. The organic fraction is gasified to fuel gas.

This paper will present a detailed process description of the 200 ton/day PUROX System demonstration plant in South Charleston, West Virginia. Equipment description and product stream analyses are also included.

SECTION I. INTRODUCTION

The development of the PUROX System technology began in the Union Carbide laboratories in the late sixties with fundamental investigations into the gasification of refuse. As a result of these theoretical studies and bench scale demonstrations, the basic PUROX System technology, the gasification of refuse in a vertical shaft furnace utilizing pure oxygen, was developed. The initial development of the concept was carried out in a 5 ton per day pilot furnace which was built and operated in the Union Carbide Technical Center in Tarrytown, New York. A history of the early development of the process and a general description of the operation of the pilot unit were presented in a paper given by Dr. J. E. Anderson, the inventor of the process, at the 1974 National Incinerator Conference.(1) The successful operation of the unit resulted in the conceptual design and economic evaluation of commercial scale PUROX System plants. The favorable results of these initial evaluations led to the decision by Union Carbide to finance and construct a 200 ton per day full scale prototype plant in South Charleston, West Virginia. Operation of the demonstration plant began in April, 1974. Initial operation of this plant was described in a paper presented in September, 1975 at the 80th National Meeting of the A.I.Ch.E.(2)

A schematic drawing showing the basic operation of the shaft furnace is presented in Figure 1. Refuse is contacted countercurrently with hot gas from the combustion reaction occurring in the hearth. The hot gas transfers heat to the refuse, and the gas is cooled in the process. As the solids proceed down the shaft they are heated by contacting progressively hotter gas. Initially, as drying of the solid occurs, free water in the refuse is vaporized. As temperatures in the solid continue to rise, gasification of the organic portion of the refuse begins to occur by pyrolytic reactions. These reactions convert from 50 to 60% of the original weight of the refuse to gaseous products. The pyrolytic residue, which consists of non-volatilizable carbonaceous material, and the inorganic portion of the refuse, is consumed in the hearth in a combustion reaction with pure oxygen. The oxygen reacts with the carbonaceous fraction of the char to liberate the energy required to melt the inorganic materials into a fluid slag product. The hot gases from this combustion reaction also provide the energy to carry out the drying and pyrolysis reactions in the upper shaft.

The details of the pyrolytic reactions and the rates at which these reactions proceed are extremely complex. However, some insight into the fundamental effects occurring in the converter can be obtained by considering the gasification process to be operating in a heat controlled manner. The drying, slag formation, and generally speaking, the pyrolysis reactions all require that energy be supplied to carry them out. This energy must be supplied by the char-oxygen reactions in the hearth. If the organic portion of the char is taken to be essentially carbon, the char can react with oxygen in either of two basic reactions which liberate energy:

Reaction	Heat of Combustion	
(1) $C + 1/2\ O_2 \rightarrow CO$	3,950 Btu/lb carbon	2,960 Btu/lb oxygen
(2) $C + O_2 \rightarrow CO_2$	14,090 Btu/lb carbon	5,280 Btu/lb oxygen

If all the energy required for gasification and slagging could be supplied via reaction (1), the energy yield of fuel gas per unit of refuse processed would be maximum. In practice, using typical municipal refuse with a nominal heating value of 5,000 Btu/lb and a carbon, hydrogen, oxygen composition approximately that of cellulose, about 1/4 of the incoming carbon is found in the product gas as CO_2. The conversion of the carbon to CO will not provide sufficient energy for the gasification and slagging requirements. There are other reactions which can affect the CO_2 level in the product gas; however, the carbon-oxygen reactions are the primary source of energy for the conversion process. It has been shown that the oxygen required to convert refuse into gas and slag is about 20% by weight of the refuse of composition similar to that described below.

SECTION II. PROCESS DESCRIPTION - 200 Ton Per Day Demonstration Plant

The PUROX System consists of the following components: a front-end refuse receiving and preparation system, a refuse gasifying system, an offgas cleaning system, and auxiliary systems including an oxygen generating plant, a wastewater treatment system, and a product gas compression and distribution system. Since one of the primary functions of the PUROX System plant might be to provide a continuous supply of fuel gas to a municipal or industrial user, 24 hour per day, 7 day per week plant operation is required. Figure 2 presents a process view of the 200 ton per day demonstration plant in South Charleston, West Virginia.

The processing of refuse in the PUROX System plant begins in the refuse receiving and storage building. The purpose of this building is to provide one day's inventory of refuse at the system's rated capacity of 200 tons per day. This storage is provided by a building 80 feet by 70 feet with a 12 foot concrete wall on three sides to provide protection for the structure during the refuse piling operation. Refuse is brought to the plant in conventional packer trucks, discharged directly onto the floor of the building, and piled against the concrete walls using a Caterpillar model 950 front loader.

The front loader is used to carry refuse into the system for further processing and to manage the refuse inventory. The front loader loads about one ton of material in its bucket and conveys it to the scale for weighing and discharge into the processing system (see Figure 2 for PUROX System Schematic). The scale used for weighing the front loader and its load is a Toledo model 820 full load cell platform scale with a model 8130 digital indicator. It can weigh in a range from 0 to 40,000 pounds in 20 pound increments. The refuse entering the system has a composition similar to that indicated in Tables I and II showing component and ultimate analyses for typical municipal refuse.

After weighing, the refuse is dumped onto a conveyor which transports the material to the shredder. The conveyor is a three foot wide apron conveyor installed at a 45° angle with respect to grade. The shredder is a Heil (Tollemache) vertical shaft hammermill equipped with a 200 hp electric motor. It is rated at 15 tons per hour shredding capacity. Significant overcapacity is required in the shredder to allow a reserve for mechanical problems in the feed system as well as routine maintenance. Since the PUROX System operation runs 24 hours per day, seven days per week, hammers can be run at most a few days before resurfacing is required. Wear surfaces on the interior of the shredder must also be built up periodically. The net effect of these requirements is that in the South Charleston PUROX System operation 2-3 hours per day are required for maintenance on the shredder.

The overall control of the feed system rests with the feed system operator who takes action in response to the requirement for fresh material by the converter. In addition, there are several automatic control circuits built into the system to prevent improper operation. One of these control circuits provides overload protection for the shredder by stopping the feed conveyor whenever the amperage drawn by the shredder motor reaches a set level. This allows the shredder to continue grinding its charge without increasing its load by adding new material. Once the material has been processed sufficiently to allow the load on the shredder to drop below the overload condition, operation of the feed conveyor resumes as control is returned to the operator.

In addition to the overload circuit described above, the shredder is also equipped with an interlocked control circuit. This control circuit requires that both the blower cooling the shredder drive motor and the discharge belt conveyor for carrying material away from the shredder be operating before the shredder can be run. This circuit ensures that the shredder will not be choked by discharging material or that its drive motor will not overheat. If either of these conditions occur, the shredder is automatically shut down. The shredder is also equipped with a restart limiting timer which prevents restarting the motor more than once per hour to protect it from overheating.

The discharge conveyor from the shredder is a high-speed, rubber-belted device which transports material from the shredder to the feed conveyor for the converter. As the shredded refuse travels along the belt conveyer, it passes through a magnetic separator which removes ferrous material. The magnet picks up pieces of iron in the shredded refuse stream and discharges it onto a second belt conveyor which runs perpendicular to the shredder discharge conveyor. The shredded, magnetically separated refuse has a composition similar to that given in Table III.

The shredded, ferrous-free refuse is dropped from the belt discharge conveyor onto a second apron conveyor for transport to the feeder. The feeder acts as an interface between the front-end refuse processing systems and the converter where the refuse is consumed. The mission of the feeder is two-fold. It introduces the refuse into the converter and provides a gas tight seal for the system.

Once the refuse is in the converter, it is contacted countercurrently with hot gas produced from combustion in the hearth. As the refuse passes down the shaft and is contacted with hotter and hotter gas, it undergoes several reactions. First, near the top of the converter, free moisture is driven off. As the temperature of the gas at the surface of the refuse increases, pyrolysis of the refuse begins to occur. In these pyrolysis reactions, the cellulosic material in refuse is broken down into smaller molecular fragments which contribute to the final gas composition. At the same time, hot gas from the combustion of char in the hearth undergoes shift and carbonization reactions which reduce the amount of CO_2 in the gas while forming CO and H_2. The complex mixture of gases and refuse undergoes a variety of reactions leading to the final offgas composition as indicated in Table IV. The offgas typically exits the converter at 200 to 600°F with a wet bulb temperature of 170-180°F.

The hearth operation is carried out at a temperature of about 3,000°F in order to slag the inorganic portion of the refuse and combust the char residue of pyrolysis. To maintain this condition requires refractory linings with service temperatures well in excess of 3,000°F and a high resistance to slag corrosion. Extensive operating experience has shown that standard refractory and water cooling on the exterior shell is sufficient to form and maintain a protective slag "skull" on the inside refractory surfaces. The molten slag pours from the hearth into a water quench tank. After quenching, the slag is withdrawn from the bottom of the quench tank using a drag conveyor which deposits the slag in a dumpster for removal. The composition of the slag stream leaving the converter is given in Table V. As can be seen from Table V, the slag residue has a bulk composition very similar to that of soda-lime or bottle glass which is its main constituent. Most of the inorganic materials in the refuse become bound in the glassy slag. Leaching tests have been conducted on the slag using both acidic and pH 7 water. The results of these tests indicate that the trace metal contaminants do not leach from the slag sufficiently to create an environmental hazard. Table VI presents a comparison of leachate water quality obtained from 6-day percolation tests in a bed of pure PUROX System slag with U.S. Public Health Service recommended drinking water standards. These results show that the slag leachate compares favorably with drinking water quality indicating that potentially leachable materials are well bound in the glassy slag. Table VII presents a comparison among 6-day leachate samples from a pure slag sample and two different blends of slag and soil that might be encountered in a landfilling operation. The changes in leachate quality can essentially be attributed to the soil components themselves.

While the inorganic fraction of the refuse exits as a molten stream from the converter, the organic fraction is converted into a fuel gas which is further processed in a gas cleaning system. Particulate matter is collected using a water scrubbing system followed by electrostatic precipitation. The material collected in both of these units is recycled to the converter for gasification or slagging. After gas cleaning, the offgas is cooled to 100°F in a condenser to remove wastewater prior to the end use of the gas. Following this step, the gas in the demonstration plant is simply flared as in Figure 2 since there is no user available. In a commercial plant, a gas compression and distribution system would handle the gas.

SECTION III. SUMMARY OF OPERATIONS

The 200 ton per day PUROX System demonstration plant has undergone extensive testing since construction was completed in April, 1974. While it initially operated on as-received refuse, in late 1974, the plant was modified by the installation of shredding and magnetic separation equipment.

More than 10,000 tons of refuse have been successfully processed through the facility. The main purpose of the plant was to develop and optimize the cost and performance of a commercial-scale system. Most of the test runs were of relatively short duration (about 1 to 3 weeks). These runs provided data to evaluate specific modifications or operating conditions aimed at optimization of the commercial process. Additionally, an extended run was conducted for the purpose of establishing system reliability. During the three-month-long run, about 7,000 tons of refuse were processed, with a demonstration system reliability of about 93%.

Table I: Component Analysis of Refuse

Wet Basis	Wt. %	Range (Wt.%)
Paper	38	25-60
Food	20	10-30
Yard	13	10-20
Wood	3	2-4
Plastic	1	0.5-2
Textile	1	0.5-4
Rubber & Leather	1	0.5-3
Glass	11	5-25
Ferrous Metal	7	5-9
Nonferrous Metal	1	0.2-1
Dirt and Ash	4	1-6
	100%	

(Moisture included in above) 26%

Table II: Ultimate Analysis of As-Received Refuse

Component	Weight %
H_2O	26.0
C	25.9
H	3.6
O	19.9
N	0.47
S	0.10
Cl	0.13
Metal	8.0
Glass	11.0
Ash	4.9
	100.0

Higher Heating Value 4992 Btu/lb.

Table III: Ultimate Analysis of Shredded, Magnetically Separated Refuse*

Component	Weight %
H_2O	27.9
C	27.7
H	3.8
O	21.2
N	0.5
S	0.11
Cl	0.14
Metal	1.7
Glass	11.8
Ash	5.2
	100.0

Higher Heating Value = 5140 Btu/lb

* Based on

a) 90% removal of magnetic metal
b) 10% non-metal in removed stream
c) 15% removal of non-magnetic metal due to attachment

Table IV: SUMMARY OF PUROX SYSTEM
FUEL GAS CHARACTERISTICS

GAS ANALYSIS at 60°F, 1 atm.	% VOLUME TYPICAL	RANGE
H_2	23.6	21-23
CO	38.3	29-42
CO_2	23.6	20-34
CH_4	5.9	4-7
C_2H_2	0.7	0.2-1.5
C_2H_4	2.06	1-3
C_2H_6	0.3	0.1-0.5
C_3H_6	0.3	0.02-0.7
C_3H_8	0.2	0.1-0.6
C_4	0.5	0.1-0.8
C_5	0.4	0.1-0.6
C_6H_6	0.3	0.1-0.6
C_7H_8	0.1	0.05-0.15
C_6+	0.2	0.1-0.7
N_2	1.0	0-1.5
Ar	0.5	0-0.5
O_2	0.1	0-0.2
H_2S	0.05	.02-.06
CH_3OH	0.1	0.05-0.15
ORGANIC VAPORS*	0.15	0.1-0.4
H_2O	1.64	1-2

*Higher alcohols, aldehydes, ketones, organic acids

TABLE V

PUROX SYSTEM RESIDUE ANALYSES

Major Components - Weight %, Expressed as Oxide

Silicon	59.7	57-62
Aluminum	10.5	9-13
Calcium	10.3	9-12
Sodium	8.0	7-10
Iron	6.2	1-8
Magnesium	2.2	1-4
Potassium	1.0	
Phosphorous	0.8	
Titanium	0.6	
Manganese	0.3	
	99.6	

Trace Compounds - ppm

Barium	1000-3000
Copper	500-3000
Zirconium	300-1000
Strontium	200-400
Chromium	100-400
Lead	50-300
Tin	50-300
Nickel	50-250
Zinc	50-250
Vanadium	25-80
Cobalt	15-40
Silver	5-30
Molybdenum	10
Antimony	3-10
Berrylium	5
Sulfur	1000-3000
Chlorine	5000 - 10,000

TABLE VI

WATER QUALITY OF PUROX SYSTEM SLAG LEACHATE

Material	Pure Slag Leachate (ppm)	U.S.P.H.S. Limit	U.S.P.H.S. Recommended Level
Total Acid	10.7		
Total Alka.	20.0		
BOD	0.93		
COD	5.0		
Chloride	12.0		250
Cyanide	0.001	0.2	0.01
Fluoride	0.03	1.6-3.4*	0.8-1.7
Aluminum	<0.8		
Arsenic	<0.01	0.05	0.01
Barium	<0.1	1.0	
Cadmium	<0.001	0.01	
Calcium	2.1		
Chromium	<0.01	0.05	
Copper	<0.1		1.0
Iron	0.33		0.3
Lead	0.07	0.05	
Selenium	<0.01	0.01	
Silver	<0.02	0.05	
Sodium	1.10		
Zinc	<0.05		5.0
Nitrate	<0.2		45.0
Diss. Sol.	27.0		
Sulfate	1.3		250
Sulfide	<0.02		
Manganese	0.02		0.05

*Fluoride concentration is temperature dependent

TABLE VII

SLAG + SOIL INTERACTIONS

Material	Pure Slag Leachate (ppm)	Slag Cont. Silt + Slag System	Slag Cont. Silt + Slag System
Total Acid	10.7	5.6	16.0
Total Alka	20.0	8.6	7.9
BOD	0.93	0.4	0
COD	5.0	12.0	9
Chloride	12.0	8.3	3.6
Cyanide	0.001	0.001	0.001
Fluoride	0.03	0.01	0.04
Aluminum	0.08	3.9	3.8
Arsenic	0.01	0.01	0.01
Barium	0.01	0.13	0.1
Cadmium	0.001	0.001	0.001
Calcium	2.1	1.6	3.0
Chromium	0.01	0.01	0.01
Copper	0.1	0.1	0.1
Iron	0.33	7.3	7.2
Lead	0.07	0.05	0.05
Selenium	0.01	0.01	0.01
Silver	0.02	0.02	0.02
Sodium	1.10	2.6	1.5
Zinc	0.05	0.17	0.05
Nitrate	0.2	0.2	0.23
Diss. Sol.	27.0	13.0	26.7
Sulfate	1.3	10.0	2.7
Sulfide	0.02	0.02	0.02
Manganese	0.02	0.14	0.02

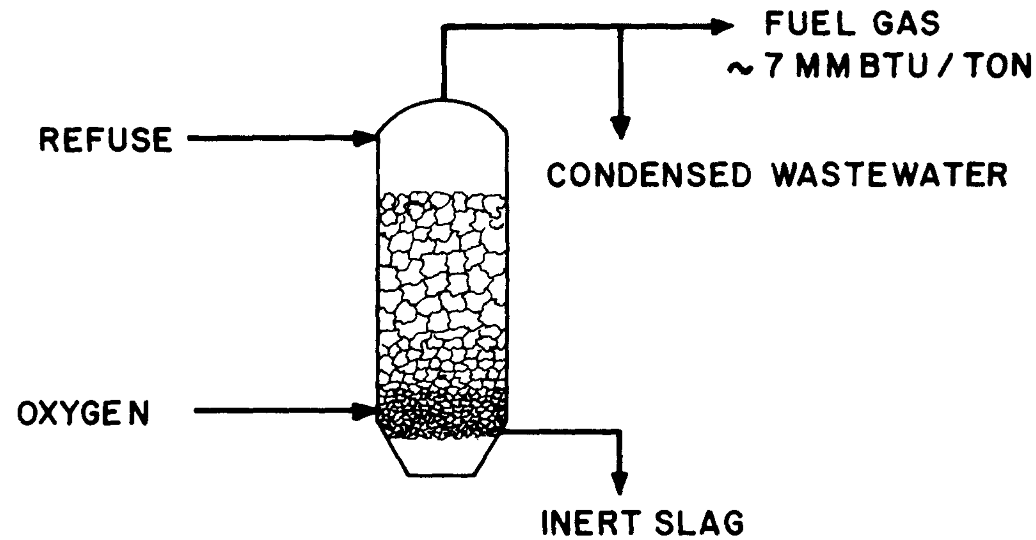
REFERENCES

1. Anderson, J.E., Proceedings of the 1974 National ASME Conference, Incinerator Division, p. 337, April, 1974.

2. Fisher, T.F., Kasbohm, M.L., and Rivero, J.R., A.I.Ch.E. 80th National Meeting, September, 1975.

3. Water Quality Criteria, 2nd Ed., June 1, 1974, State of California, p. 89.

PUROX SYSTEM OXYGEN REFUSE CONVERTER



NOTE: ENERGY PRODUCED GREATER THAN ONE BARREL OF OIL PER TON OF REFUSE

FIGURE 1

200 T/D DEMONSTRATION PLANT
SHREDDED REFUSE PROCESS DESIGN

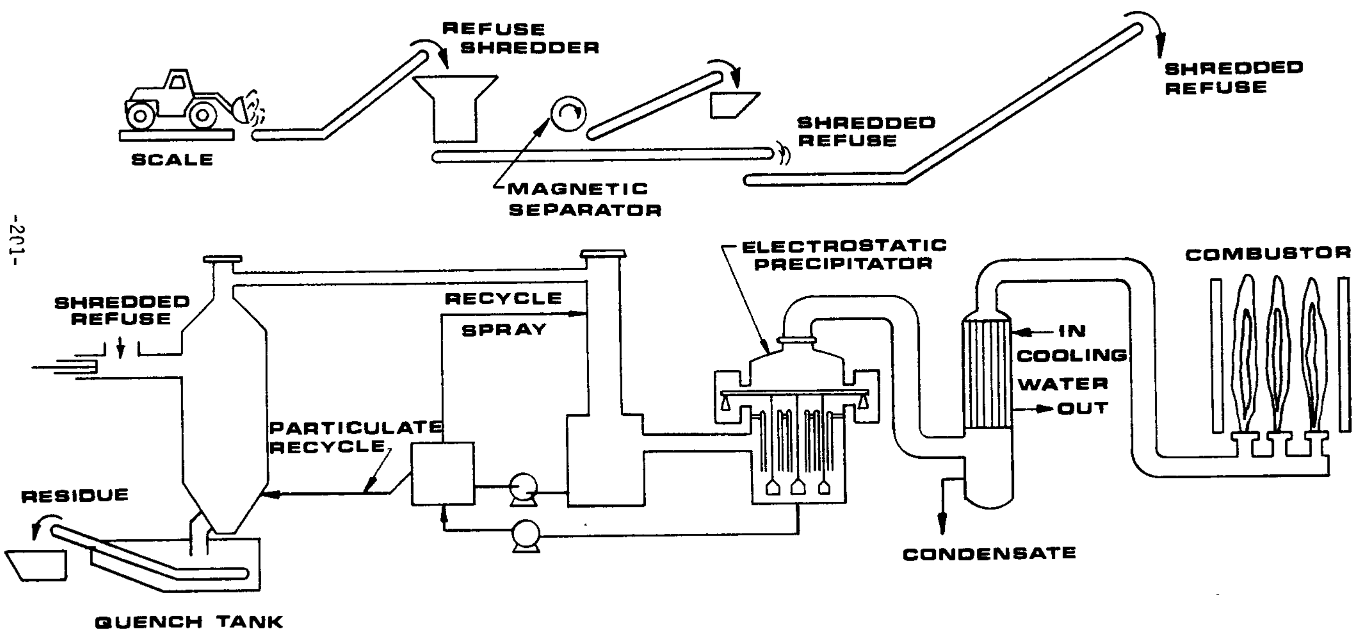


FIGURE 2

K.F. 11-2-76

RESCO - FIRST YEAR OF OPERATIONS

John M. Kehoe, Jr.
Vice President - General Manager
Energy Systems Division
Wheelabrator-Frye, Inc.

Our RESCO facility in Saugus, Massachusetts, is a 1200 ton per day waste disposal system and power plant. We placed it into operation in September, 1975, and began delivering steam to General Electric on November 15, 1975.

Our first year of operation has been devoted to the sequential start-up and shakedown of the two 750 ton per day boilers. During this start-up period we have processed in excess of 250,000 tons of refuse, produced over one billion pounds of steam, and recovered an estimated 16,000 tons of ferrous metals. We are currently processing refuse at an average rate of 800 tons per day and expect to reach our capacity early next year.

RESCO has proven to be an environmentally sound operation. The plant, operating at full capacity, has surpassed the Massachusetts air emission code of .05 grains per SCF, corrected to 12% CO_2. Chemical and leachate analysis studies have shown that the plant's residue is inert and will not effect the surrounding marsh and shellfish environment. The plant has operated completely free of odor. Noise recordings at the property lines are maintained at less than 50 decibels.

Research and development programs conducted since the inception of operations have provided us with additional encouragement that our total recycling goal is achievable. There are indications that with further processing the ferrous metals can be upgraded to a No. 1 quality. The aluminum and non-ferrous metal content has been estimated between .5% to .7% concentration, and the technical feasibility of recovering a marketable product has been demonstrated. The aggregate residue has been found acceptable for product applications, such as landfill cover, road base and embankment fill, and for use in bituminous concrete and concrete blocks. Studies on its use in portland cement are encouraging but as yet are not completed.

At the present time, RESCO residue is being stored adjacent to the plant site awaiting completion of studies to determine the economic feasibility of recoverying non-ferrous metal and receipt of state approvals for its sale as a fill or aggregate material. The land requirements for residue storage are approximately 3% of that required to landfill the raw refuse from which it was derived.

BACKGROUND

Before discussing the RESCO operations in detail, I would like to give you a brief understanding of the project organization, the background experience upon which it is based, its performance requirements, and structure of our energy and waste disposal contracts.

RESCO is operated as a joint venture between Wheelabrator-Frye and M. DeMatteo Construction Company and organized as "Refuse Energy Systems Company." The joint venture made a substantial equity contribution to the facility and arranged industrial revenue bond financing for the debt portion of its investment. No public funds are committed or obligated to the project.

System design and construction management were carried out by The Rust Engineering Company, a wholly owned subsidiary of Wheelabrator Frye, and construction was undertaken by M. DeMatteo Construction Company.

The plant design concept is based upon Wheelabrator's exclusive U.S. license with Von Roll, Limited, of Zurich, Switzerland. It is the most advanced version of the over 120 Von Roll refuse-to-energy plants operating or under construction in Europe, Australia, Japan, and Canada. RESCO is designed to meet more severe environmental requirements and a number of specialized demands imposed by site conditions and unusual requirements for reliability and continuity of refuse acceptance and steam production. It also employs several advanced design features to enhance cost effective and reliable performance at high steam temperatures.

Minimizing operating costs over the life of the plant were considered essential to provide protection against inflation. The approximate $40 million capital cost for the plant recognizes these requirements and special conditions. It includes all costs for land, maintenance, shops, roads, weighing stations, vehicles, spare parts, utilities, and a one-half mile pipeline and bridge system extending across the Saugus River to the General Electric Company for steam delivery, condensate return, and electric power.

RESCO's basic requirements are to accept an average of 1200 tons per day of municipal and commercial refuse and deliver steam to General Electric at 625 psig and 825°F. The plant is operated

24 hours a day, 7 days a week. Peak steam delivery is 350,000# per hour and not less than 65,000# per hour. A minimum of 2.0 billion pounds per year of steam will be delivered to the customer. The primary uses of the steam are for electric power production, processing, and testing operations.

Through close cooperation with General Electric, a long term contract for the sale of steam to their Lynn River Works Plant was consummated. In addition, a combination of long and short term contracts have been completed with eleven surrounding communities and two districts of Boston for waste disposal services.

Steam charges to General Electric are somewhat lower than their cost to produce steam from oil and will escalate or de-escalate with variations in their oil prices. The communities are charged a base disposal fee for each delivered ton of waste. This fee is adjusted annually at approximately 50 percent of the rate of change in a local labor rate index. Excessive increases in operating costs or added capital costs are absorbed by RESCO.

OPERATING EXPERIENCE

The success achieved in our first year of operations could not have been accomplished without the utilization of proven experience and technology in the design, construction and start-up phases of this project. Every basic subsystem has proven to be operationally sound and capable of meeting its projected life cycle. This is not to say that operations have been trouble free but reaffirms our belief that the utilization of a proven technology and system design is essential to avoid the risk of excessive overruns in capital and operating expenses.

Priorities

Our first and primary responsibility at RESCO is to provide an environmentally sound and reliable disposal service to the communities we serve. To date, not one truck has been diverted to an alternate disposal site.

Secondly, the plant's steam production will permanently replace approximately 40% of General Electric's required steam generating capacity. G.E. employs over 13,000 people at the Lynn Plant, and continuous steam flow from RESCO will be essential to insure normal operations. Each refuse boiler and the two back-up package boilers have achieved rated steam capacity and steam quality specifications under full load operating conditions. Final tuning and control modifications should be completed by year end, and G.E.'s transition to full dependency on RESCO steam is expected to go smoothly.

These services must be provided in an environmentally sound manner. As mentioned earlier, RESCO has met and surpassed the Commonwealth of Massachusetts and Federal environmetnal regulations.

Finally, there is a strong commitment to the separation and recovery of material resources from the system's post-combustive residue. The original plant design incorporated a capability to physically separate ferrous metals. At the time the plant was being designed, through construction and after the first year of operations, we have seen no economically viable recovery technology developed for the aluminmu, non-ferrous metals, and glass produced by the system. We have seen the technical feasibility of recovering and upgrading these material resources however, and are presently evaluating the economics of recovery system designs and trying to develop firm market commitments. Based upon our present knowledge, we do not anticipate these products generating more than $3 per ton of refuse in net revenues unless there are significant increases and stabilization in their market values.

PLANT DESCRIPTION

The following discussion combines our specific operating experiences with a physical description of the operating areas of the facility.

Refuse Receiving and Handling Area

This area of the plant incorporates the weighing station at the entrance to the plant, the queuing and receiving areas for the trucks, the storage pit for the refuse, the refuse mixing and furnace loading operations, and the shredder plant. All refuse trucks entering and leaving the plant must cross the semi-automatic scales. Tare weight cards are maintained on each municipal truck to avoid delays. The reception area allows adequate turnaround and waiting space for several trucks. Sixteen outloading bays are provided for approximately 250 trucks per day. The average turnaround time for each truck has been between five and seven minutes. The traffic flow patterns designed into the plant operations have proven to be highly efficient.

The refuse storage pit is 35' wide, 95' high, and 200' long and has a capacity to hold over 6,000 tons of refuse. The refuse mixing and loading is handled by two overhead cranes which have a refuse lifting capacity of approximately 3 tons per load. Initially, the heavy duty placed upon the cranes caused considerable cable and brake wear. Changes in the operating control system enabled us to correct the problem and achieve acceptable performance.

The shredder is a 50 ton per hour, 1000 horsepower hammermill installation. Our original intent was to shred bulky metals, such as refrigerators, stoves, water tanks, etc., and large combustible items such as sofas, tree trunks, etc. The shredder operation has been reduced to one day per month and only for bulky combustibles that would normally require more than one hour retention time in the furnace for complete energy conversion. The furnace opening is 22' long and 4' wide and has proven to be sufficiently large to process all of the bulky metals received without preprocessing.

This inherent flexibility in the design has enabled us to eliminate the costly expense of operating and maintaining the shredder. Based upon the variation in bulky material delivered to RESCO over the last year, we are becoming convinced that future plants can be built without the need of a shredder.

REFUSE COMBUSTION AREA

Refuse received from the feedhoppers is burned on a Wheelabrator/Von Roll reciprocating grate system without the use of auxiliary fuel. In addition to the grates, this area also incorporates the auxiliary equipment which automatically controls the grate speeds and air distribution. The grate system consists of three independently controlled grates separated by steps over which refuse tumbles to provide complete combustion. The first or feed grate controls the rate at which refuse is fed. The second or combustion grate is maintained at a speed which will insure an estimated 90% of the combustion. The last grate is the burnout grate which is controlled to insure the completion of the combustion process and partial cooling of the inert residue.

Combustion gas temperatures are maintained in the range of 1600 - 1800°F, which is sufficiently high to destoy odors. Combustion and overfire air systems are integrated with individual grate speed controls to provide uniform and stable energy production from changing refuse compositions while insuring complete burnout.

Some recent design improvement incorporated at RESCO permit the direct combustion of unpreprocessed municipal refuse at the higher steam temperatures needed to achieve efficient electric generation. They include air jets positioned to introduce air along the side walls and under the stepped grate systems. The air system provides protection against corrosion that might occur in the presence of reducing atmospheres, limit slag buildup on the side walls, and add to the gas turbulence needed to minimize hot spots on the furnace walls and boiler tubes.

As is the case in any major plant start-up we encountered problems. However, only two start-up problems were cause for concern. These problems included a failure in the sliding grate shoe support shoes caused by a departure in the specified metallurgy and unevenness in the hydraulic grate drives. Remedial actions were identified, modifications made, the problems disappeared.

STEAM PRODUCTION (BOILER) AREA

The steam production area incorporates the most advanced design in refuse boilers. This design has evolved from over 20 years and 4 million hours of operating experience with the Von Roll technology. Also included is the radiation or water wall section of the boiler which is located in the furance area and is of a conventional design.

The hot flue gases from the furnace pass through three convection sections which transfer the heat to produce superheated steam. These sections are designated as the economizer, evaporator, and superheater. Vertical pendant hung boiler tubes are constructed and specially designed with a mechanical rapping mechanism.

The convection passes include economizer, evaporator and superheater sections. Each section is constructed with pendant boiler tubes which are equipped with specially designed boiler tube rapping mechanisms to remove dust and scale from the tube surfaces. This unique cleaning system enables the tubes to retain the protective oxide layer that is normally removed when soot blower or steel shot is used for cleaning. Recent European experience has demonstrated the effectiveness of this cleaning system by eliminating shutdowns for tube cleaning.

An automatic temperature regulatory system provides uniform steam flow at full capacity without exceeding temperature limits as the heat contact of refuse varies. These and other advancements combine to promote reliability and provide boiler availability percentages in the same range as utility boilers fired by fossil fuel.

The problems encountered in this area of the plant are corrosion of tube metal wastage. Fortunately, from our experience with Von Roll's plants in Europe, we have been fully aware of the potential for corrosion and incorporated a boiler specifically designed for the combustion of refuse. With the knowledge we have gained about solid waste and our anticipated modificaitons, we believe we have the fix.

Before going on, there are two points I'd like to make:

1) If you are going to burn refuse and produce steam at high pressures and temperatures you are going to have corrosion. You are not going to control it by removing PVC's. There are a myriad of other elements in municipal waste that contribute to corrosion.

2) Conventional boilers are designed to burn homogeneous conventional fuels. Refuse is not a homogeneous fuel nor do you control its chemical composition by preprocessing it to remove non-combustibles.

A few faulty welds in the pressurized section of the boilers, insufficient shielding, a need for improved metallurgy in a portion of the superheater exposed to direct radiation, and a failure of a steam temperature controller represent the extent of difficulties encountered. With few exceptions, all modifications have been completed.

AIR POLLUTION CONTROL AREA

Air emissions from the plant are controlled by Wheelabrator/Lurgi electrostatic precipitators, and emissions emitted to the atmosphere through a 178 foot masonry stack. The precipitators are operating at approximately 99 percent efficiency. This has permitted the system to surpass the local particulate emission requirements of .05 grains per standard cubic foot, corrected to 12% CO_2. Each precipitator handles 240,000 cuff/min. of flue gas at 425°F. We have experienced no operating problems in this area.

MATERIAL SEPARATION AND RECOVERY AREA

This area begins with the collection of fly ash from boiler and precipitator hoppers, riddlings and grate siftings, and residue from the burnout grate. These residues are presently transported to a common and redundant water quenching and washing system. The system is continuously neutralized to a pH of approximately 7. In addition to cooling the residue, it removes soluble salts which could be an environmental nuisance. As the residue settles to the bottom of the quenching system, it is removed by a drag chain conveyor which transports it to the material recovery building.

The material recovery system consists of a rotary trommel screen with two inch holes, magnetic separators, and appropriate conveying and collection systems.

The plus two inch material is classified as the bulky metal residue and has a ferrous metal content of approximately 60%. The minus two inch material falling through the screen is conveyed to a permanent magnet separator which collects the fine ferrous metals. The ferrous metal recovered represents approximately 7.5% by weight of the incoming refuse, and the fine ferrous fraction is estimated to be 20% of the total ferrous product recovered. Both fractions are presently sold to a local secondary market under short term contracts.

The remaining residue is aggregate material which contains the glass and approximately a 2% concentration other non-ferrous metals. Chemical and leachate analysis studies show that the aggregate is inert and acceptable as a fill material.

Research and development studies designed to analyze the feasibility of upgrading the ferrous metals, of recovering a marketable aluminum and non-ferrous metal product, and developing product applications for the aggregate are all encouraging.

Utilizing Wheelabrator foundries, we have made pig iron from several samples of the recovered ferrous metals. Working closely with the major steel companies, we have made comparative chemical and metallurgical analysis. The results show that the copper content is too high for No.1 grade applications. Further studies have shown that copper can be separated with shredding and further magnetic separation. A program is underway to determine economic benefits that can be derived from further processing to remove the copper.

Through size classification of the aggregate, we have produced a 60% aluminum and non-ferrous product which is salable. In addition, we are presently analyzing the small quantity of melted aluminum product collected under the grates. Although results to date look favorable for aluminum recovery, there is the possibility that the final recovery system requirements may make it economically impractical.

The aggregate which comprises approximately 50% to 60% of the residue from the plant has been successfully used in bituminous concrete, decorative concrete for floorings and walls, and concrete block applications. It has also been proven acceptable as a road base and embankment fill material. Research studies are continuing to expand its product applications as a cement supplement and light weight aggregate for construction.

COMMUNITY EXPERIENCES

This status report on RESCO would not be complete without briefly summarizing some of the benefits, other than waste disposal, that the communities have received from participation in the project.

The following benefits have resulted in a reduction of collection expenses which in effect have reduced their overall budgets for waste collection and disposal.

> Because no presorting or separation is required at RESCO, the communities have been able to combine garbage, rubbish, and bulky trash collections into a single pickup operation. RESCO routinely supplies to the communities scale weights on each truck delivery. With this data the communities have been able to reduce the number of collection routes and optimize loading of collection vehicles.

Cost benefits have been derived by reduction of vehicular requirements and shifting of manpower to other municipal departments.

CONCLUSION

The success we have achieved during the first year of operations at RESCO demonstrates, on a commercial scale, that refuse fired boilers of this type can provide an environmentally sound solution to the municipal waste disposal problems facing the urban areas of this country. In addition, it demonstrates that private enterprise can provide this solution without tapping municipal, state or federal financial or taxing resources.

However, it is only a partial solution. There still is and will be for many years to come a need for sanitary landfill for those wastes generated that cannot be handled by resource recovery systems of all kinds.

FEATURED ADDRESS

FEATURED PRESENTATION

FIFTH NATIONAL CONGRESS ON WASTE MANAGEMENT TECHNOLOGY AND RESOURCE AND ENERGY RECOVERY

DALLAS, TEXAS - DECEMBER 1976

PETER VARDY
VICE PRESIDENT-ENVIRONMENTAL
MANAGEMENT & TECHNICAL SERVICES
WASTE MANAGEMENT, INC.

Welcome to the Fifth National Congress on Waste Management Technology and Resource and Energy Recovery. This is also the third Waste Management Technology Conference co-sponsored by NSWMA's Institute of Waste Technology.

As most of you will recall, the Institute of Waste Technology was established by NSWMA's Board of Directors in the summer of 1974 in response to the Association's expanding scope of activities and technical programs. The main purpose of the Institute is to provide a national forum for technology assessment and planning for the entire waste management field.

Through its three major member committees and two councils, the Institute has, during the past two and one-half years, taken a very active role in assisting government, industry, members of NSWMA and its Legislative Planning Committee with technical and planning expertise. The Chemical Waste, National Sanitary Landfill and Industry Resource Recovery Committees have reviewed and provided valuable input into legislation, regulations and technical information generated by Congress, the U.S. Environmental Protection Agency, and state legislatures and regulatory agencies. Through the varied activities of its committees, the Institute has also promoted the development of new, technically reliable, economical and safe waste processing, resource recovery and disposal systems.

Since my appointment as Chairman of the Institute in 1974, I have had the privilege of working with many of you in Government, industry and the consulting professions, and the opportunity to observe some rather profound changes in our industry during this relatively short period of time.

Permit me, at this time, to make a few brief and personal observations on some of this industry's accomplishments and failures during the past two and one-half years.

During 1974, I said that there was a general feeling of euphoria concerning development of resource recovery in this country and the great economic and technical promise which it held for the solid waste management industry. A number of EPA-funded resource recovery demonstration projects were receiving wide publicity and the construction of full-scale facilities was strongly encouraged by various government agencies. This climate of extreme enthusiasm generated immediate demands by a rather naive and misinformed public to eliminate land as an acceptable sink for the disposal of residues and achieve, almost overnight, total recovery from waste of material and energy resources. Many within and outside the solid waste industry were thus led to believe that full-scale resource recovery, representing a new multi-billion dollor market in equipment, facilities and services, was just around the corner. In retrospect, of course, we recognize that such expectations were premature.

By fall 1975, during our Fourth National Congress in Atlanta, the realities of life have become apparent and depression set in. The falacies of rapid scale-up;

the difficulties encountered in obtaining long-term financing on the strength of short-term, fluctuating markets for recovered resources; serious difficulties encountered in the effective control of waste; and the real impact on disposal fees of the highly capital intensive resource recovery systems were reported by all who tried their hand at this new area of opportunity.

This year I sense that you will find a very healthy spirit predominating at this conference, a spirit which will be characterized by pragmatism and cautious optimism. You will hear reports of some successes with full-scale facilities (information essential to rational assessment of resource recovery alternatives), of communities moving into the area of resource recovery cautiously and realistically, and of the readiness of the financial community to fund such projects provided they are approached in a business-like and responsible manner.

The Institute's Industry Resource Recovery Committee, which has in its membership eight of the country's leading systems and service companies in the solid waste management field, has been very active in evaluating and disseminating information on all aspects of resource recovery systems, including waste processing technology, financing, markets for materials and energy products and peripheral delivery and disposal system. By conducting roundtable seminars for interested communities, assessing and disseminating information on resource recovery projects around the country, and by providing continuing technical assistance to government and industry in the promulgation of resource recovery procurement and other implementation guidelines, the Committee is playing an important and active role in promoting the advancement of responsible and effective resource recovery in this country.

The Chemical Waste Committee, in anticipation of overdue hazardous waste legislation, regulation and enforcement has been actively engaged in the development of a comprehensive Legislative Guide for a Statewide Hazardous Waste Management Program. This guide, incidentally, provides considerable background material and outlines the industry's version of the guidelines which EPA must promulgate by Spring 1978 under the newly enacted P.L. 94-580. The Committee has also developed a model manifest to complement the legislative guide and has been working closely with the U.S. EPA Hazardous Wastes Management Division in reviewing and commenting on the various studies undertaken by that division. During the coming year, the Committee will be working on such projects as chemical landfill standards, monitoring requirements for land disposal sites, the development of closure plans, and perpetual care and long-term responsibility problems associated with hazardous wastes.

The newly enacted Resource Conservation and Recovery Act of 1976 provides for the establishment of a national hazardous waste management program under the auspices of the U.S. Environmental Protection Agency. This law requires that, within two years, EPA must draft, promulgate and implement a comprehensive regulatory program for hazardous wastes affecting the generators, transporters, owners and operators of chemical waste facilities. The Chemical Waste Committee will continue its very ambitious program of activities and will make the industry's experience in this field available to the U.S. EPA and states developing and implementing hazardous waste management programs.

At the 1974 San Francisco Conference, I had the pleasure of presenting a paper entitled "Land Disposal: 1975-1990." That presentation was made during a time when resource recovery held center stage and, while I managed to stir up some controversy on that occasion, I had a strong feeling then that speaking out strongly for land disposal was but a voice in the wilderness. Two years have passed since that meeting and a good measure of rationality has returned to the resource recovery area; yet, I am sorry to note that sanitary landfill is still the neglected stepchild of the waste disposal field.

I am sure that I need not project for you again the future role of land disposal. There may be disagreement as to whether materials and energy recovery, or other waste conversion systems, could handle five, ten or twenty per cent of the urban waste generated ten years hence. The fact remains that sanitary landfill is and will continue to be the primary method of waste disposal in this country at least through the end of this century. It is very disappointing that this simple fact of life is not being communicated to the public in clear and positive terms.

In order that the sanitary landfill may properly fulfill its important role as a primary, or even secondary, disposal system, it is imperative that it regain a legitimate status. This can only be accomplished with the full cooperation and commitment of the responsible federal and state agencies, not only in the implementation of the provisions of the Resource Conservation and Recovery Act of 1976, but also in recognition of government's responsibility -- well in advance of the timetable outlined in the Act -- to continue to provide reliable and environmentally acceptable disposal to land by expediting the landfill permitting and approval process.

With the help of government, we in the private sector can, and indeed must, proceed immediately to develop new, urgently needed land disposal sites, making reasonable resource allocations and risk judgments and utilizing the best that today's technology has to offer. Delaying the establishment of new sites in anticipation of new definitions and guidelines will prolong the existence of sub-standard or totally unacceptable disposal facilities and will delay the development of in-field experience which could lead to the promulgation of better and more realistic land disposal guidelines and standards.

The National Sanitary Landfill Committee has prepared a number of position papers on varying important sanitary landfill subjects and has provided input to EPA contract studies on landfill monitoring, permitting and inspection. The Committee has also embarked on a very ambitious program of activities for the coming year which, in conjunction with governmental activities mandated by the Resource Conservation and Recovery Act of 1976, should bring about renewed interest and substantial improvements in sanitary landfill design, development and operating practices.

I would be remiss if I did not acknowledge the close and cooperative relationship which the Institute of Waste Technology has developed with the Association of State and Territorial Solid Waste Management Officials and its past chairman Moses McCall. We look forward to a continued close relationship with the State Solid Waste Officials in the years to come.

As the Resource Conservation and Recovery Act of 1976 moves into implementation, we at the Institute of Waste Technology look forward to working closely with the U.S. EPA, the state agencies, and the Association of State and Territorial Solid Waste Management Officials to accomplish the goals of the Act and make, what we hope will be, a significant impact on future solid and hazardous waste management plans and practices.

I should like to take this opportunity to express my deep appreciation and gratitude to the Institute's past and present council and committee chairmen: John Vanderveldt, Wayne Trewhitt, Sandy Hale, Don Shilesky, Gene Nesselson, Joe Ferrante and Jack

Lurcott, and the many dedicated and hard-working members of their committees, for their tremendous contribution in time and effort to the Institute, the National Solid Wastes Management Association and the entire industry. I wish to express very special thanks to Gene Wingerter and Jim Greco and their entire NSWMA staff for giving so much of their time, energy, dedication and extraordinary talent to turn the Institute of Waste Technology, in such a short time, into a most important, visible, respected and effective arm of NSWMA and the industry as a whole. They have made my job not only an easy one, but a most rewarding one.

LANDFILL AND CHEMICAL WASTES DISPOSAL

SITE SELECTION FOR A CHEMICAL WASTE LAND DISPOSAL FACILITY: MINNESOTA'S EXPERIENCE

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BACKGROUND

As many of you know, Minnesota was selected by EPA's Office of Solid Waste to carry out its Chemical Waste Land Disposal Demonstration Project. The five year demonstration will examine the organizational, institutional, technical, economic, and social considerations involved in establishing and maintaining an environmentally secure chemical waste land disposal facility.

Specifically, the project will seek to demontrate:

1) site selection methods;
2) site preparation techniques to prevent groundwater infiltration;
3) techniques to adequately prepare wastes for land disposal;
4) monitoring and surveillance methods;
5) site management techniques including waste analysis, inventory control, quality control, and cost accounting procedures;
6) long term care, liability, and liability insurance considerations:
7) public education methods, and
8) institutional review procedures.

At the present time, the project is in the Step One phase. The objective of Step One is to produce a preliminary facility plan. This plan will include the site selection methodology, the results of the initial phases of site selection, waste characterization studies, and a concpptual facility design. Step One will be completed in the spring of 1977.

Step Two will continue from Step One and bring the project through final site selection, environmental reviews, economic impact studies, final facility design, and permit review and issuance. The length of time for Step Two will depend on the public review of the site, design, and the potential for adverse environmental impact. Our current projections estimate that Step Two will conclude by mid-1978 with facility operation commencing in late 1978.

Today, I would like to discuss one of the most crucial aspects involved in establishing a chemical waste land disposal facility. That aspect is the site selection process. First, a general overview and analysis of past site selection methods will be presented. From the analysis of past methods, the approach which is being used in Minnesota will be described. Finally, the Minnesota approach will be evaluated with respect to its cost effectiveness, adaptability to other regions, and the long term consequences of its use.

Analysis of Past Methods

In the past, facility organizers have employed various methods for selecting the locations of their chemical waste disposal sites. These methods have emphasized land cost, nearness to waste sources, ease of acquiring the land, and ease of site approvals. Today, as we begin to learn more about the long term consequences of disposal of industrial wastes, considerably more effort is being directed to securing sites

WHICH CAN BEST PROVIDE PROTECTION OF GROUND AND SURFACE WATERS FROM LEACHATE GENERATED. IN SHORT, THE DECISION-MAKING ENVIRONMENT FOR SELECTING A SITE FOR A CHEMICAL WASTE AND DISPOSAL FACILITY IS CHANGING THIS NEW DECISION-MAKING ENVIRONMENT INCLUDES NEW TECHNOLOGY, LEGAL INCENTIVES TO REQUIRE COMPREHENSIVE SITE EVALUATION PRIOR TO SITE CONSTRUCTION, AND MORE OPEN PUBLIC REVIEW TO CONSIDER PRESENT AND FUTURE LAND USE, LONG TERM CARE OF THE SITE, OPERATIONAL SAGETY OF THE SITE, AND ALTERNATIVE METHODS TO MANAGE THESE WASTES.

IN THE PAST, THE MOST POPULAR METHODS OF SITE SELECTION WERE NORMALLY THOSE WHICH REQUIRED THE LEAST COST AND INVOLVED THE FEWEST NUMBER OF PEOPLE AND GOVERNMENTAL AGENCIES. USING LAND ALREADY OWNED AND PARTIALLY DEVELOPED, ACQUIRING LAND FROM A SYMPATHETIC OR UNKNOWING BUYER, WERE THE EASIEST AND CHEAPEST METHODS OF SITE SELECTION. TOO OFTEN THESE HAVE ALSO PRODUCED THE BIGGEST HEADACHES AND POCKETBOOK PAINS FOR SITE OWNERS. SITES WHICH HAVE BEEN SELECTED SOLELY ON THE BASIS OF COST AND EASE OF PURCHASE HAVE OFTEN BEEN SITES WHICH HAVE CAUSED CONSIDERABLE ENVIRONMENTAL DAMAGE, DAMAGE WHICH IS EXTREMELY COSTLY TO CLEAN UP.

BECAUSE THE OLD SITE SELECTION METHODS HAVE SO OFTEN RESULTED IN SOURCES OF POLLUTION, INDUSTRIAL WASTE DISPOSAL FACILITIES HAVE ACQUIRED A PUBLIC IMAGE AKIN TO NUCLEAR POWER GENERATING FACILITIES. IT HAS ALSO BECOME IMPORTANT TO CONSIDER THE GENERAL PUBLIC AND ITS RESPONSE TO SITE SELECTION AS A FACTOR IN THE DECISIONS REGARDING SITE SELECTION. THE ISSUE OF PUBLIC EDUCATION IS AN IMPORTANT ELEMENT IN ESTABLISHING A CHEMICAL WASTE LAND DISPOSAL FACILITY, BUT MUST BE THE SUBJECT OF A SEPARATE DISCUSSION AT SOME OTHER TIME. FOR NOW, I WOULD PREFER TO CONCENTRATE ON THE OVERALL APPROACH TO CITE SELECTION WHICH IS BEING DEMONSTRATED IN MINNESOTA.

MINNESOTA'S APPROACH

TO UNDERSTAND THE APPROACH TO SITE SELECTION WHICH WE HAVE DEVELOPED IM MINNESOTA FOR THE DEMONSTRATION PROJECT, KNOWLEDGE OF THE DECISION-MAKING ENVIRONMENT IS IMPORTANT. THE LEGAL INCENTIVES TO SELECT AN ENVIRONMENTALLY ADEQUATE SITE ARE VERY STRONG. IN ADDITION TO A STATE ENVIRONMENTAL IMPACT STATEMENT PROCESS, WE WILL HAVE COMPREHENSIVE STATE REGULATIONS FOR ALL ASPECTS OF HAZARDOUS WASTE MANAGEMENT. THE PROPOSED STATE REGULATIONS WILL ADDRESS THE HANDLING OF HAZARDOUS WASTE FROM THE SOURCE OF ITS GENERATION THROUGH TRANSPORTATION TO ULTIMATE DISPOSAL. THE RESPONSIBILITIES AND DUTIES OF EACH PARTY INVOLVED IN WASTE MANAGEMENT ARE CLEAR AND WELL DEFINED. WASTE FACILITY PROPOSERS MUST SUBMIT DETAILED PRELIMINARY PLANS AND FINAL APPLICATIONS FOR REVIEW BY THE STATE. IF NECESSARY, REVIEW BY A PUBLIC HEARING WILL BE PROVIDED. DURING THIS REVIEW PROCESS, PROPOSALS WILL BE EVALUATED WITH RESPECT TO THE PROPOSED FACILITY'S CAPABILITY TO SAFELY HANDLE AND DISPOSE OF THOSE WASTES WHICH ARE PROPOSED TO BE ACCEPTED, AND FINANCIAL ARRANGEMENTS FOR LONG TERM CARE MUST BE ASSURED. IN ADDITION TO THE ATTENTION PAID TO PROPOSED HAZARDOUS WASTE FACILITIES BY PUBLIC AGENCIES, MINNESOTA, LIKE MANY OTHER STATES ENJOYS A HIGH LEVEL OF CITIZEN PARTICIPATION IN ISSUES RELATING TO THE ENVIRONMENT, AND THIS PROJECT IS CERTAIN TO CATCH THE ATTENTION OF THE GENERAL PUBLIC AS WELL AS THE COMMUNITY ULTIMATELY SELECTED AS THE LOCATION FOR THE SITE.

FROM THE PERSPECTIVE OF THE CHANGES COMING ABOUT IN THE DECISION-MAKING ENVIRONMENT SURROUNDING THE CHEMICAL WASTE FACILITY, THE BASIC GUIDELINES AND STEPS TO SITE SELECTION WILL NOW BE PRESENTED.

THE FIRST STEP TO SITE SELECTION IS TO DETERMINE WHAT THE FACILITY WILL DO AND HOW IT WILL DO IT. DETAILED SITE AND ENGINEERING PLANS ARE NOT NECESSARILY REQUIRED AT THIS POINT, RATHER THE BASIC CONCEPTS BEHIND THE FACILITY SHOULD BE FORMULATED. QUESTIONS SUCH AS: WILL THE FACILITY HANDLE ONE WASTE STREAM OR A WIDE VARIETY? HOW MUCH LAND WILL BE REQUIRED? WILL THE FACILITY HAVE WASTE TREATMENT PRIOR TO ULTIMATE DISPOSAL? WHAT ARE THE WASTE SHED AND WASTE CENTROID CHARACTERISTICS? IS THEIR A NEED FOR NEARBY SEWER HOOK-UP? ARE SOME OF THE FUNDAMENTAL DETERMINATIONS MADE PRIOR TO ANY SITE SELECTION WORK?

THE SECOND STEP IN THE SITE SELECTION PROCESS IS THE MOST CRUCIAL TO ITS OVERALL AND LONG TERM SUCCESS: FORMULATION OF A WELL REASONED SITE SELECTION CRITERIA. HOW THIS CRITERIA SHOULD BE DEVELOPED WILL BE DISCUSSED SHORTLY.

THE THIRD STEP IN THE SITE SELECTION PROCESS IS TO DEFINE A MAJOR GEOGRAPHICAL SEARCH AREA. IN OUR CASE, THE MAJOR SEARCH AREA IS THE SEVEN COUNTY METROPOLITAN TWIN CITIES REGION. IN OTHER CASES IT COULD BE AN ENTIRE STATE, A COUNTY, OR A CLUSTER OF COUNTIES. THE SELECTION OF THE MAJOR SEARCH AREA SHOULD DEPEND UPON THE GEOGRAPHICAL REGION TO BE SERVED BY THE FACILITY.

THE FOURTH STEP IN THE PROCESS IS TO APPLY THE CRITERIA FORMULATED IN THE SECOND STEP AGAINST AVAILABLE INFORMATION AND DATA ON THE MAJOR SEARCH AREA TO IDENTIFY A NUMBER OF DISCRETE MINOR SEARCH AREAS. SOURCES OF DATA INCLUDE THE SOIL CONSERVATION SERVICE, MAJOR UNIVERSITY STUDIES, STATE AND FEDERAL GEOLOGIC SURVEYS, LOCAL PLANNING COMMISSIONS, WELL DRILLING LOGS, STATE AGENCIES, AND LAND USE STUDIES PREVIOUSLY CONDUCTED.

THE FIFTH STEP IN THE PROCESS IS TO IDENTIFY CANDIDATE SITES BY FURTHER, MORE DETAILED EVALUATION OF THE MINOR SEARCH AREAS USING THE SITE CRITERIA AS A GUIDE. AT THIS POINT, SOME ACTUAL INFIELD OBSERVATION

OF THE AREAS SHOULD BEGIN. IF THE INFORMATION IS REASONABLY ACCURATE AND YOUR CRITERIA IS CAREFULLY FORMULATED, LARGE LAND AREAS SHOULD BE EXCLUDED FROM FUTURE CONSIDERATION AT THIS POINT. THE EMPHASIS UP TO THIS STEP SHOULD BE TO ELIMINATE THOSE AREAS WITH THE GREATEST LIMITATION TO USE AS A CHEMICAL WASTE LAND DISPOSAL FACILITY.

THE SIXTH AND FINAL STEP IN THE SITE SELECTION PROCESS IS THE SELECTION OF THE MOST FAVORABLE SITE WHICH ALSO MEETS MINIMUM PERFORMANCE STANDARDS. THIS IS DONE BY CONDUCTING PROGRESSIVELY MORE DETAILED SITE EVALUATIONS ON THE CANDIDATE SITES DEFINED IN THE PREVIOUS STEP WITH THE SITE SELECTION CRITERIA AS A GUIDE FOR COMPARING SITES. THE DATA BASE FOR MAKING SITE EVALUATIONS AT THIS LEVEL DEPENDS ENTIRELY ON FIELD INVESTIGATIONS AT THE CANDIDATE SITES.

THE SIX STEP PROCESS OF SITE SELECTION ATTEMPTS TO CONDUCT A COMPREHENSIVE SITE SEARCH BASED ON PRESENTLY AVAILABLE INFORMATION USING A WELL REASONED SITE CRITERIA. ONE OF THE STRENGTHS OF SUCH A PROCESS IS THAT IT GIVES EQUAL CONSIDERATION TO ALL AREAS WITHIN THE MAJOR SEARCH AREA. BY INITIALLY CONSIDERING ALL AREAS WITHIN THE MAJOR SEARCH AREA AND ELIMINATING THOSE PORTIONS WHICH HAVE OBVIOUS LIMITATIONS, A RATIONAL, SYSTEMATIC, AND RELATIVELY COST EFFECTIVE APPROACH TO SITE SELECTION IS ACHIEVED.

IN FORMULATING A WELL REASONED SITE SELECTION CRITERIA, THE FOLLOWING GUIDELINES SHOULD BE OBSERVED:

1) FIRST, THE CRITERIA SHOULD CONTAIN A NUMBER OF PARAMETERS TO BE EVALUATED. SOILS, TOPOGRAPHY, GEOLOGY, HYDROLOGY, LAND USE, ENGINEERING SUITABILITY, AND TRANSPORTATION ARE OBVIOUS FACTORS TO BE CONSIDERED IN ANY SITE. OF COURSE, OTHERS MAY BE INCLUDED.

2) SECOND, THE EVALUATION AND MEASUREMENT OF EACH PARAMETER SHOULD FOLLOW GENERALLY ACCEPTED METHODS AND TECHNIQUES. SUCH EVALUATIONS SHOULD STRESS OBJECTIVE AND QUANTIFIABLE MEASUREMENTS OF EACH PARAMETER.

3) THIRD, THE INFORMATION REQUIRED TO MAKE INITIAL JUDGEMENTS SHOULD BE BASED ON AVAILABLE INFORMATION. MOST SITE SELECTION EXERCISES HAVE AND ARE EXPECTED TO OCCUR NEAR LARGE INDUSTRIAL CENTERS. THESE AREAS TYPICALLY HAVE BEEN STUDIED INTENSIVELY BY GOVERNMENT, ACADEMIC INSTITUTIONS, AND PRIVATE INTERESTS. SOIL MAPS, LAND USE STUDIES, WELL LOGS, GEOLOGIC PROFILES, AND DEMOGRAPHIC INFORMATION SHOULD BE READILY AVAILABLE AND FAIRLY CURRENT. IN MORE REMOTE REGIONS WHERE LITTLE INFORMATION IS AVAILABLE, FACILITY PROPOSERS MAY HAVE TO COLLECT THEIR OWN BACKGROUND DATA.

4) FOURTH, EACH PARAMETER SHOULD BE EVALUATED INDEPENDENTLY RATHER THAN ON A WEIGHTED AVERAGE BASIS SO THAT THE IMPORTANCE OF EACH PARAMETER TO THE OVERALL EVALUATION CAN BE ASSESSED. WEIGHTED-AVERAGE METHODS SHOULD BE AVOIDED FOR TWO REASONS: FIRST, THE WEIGHT ASSIGNED TO A GIVEN PARAMETER IS MADE ON A SUBJECTIVE BASIS AND SECOND, THE RELATIONSHIPS AMONG PARAMETERS ARE NOT NECESSARILY ADDITIVE. FOR EXAMPLE, ASSUME THAT A SITE UNDER CONSIDERATION IS EVALUATED ON ONLY THREE FACTORS: LAND USE, SOILS, AND GEOLOGIC CONDITIONS. AFTER INITIAL EVALUATION, EXCELLENT MARKS IN THE LAND USE AND SOILS ARE SCORED, BUT THE SITE LIES OVER AN ACTIVE FAULT. WHEN WEIGHTS AND VALUES ARE ASSIGNED TO EACH PARAMETER AND THE SCORES ARE SUMMED, IT IS POSSIBLE THAT THIS SITE COULD COME OUT WELL AHEAD OF OTHER

OF OTHER SITES WHICH HAVE MODERATE MARKS FOR ALL PARAMETERS. I THINK MANY OF YOU WILL AGREE THAT SITING CHEMICAL WASTE DISPOSAL FACILITIES OVER ACTIVE FAULTS IS ENTIRELY OUT OF THE QUESTION. THIS PARTICULAR EXAMPLE MAY BE A BIT EXTREME, BUT IT DOES POINT OUT THE WEAKNESS OF THE WEIGHTED-AVERAGE METHOD OF INTERPRETING THE RESULTS OF SITE SELECTION.

5) THE FIFTH GUIDELINE FOR DEVELOPING A WELL REASONED SITE CRITERIA IS THAT THE CRITERIA SHOULD ESTABLISH CERTAIN MINIMUM PERFORMANCE STANDARDS. BY ESTABLISHING MINIMUM STANDARDS, THE SITE WHICH IS ULTIMATELY SELECTED WILL NOT ONLY BE THE MOST FAVORABLE AMONG THOSE CONSIDERED, BUT IT WILL BE ACCEPTABLE FROM THE STANDPOINT OF EACH MAJOR SITE PARAMETER. TO ILLUSTRATE THE IMPORTANCE OF ESTABLISHING MINIMUM STANDARDS, LET'S GO BACK TO THE PREVIOUS EXAMPLE WHERE LAND USE, SOILS, AND GEOLOGY ARE THE PARAMETERS, AND SUPPOSE THAT THE MAJOR SEARCH AREA LIES OVER AN ACTIVE FAULT. THE SITE SELECTION PROCESS WILL PRODUCE A "MOST FAVORABLE" SITE WHICH ALSO LIES OVER THE FAULT. AGAIN, DUE TO THE OBVIOUS LIMITATION OF AN ACTIVE FAULT, NONE OF THE SITES IN THE MAJOR SEARCH AREA SHOULD BE SELECTED REGARDLESS OF THE SCORES WHICH THEY MIGHT RECEIVE AFTER COMPREHENSIVE EVALUATION.

THE FINAL RESULT OF THE COMPUTER ASSISTED SEARCH IS THE IDENTIFICATION OF MINOR SEARCH AREAS.

THE USE OF THE COMPUTER IN PARING THE MAJOR SEARCH AREA DOWN TO A DISCRETE NUMBER OF MINOR SEARCH AREAS HAS A NUMBER OF ADVANTAGES:

1) IT IS OBJECTIVE.
2) IT MAKES USE OF AVAILABLE INFORMATION.
3) IT MINIMIZES SUBJECTIVE JUDGEMENTS.
4) IT CONSIDERS THE ENTIRE MAJOR SEARCH AREA RATHER THAN ARBITRARILY SELECTED LOCATIONS WITHIN THE MAJOR SEARCH AREA.
5) IT IS VERY FAST. AS LONG AS THE RAW DATA IS IN PLACE, THE RATE LIMITING FACTOR IS THE TIME NECESSARY TO FORMULATE AN ACCEPTABLE RATING SYSTEM.
6) IT IS RELATIVELY INEXPENSIVE. APPROXIMATELY $2,000 WAS REQUIRED FOR THE COMPUTER TIME, CODING, PROGRAMMING, AND INTERPRETATION OF RESULTS IN OUR CLASS.

DESPITE ITS STRENGTHS, THE COMPUTER-ASSISTED SITE SELECTION TECHNIQUE DOES HAVE SOME LIMITATIONS.

1) THE ACCURACY OF THE RAW DATA IS HIGHLY DEPENDENT ON THE AGE AND COMPLETENESS OF THE ORIGINAL SOURCE. IT IS ALSO DEPENDENT UPON THE PERSON INTERPRETING THE DATA.
2) THERE ARE LIMITATIONS TO THE KIND OF DATA STORED IN THE COMPUTER.
3) THE COLLECTIVE JUDGEMENTS OF A PANEL OF "EXPERTS" MAY INTRODUCE CERTAIN BIASES INTO THE INTERPRETATION OF THE DATA.
4) EVEN THOUGH CERTAIN CONCLUSIONS CAN BE REACHED FOLLOWING THE COMPUTER ASSISTED PROCESS, PROJECT ORGANIZERS MUST UNDERSTAND THAT CONSIDERABLY MORE TIME AND RESOURCES MUST BE BE EXPENDED TO REACH CONCLUSIONS REGARDING THE FINAL SITE SELECTION.

CONCLUSIONS

THE SITE SELECTION PROCESS WHICH HAS BEEN PRESENTED TODAY IS THE RESULT OF A MAJOR CHANGE IN THE DECISION-MAKING ENVIRONMENT SURROUNDING THE ESTABLISHMENT OF NEW CHEMICAL WASTE DISPOSAL FACILITIES. THIS DECISION-MAKING ENVIRONMENT IMPOSED BY STATE AGENCIES, LOCAL AUTHORITIES, AND MORE RECENTLY THE FEDERAL GOVERNMENT,WILL REQUIRE WASTE DISPOSAL FACILITY ORGANIZERS TO MORE CAREFULLY CONSIDER THE SHORT AND LONG TERM ENVIRONMENTAL CONSEQUENCES OF A PROPOSED WASTE FACILITY AND ITS LOCATION.

THE SITE SELECTION PROCESS PRESENTED TODAY APPEARS TO BE A RATIONAL, SYSTEMATIC, AND THOROUGH METHOD OF SELECTING A SUITABLE LOCATION FOR A CHEMICAL WASTE FACILITY. WITHIN THE CONSTRAINTS OF THE DECISION-MAKING ENVIRONMENT IN MINNESOTA, IT ALSO APPEARS TO BE A COST EFFECTIVE METHOD FOR SITE SELECTION BY EMPHASIZING THE USE OF CURRENTLY AVAILABLE INFORMATION WHICH IS QUICKLY AND EFFICIENTLY MANAGED BY A COMPUTER AFTER INSTRUCTION FROM A VARIETY OF KNOWLEDGEABLE PEOPLE.

I WOULD LIKE TO AGAIN THANK THE NSWMA FOR THIS OPPORTUNITY TO PRESENT THIS STATUS REPORT ON THE DEMONSTRATION PROJECT AND HOPE THAT WE MAY RETURN TO DISCUSS OTHER RESULTS OF THE PROJECT AS THEY BECOME AVAILABLE.

I WOULD LIKE TO MOVE NOW FROM THE SUBJECT OF SITE CRITERIA TO THE SUBJECT OF HOW WE, IN MINNESOTA, HAVE APPROACHED THE EVALUATION OF A MAJOR SEARCH AREA. TO AID IN THIS EVALUATION, A COMPUTER WAS USED TO STORE, COLLATE, AND PRODUCE INTERPRETIVE "DATA MAPS" SHOWING THOSE AREAS WITHIN THE MAJOR SEARCH AREAS WHICH CAN BE ELIMINATED FROM FURTHER CONSIDERATION AND IDENTIFY THOSE AREAS WHICH SHOW THE <u>LEAST</u> LIMITATION ON THEIR USE AS A WASTE DISPOSAL SITE. THIS COMPUTER BASED TECHNIQUE WAS DEVELOPED BY THE UNIVERSITY OF MINNESOTA IN ITS CENTER FOR URBAN AND REGIONAL AFFAIRS FOR APPLICATION IN A WIDE VARIETY OF LAND USE RELATED EVALUATIONS.

THE FIRST STEP IN MAKING USE OF THE COMPUTER-ASSISTED TECHNIQUE IS TO ASSEMBLE THE AVAILABLE INFORMATION AND PLACE IT IN THE COMPUTER. FOR THIS PARTICULAR SYSTEM, THE MAJOR SEARCH AREA WAS BROKEN INTO 40 ACRE PARCELS. THE TOTAL NUMBER OF PARCELS WAS APPROXIMATELY 47,000. NEXT, THE AVAILABLE INFORMATION WAS COLLECTED, INTERPRETED, AND ENCODED IN A FORM UNDERSTANDABLE TO THE COMPUTER. SOURCES FOR THIS DATA BASE INCLUDED:

AERIAL PHOTOS, U.S. GEOGRAPHIC SURVEY TOPOGRAPHIC MAPS, SOIL MAPS FROM THE SOIL CONSERVATION SERVICE AND THE UNIVERSITY OF MINNESOTA, LAND USE PLANS, AND LAND OWNERSHIP SURVEYS. NEXT, A COMMITTEE OF TECHNICAL EXPERTS AND PUBLIC AGENCY REPRESENTATIVES FORMULATED A RATING SYSTEM WHICH EVENTUALLY BECAME AN INSTRUCTION SET FOR THE COMPUTER. THE COMPUTER WILL TAKE THE DATA AND INSTRUCTIONS AND PRINT OUT A SERIES OF INTERPRETIVE MAPS SHOWING THE DEGREE OF LIMITATION FOR EACH LOCATIONAL FACTOR. WITH APPROPRIATE INSTRUCTIONS, THE COMPUTER CAN ALSO OVERLAY THE RESULTS OF AN INTERPRETIVE MAP FOR ONE FACTOR ON OTHER MAPS TO GIVE A TOTAL PICTURE OF WHERE THE MINOR SEARCH AREAS MAY LIE AND WHAT AREAS CAN BE ELIMINATED FROM FURTHER CONSIDERATION

GROUND WATER PROTECTION SYSTEMS- WHERE THEORY MEETS PRACTICE

John Reinhardt, Chief
Solid Waste Management Section
Wisconsin Department of Natural Resources

The possible pollution of ground water by landfill sites is becoming of greater concern to the public. In a number of instances, raising it as an issue is used by the opposition to block the establishment of a disposal site.

> "How serious are the impacts of land disposal sites on ground water?"
>
> "Isn't this issue really an over reaction on the part of environmentalists and alarmists?"
>
> "After all, no one ever died from drinking leachate did they?"

In my opinion, the impact of landfills on ground water can be very serious. The issues raised by the potential for ground water pollution by landfill sites will have far reaching impacts on the solid waste industry if in some areas, landfills will be permitted in at all, where they will be located, how they will be designed, who actually will own them and the economics of disposal.

As far as I know, to date, it has not been established that any human has died from leachate. Maybe someone in the audience can correct me on this. This is probably due only to the difficulty in getting water polluted with leachate past one's nose. Damage assessment at many older existing landfill sites in Wisconsin indicates many cases of undrinkable water in the immediate vicinity of the landfills due to the landfill.

The Congressional Record, September 27, 1976 documents the serious economic consequences of ground water pollution. Congress is requested to provide \$650,000 for the correction of the ground water pollution problem at the Llangollen landfill in New Castle County, Delaware. \$2,000,000 already has been spent on the problem. The operating costs of the present barrier well protection system is \$200,000 per year, and total estimated costs for correction range from an estimated \$15,000,000 to \$25,000,000. An expenditure of this magnitude, by any public or private landfill owner, would certainly be a financial disaster. Admittedly, the Llangollen landfill was an old existing site established at a time when little or nothing was known about the undesireability of establishing a site in a gravel pit. However, sites are being established today, in which you and I are playing a role, which could have such an impact if we are wrong in our analysis of what ground water protection systems are required or if these systems fail.

Landfill site operators, consultants and regulatory officials are all facing a common dilemma, viewed from different prospectives, in establishing land disposal sites for residuals. On one hand is the strict environmental (and in some instances legal) stance that under no circumstances shall a disposal site change the ground water quality - "zero discharge". On the other hand is the viewpoint that the waste must go somewhere as it is produced every day. The urgency of the need to dispose of waste, as it is generated, means a few wells or a minor trout stream must be sacrificed here or there to prevent the garbage from piling up on the streets; the old "end justifies the means" concept.

In between these two extremes, landfill sites must be found that provide a high degree of protection of the ground water and also meet other economic, social, political, legal, and environmental constraints and requirements.

The purpose of this presentation is to describe some of the problems with putting the theory of ground water protection systems into practice and to provide a framework for a forum discussion of some of the dilemmas in addressing the ground water protection aspects of landfill site location.

The objectives of this presentation are to:

*Provide several definitions of the ground water which must be considered in ground water protection systems.

*Point out several reasons why the ground water protection systems must be considered in landfill site location.

*Describe some of the more classical ground water protection systems.

*Raise some of the more pertinent issues facing the location of landfills from a ground water protection standpoint.

"What is 'ground water'?" The lack of a clear understanding of, and agreement on, the various definitions of ground water on the part of the designer can result in a regulatory agency asking for a re-evaluation of some of the proposed concepts for ground water protection systems. If ground water is to be protected, one has to know what it is. Ground water is usually technically defined as water below the ground water table. Davis & De Wiest in their text book "Hydrogeology", define "water table" as "the surface in unconfined materials, along which the hydrostatic pressure is equal to the atmosphere pressure." While this is one of the more widely accepted technical definitions, statutory definitions may vary from this. Chapter 162.02(2) of the Wisconsin State Statutes defines ground waters as, "subsurface water supplied for human consumption." This could be interpreted to mean all water under ground. Section 147.015(13) of the Wisconsin State Statutes, which establishes the WPDES (Wisconsin Pollution Discharge Elimination System), specifies waters of the state to include ground water without defining ground water. The differences in definition must be addressed in any ground water protection system.

Another definition of ground water, which must be considered is the definition established by court cases. The outcome of a future lawsuit, for alleged damages to your neighbor's ground water, could depend on the definition put forth in a past court suit. It wasn't too long ago in Wisconsin that a court suit talked in terms of water flowing in "underground rivers".

An understanding that must be understood are different meanings to ground water is necessary if ground water protection is to be meaningfully addressed in landfill site location.

Another term that must be understood is "aquifer". It generally is technically defined as "a formation or group of formations, or part of a formation that contains sufficient saturated permeable intervals to yield or be capable of yielding significant quantities of water to wells or springs." There is, at times, a tendency to ignore shallow aquifers capable of providing water only to domestic wells. It is important that the designer and others with an interest in ground water protection system understand from the start if the system needs to protect all ground water or only certain types or classes of aquifers.

A below the zone of saturation landfill in tight clay could be polluting the ground water as defined technically, by statutes and by court cases, but not harming any aquifers because water cannot be withdrawn from the clay in significant quantities even for domestic wells.

Why protect the ground water? First, there have been for some time various state statutory obligations. Also, of present and future significance is the Safe Drinking Water Act on the Federal level. You can be sued by your neighbor if you pollute his ground water. Not protecting ground water is considered anti-social; neighbors appreciate landfills even less than they usually do if the landfill can pollute their ground water. Neighbors near proposed landfill sites are greatly influenced by past ground water pollution from landfills. Environmental groups and others who oppose a particular landfill or, in fact, oppose any landfill anywhere, can successfully stop a landfill from being established or from continuing operation if they can show that ground water may be polluted. Politically, no elected official can be in favor of a landfill which may pollute ground water. Thus, an elected official must oppose any landfill which may pollute the ground water.

In summary, the issue of ground water protection must be addressed and resolved by those groups who are represented in the audience if landfill is to provide a viable, residual disposal solution into the future. The problems of putting theory into practice, in ground water protection systems, must be overcome in a manner that they work in the field and in a manner that the public can have confidence in them. If the "doers" ignore the issue as they believed the "refuse has to go somewhere"; the end justified the means, then, the alternative may be the creation of many unwisely conceived resource recovery and processing concepts in the guise of protecting the ground water.

How can the ground water be protected? The concept, in theory, is easy; the implementation, in practice, is difficult. In concept, contaminants from residual disposal must be prevented from reaching the ground water, either entirely to meet statutory definitions or limited to some amount that is legally specified or would not make the water unusable. The amount of degradation which can be tollerated will depend on if the water is to be used for drinking, cooling, irrigation, etc.

The traditional problem solving procedure, used in large scale engineering projects, is probably the best approach to developing ground water protection systems. This approach can be especially effective when incorporating systems concepts of looking at alternatives and re-evaluating solutions into it.

A clear understanding of what is to be protected, in terms of the legal, social and technical definitions of ground water, is needed. Also, a clear, written definition of other economic, political, and social constraints to the problem is desirable.

A good physical definition of the actual area where the waste will be placed, along with the surrounding area, is needed. The physical definition of topography, surface water, geology, soils, hydrogeology, inter-relationship of aquifers, etc., is needed to assess alternate solutions.

Theoretically, the anticipated time-rate of production of contaminants should be determined, and the ability of the physical site location to attenuate them should be established. The difference between contaminant loading and the natural ability of the physical site to protect the ground water should then be addressed through engineering design of man-made site modification systems. Unfortunately, only in a crude way has contaminant production been defined in terms of quality and quantity at this time. Assessing the contaminant variation from landfills with time is extremely difficult. If all landfills were located in homogeneous soils with readily defined flow systems, the capacity of the site to handle contaminants could be more easily addressed. As soils and flow systems in nature are not always easily defined, the task is usually difficult.

Thus, the theoretical approach is easy to describe, but as most of you know through your own experience, at this time, there is a long way between theory and practice. Landfill disposal site location and design for ground water protection are not yet a science, let alone a well-developed art. Some say it is a black art; others say it is an emerging art at best. However, the development of ground water protect system theory and practice has come a long way in the past ten years. The more traditional 10 year time-lag of knowledge from theory to practice, through laboratory, pilot projects, etc., has been short-circuited. The need to do something now has necessitated placing theory directly into practice in many cases. Only time will tell if the theory works. It may not have always been the wisest course, but then we place waste at the curb every day and something is better than nothing. In my opinion, the theory that is available should be utilized to the maximum, even if it is sometimes in an imperfect state. In order that ten years from now,. the imperfect art we practice, today can be called even a fledging science, we must utilize it to its maximum today.

Also, of prime importance is that the problem not be viewed from the standpoint of meeting some minimum regulation. Minimum regulations are just that--solutions designed around such a narrow concept are usually short-lived and in the long run inadequate.

What are some of the major ground water protection systems which are proposed and in use today? They can be categorized as natural protection systems, man-made systems, or combinations of both.

The most obvious approach to protecting the ground water is to limit the amount and/or rate of leachate production by reducing water coming into contact with solid waste. The diversion around the landfill of surface water around the landfill from areas outside of the landfill is one of the first engineering considerations that should be made in landfill design. Traditional storm water design equations and concepts should be used. The solutions are expressed in the field in terms of ditches, storm sewers, and berms. Some civil engineers, who would not think of designing a highway or parking lot without computing the size of ditches and storm sewers to protect the project from storm water, do not see the same need when designing landfills. The possibilities of surface water entering the landfill through sand stringers, where these sand stringers extend or surface outside the landfill, should be examined. The sand stringer can be sealed with clay, both inside and outside the landfill. As simple as this may seem, this approach often is not taken in landfill design.

The location and design of cover dirt sources and stockpiles must be done in a manner that they do not route surface water into the fill. All earth moving activities connected with a landfill should be designed in a manner that they do not add water to the fill or if possible in a manner that conducts water off the site. Many cases of unnecessary leachate production at landfills have resulted from not considering this problem.

Leachate production can also be reduced by detailed consideration of the handling of precipitation on the landfill site proper. Detailed phasing plans for each cell which route surface water in a manner that it can be directly away fill will reduce leachate. Every gallon of water that is pumped or drained off of a refuse cell is one less gallon to infiltrate and produce leachate. A design of the final contours and cover to reduce infiltration can also greatly reduce leachate production. The final contours should channelize water and provide the shortest possible length of overland flow. Runoff can also be increased by increasing the slope and choosing a cover material that has a low permeability and will not readily crack. As an extreme, a man-made material such as plastic or rubber can be used to attempt to obtain zero infiltration.

The impacts of various concepts are easily evaluated by utilizing traditional engineering design procedures utilized in storm water design. Rational approaches to evaluating designs are also given in the many Soil Conservation Service manuals.

Obviously, once leachate is produced, consideration must be given to handling it in a manner to not pollute ground water. Natural systems to handle leachate once it is produced are generally preferable to man-made systems. Man-made systems are usually expensive to build, operate, and often require long-term maintenance and operation. Which system or combination of systems should be used is dependent on detailed definition of the site location in terms of soil type, geology, hydrogeology, and other physical criteria. Hopefully, the site is located so that the underlying soils will attenuate the leachate so it will not pollute the ground water, or so it would flow through the hydrogeologic setting in a manner not to create a problem. This approach takes advantage of soils, upward ground water gradients, flow paths for contaminants that will not impact on ground water use in a detrimental manner, and possibly others. Thomas Clark, in the July-August 1975 issue of Ground Water gives a detailed mathematical approach to evaluating a natural attenuation site.

Artificial systems vary all the way from man-made fabric liners used in concepts which completely collect and treat leachate to wells installed into the center of a landfill in case leachate "has to be withdrawn at a future date".

Liners can be classified in terms of man-made materials such as rubber and plastic or natural materials such as clay. The use of man-made materials usually is based on the concept that no leakage will occur. This implies collection and treatment of leachate. Use of clay or other natural materials usually implies some leakage will occur. Thus, the site location still must be considered as part of the ground water protection system.

Use of liners usually will call for leachate collection and treatment at some time and in some manner, as in many areas of the United States infiltration through the cover will exceed the exfiltration through the lined bottom and sides of the fill. If the leachate is not withdrawn, it will ultimately build up to where it will spill out on the ground. All the problems associated with leachate collection and treatment must be addressed. This includes the problems associated with the long-term operation, maintenance, and financing of these systems. While there is some question about the theory of treating leachate, increasing numbers of projects are being reported, where treatment either is being done or proposed. Usually the collected leachate is treated in an existing municipal waste water treatment plant.

The combination of natural and man-made systems are being proposed for new disposal sites and many have actually been built in the field. These include the concept of below the zone of saturation location of landfills in tight soils with the maintenance of inward gradients by leachate withdrawal. This and other such concepts were discussed in some depth as early as 1972 by George Hughes in the Illinois Geological Survey Environmental Geology Notes.

Barrier wells, under drains, spot sealing of permeable soils are other concepts proposed or in use. One recent concept proposes to use a clay liner and air from an air compressor to restrict leachate from flowing out of the landfill and carbon dioxide from migrating out of the landfill. The problems of ground water pollution caused by methane and carbon dioxide migration are just beginning to be addressed.

One interesting concept of choosing between complete collection and treatment of leachate and no protection for the ground water is using the shallow flow system adjacent to large rivers or discharge areas which handle polluted ground water without producing major problems. A location is chosen adjacent to a large river where the ground water flow system is primarily horizontal toward the river. Preferably, the site is adjacent to a flood plain where development of wells will never occur. The flow path of the contaminants should be long enough in time and distance that when they reach the river or discharge point, they will not have a detrimental impact on the surface waters. Of course, the problems with flow laterally along the river bank must also be evaluated, along with any problems due to reversal of ground water gradients during high river flow periods. Basically, this is a deliberate pollution of a portion of the shallow ground water resource which is unlikely to even be used to overcome the many problems with locating in other settings. The approach is based on the concept that it is better to use part of the ground water flow system where the pollution will be minor in extent and the result predictable. An interesting version of this approach will a step-by-step mathematical design was presented in the April 1975 issue of Public Works by Dilaj and Lenard.

Unfortunately, such questions as what is a natural attenuation site, which man-made system is needed to protect the ground water to what extent, etc., largely depended on a number of resource allocation questions which are, to a great degree, unresolved. Two of the most pertinent are:

*To what degree can the ground water be used for waste assimilation from a technical, legal, social, environmental and regulatory standpoint?

*How can the problem of waste load allocation to air, water and land be resolved in the context of federal and state regulatory programs and other constraints placed on the problem by society?

Two major questions must also be resolved ultimately if man-made systems are to prove usable in the long run. These are:

*How can the issue of long-term responsibility and liability for ground water protection at landfill sites be resolved?

*How can the public be assured that the technical concepts are adequately translated into engineering design and then actually constructed and operated into the field in keeping with the engineering design. This appears to be a major problem in the immediate future which must be overcome. Evaluation of how viable present concepts are will be difficult, if not impossible, if they are not properly converted to engineering design, constructed in the field, or evaluated from data gathered in the field?

If the theory and design of ground water protection systems ever are to work in practice, quality control of construction and operation in the field is a necessity. If the studies and designs are only made to obtain an approval and license from a regulatory agency, then all is lost. Unfortunately, it is not uncommon to find engineering plans being ignored in the field and in some instances, the landfill operator unable to read the plans and unwilling to retain the necessary professional help who can.

Last, but not least, translating the theory of ground water protection systems, into practice, requires monitoring and evaluating performance. Some view such activities as research projects for state regulatory agencies. In my opinion, monitoring and evaluation of ground water protection systems are of great value to the landfill owner. It provides him proof against charges of his neighbors that he is polluting the ground water. It provides information for him on which to make future investments in landfills. It allows early corrective action when designs do not work. It also provides the landfill site with some degree of public credibility.

Certainly, the subject matter and issues raised in this presentation can only be covered in some depth by a four or five-day conference. However, this forum presents an opportunity for a wide cross-section of those involved in landfill siting to put forth their views on the issues raised. If those present think the issues can be ignored, there are others who will not ignore them but will provide answers none of us will like.

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CONSIDERATIONS FOR STATE HAZARDOUS
WASTE PROGRAMS

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- CONGRESSIONAL INTENT FOR STATES TO ASSUME HAZARDOUS WASTE PROGRAM

- EPA GUIDELINES TO ASSIST STATE PROGRAM DEVELOPMENT

- INTERIM AUTHORIZATION POSSIBLE

- FEDERAL GRANTS PROVIDED FOR INITIAL DEVELOPMENT AND IMPLEMENTATION

- STATE PROGRAMS TO BE "EQUIVALENT" TO FEDERAL PROGRAM

- STATE PROGRAMS TO BE "CONSISTENT" WITH FEDERAL AND OTHER STATES' PROGRAMS

GOALS OF STATE HAZARDOUS WASTE PROGRAMS

1) COGNIZANCE OVER HAZARDOUS WASTE

- SOURCES
- QUANTITIES
- TYPES
- DESTINATIONS

2) CONTROL OVER HAZARDOUS WASTE

- STORAGE
- TRANSPORTATION
- TREATMENT
- DISPOSAL

3) CAPABILITY TO

- PROVIDE TECHNICAL ASSISTANCE
- ENFORCE REGULATORY PROGRAM

4) ALTERNATIVES TO INADEQUATE PRACTICES

5) PREVENTION OF PUBLIC HEALTH AND ENVIRONMENTAL DAMAGES

ELEMENTS OF AN EFFECTIVE STATE PROGRAM

1) LEGISLATIVE AUTHORITY

2) ADEQUATE RESOURCES

3) PUBLISHED CRITERIA AND STANDARDS

4) FACILITY PERMIT SYSTEM

5) TRANSPORTATION MANIFEST SYSTEM

6) SURVEILLANCE AND ENFORCEMENT FUNCTIONS

SUGGESTED SEQUENCE OF DEVELOPMENT

1) HAZARDOUS WASTE SURVEYS

   - ESTABLISH SCOPE OF PROBLEM

2) STATE PLAN

   - HAZARDOUS WASTE SUBSET OF SWM PLAN
   - FACILITY CAPACITY NEEDS

3) LEGISLATION

   - NEW OR AMENDMENTS

4) REGULATIONS

5) PERMIT PROGRAM

6) GENERATOR REPORTING

7) TRANSPORT MANIFEST SYSTEM

8) SURVEILLANCE AND ENFORCEMENT

"FULL" AUTHORIZATION OF STATE PROGRAM

° STATES CAN APPLY AT ANY TIME

(?) ° ALL PROGRAM ELEMENTS IN PLACE (EQUIVALENT)

(?) ° CONSISTENT WITH FEDERAL AND OTHER STATES' PROGRAMS

(?) ° FRAMEWORK AND RESOURCES FOR ENFORCEMENT IN PLACE

(?) ° SINGLE LEAD AGENCY (SEVERAL MAY BE INVOLVED, BUT ONE MUST LEAD)

(?) ° INTERSTATE COOPERATION POLICY

"INTERIM" AUTHORIZATION OF STATE PROGRAM

- "SUBSTANTIALLY EQUIVALENT" PROGRAM IN EFFECT BEFORE JULY 21, 1978
- TEMPORARY AUTHORIZATION IN EFFECT FROM OCTOBER 21, 1978 TO OCTOBER 21, 1980
- INTENT TO OBTAIN "FULL" AUTHORIZATION DURING THIS PERIOD
- STATE MAY TEMPORARILY LACK
  - CERTAIN PROGRAM ELEMENTS
  - RESOURCES
  - FACILITY CAPACITY

ISSUES CONCERNING STATE PROGRAMS

- ° FEDERAL DEFINITION OF HAZARDOUS WASTE
  - BROAD OR NARROW SCOPE
- ° INTERPRETATION OF
  - "EQUIVALENT"
  - "CONSISTENT"
  - "SUBSTANTIALLY EQUIVALENT"
- ° CAN STATE PROGRAMS BE MORE STRINGENT THAN FEDERAL PROGRAM?
- ° ARE WASTE NON-IMPORTATION POLICIES FAIR TO OTHER STATES? ARE THEY "CONSISTENT"?
- ° SHOULD STATE PROGRAMS BE SELF-SUSTAINING? HOW? USER FEES?

CONTROL OF HAZARDOUS WASTES IN CALIFORNIA

by

Harvey F. Collins[1] Ph.D.

The California Department of Health's hazardous waste control program was started in the fall of 1973 pursuant to the Hazardous Waste Control Act of 1972, which authorized the Department to: (1) establish and enforce regulations for the handling and disposal of hazardous wastes; (2) provide for appropriate surveillance of hazardous waste processing and disposal practices in the state; (3) conduct appropriate studies relating to hazardous wastes; and (4) maintain a technical reference center on hazardous waste disposal, recycling practices, and related information for public and private use.

Regulations. The Department adopted regulations governing hazardous wastes in June, 1974. These regulations list wastes determined to be hazardous and extremely hazardous, establish requirements for producers and haulers of hazardous wastes and for operators of waste disposal sites, and specify approval by the Department of Health as a prerequisite to the disposal of extremely hazardous wastes. The regulations also established fees to be paid by

[1] California Department of Health, Sacramento, CA

operators of disposal sites accepting hazardous wastes. The fees support the regulatory activities of the Department's program, which is not funded from the State Treasury.

We have recently finalized hazardous waste regulations which the Department proposes to adopt within the next few months after a public hearing. These regulations will greatly expand the Department of Health's regulatory activities. Where the present regulations apply only to operations at waste disposal sites that receive hazardous wastes from more than one source, the proposed regulations will apply to operations at all disposal sites that receive hazardous wastes. They will also apply to all transfer stations, storage facilities, and treatment facilities that receive hazardous wastes. The proposed regulations are far more detailed than the present regulations and explicitly prohibit undesirable procedures which we have observed at some of the disposal sites.

Surveillance and Enforcement. The program presently has personnel operating out of Sacramento, Berkeley and Los Angeles. Our inspectors make field inspections to ensure that hazardous wastes are properly handled and disposed of. These inspectors: (1) visit plants and facilities where hazardous wastes are generated, processed, and stored, (2) field-monitor the haulers of hazardous wastes to discourage illegal disposal at unauthorized disposal sites; and (3) visit hazardous waste disposal sites to inspect the sites and audit records of receipt of hazardous wastes. Since April 1976 when we initiated our intensive field efforts, we have visited 161 factories or plants which generate hazardous wastes and have made 218 visits to sites where such wastes are disposed of.

A total of 76 illegal hazardous waste disposals or unsafe handling practices has been found by our inspectors. In most cases these irregularities were rectified by informing the waste handler of the law and providing him with guidance on proper methods to handle and dispose of his waste. In four cases the violations were serious enough that we have sought legal action.

The Hazardous Waste Control Act requires that each load of hazardous waste transported in California be accompanied by a manifest which describes the composition and volume of the waste. Disposal site operators are required to sign the manifests when the waste loads are accepted at their sites and mail copies to the Department on a monthly basis.

We receive several thousand manifests each month and enter the reported information into a computer. Each month the computer prepares a report that shows the types and volumes of hazardous wastes disposed of, the firms which generated the wastes, and the disposal sites used. The computerized data aids the Department in its enforcement program and in program planning.

Studies (Field Surveys). The Department is conducting studies of the generation of all hazardous wastes, including those which are disposed of on land owned by waste producers. We are visiting plants and factories to determine the volumes and types of industrial wastes produced and how they are disposed of. The data will aid the Department in its regulation of the management of hazardous wastes and in its development of periodic publications which will report to the industries what types of wastes are available from other industries for use by them.

We have enlisted the help of local agencies to survey some of the counties. Six counties[1] have been surveyed with the aid of county or other local agencies. Nine other counties[2] are now being surveyed by county health agencies with financial and technical aid from the Department. Fifteen other counties will soon be surveyed by Departmental and county staff. In February we expect to have an estimate of the amounts of all hazardous wastes disposed of throughout the state, including wastes disposed of on land owned by waste producers.

PROBLEMS

Difficulties we have encountered have mostly resulted from administrative problems inherent in the initial developmental phase of a regulatory program. The one significant exception is that we do not have a practical means to discourage clandestine disposal of

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(1) Amador, Alameda, San Benito, Santa Cruz, Monterey, and Ventura

(2) Kern, Kings, Fresno, Madera, Mariposa, Merced, San Joaquin, Stanislaus, Tulare

hazardous wastes. The threat of revocation of a permit needed to handle hazardous wastes would provide a proper disincentive against such activity, as would the threat of imposition of a stiff monetary fine.

Our proposed regulations will require that all operators of facilities who transfer, store, treat, or dispose of hazardous waste have a permit issued by the Department and will provide for revocation of the permit of any who violate the regulations. We have proposed legislation for review by the Health and Welfare Agency and by the Governor that would prohibit the hauling of hazardous waste by persons who do not hold a license issued by the Department and which would authorize the Department to revoke the license for due cause.

The proposed legislation would also authorize imposition of a substantial monetary fine for violations. The Federal Resource Recovery Act of 1976 provides a precedent for such legislation, as it empowers the EPA to impose monetary fines on violators of federal requirements.

CONSIDERATIONS REGARDING HAZARDOUS WASTE REGULATORY POLICY ALTERNATIVES

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The Resource Conservation and Recovery Act 1976 (P.L. 94-580) at the outset recognizes the greater potential for health and environmental harm by requiring a greater degree of regulation than non-hazardous wastes management. The option to have or not to have a hazardous waste management program has been eliminated with the passage of this Act. We are not here to discuss the greater potentials for harm in hazardous waste management, but to discuss the different regulatory philosophies and attendant enforcement options. In conjunction with the need for health and environmental protection, the law also stresses resource conservation. This term is normally associated with resource recovery and materials policy decision-making. However, a policy of resource conservation pervades all sections of the law, including Subtitle C, Hazardous Waste Management. Therefore if resource conservation (that is, the maximum utilization of materials and optimum protection of resource -- land, water and air) is adopted as a regulatory philosophy, the implementation agency will bias its decision-making in the permit process with policies to provide further requirements for material recovery from residuals, or energy potential, rather than solely a concern for the safe deposition of hazardous waste to the land. The Association through IWT-Chemical Waste Committee and its testimony throughout the legislative history of P.L. 94-580 and on several EPA guidances on hazardous waste management has supported consideration of priority management alternatives(in order) which are - waste reduction, waste separation, waste exchange, energy/material recovery, treatment secure landfill. Given this scheme of descending alternatives, the implementation agency-Federal,state-will and can be expected to implement this philosophy in the permitting process. For example, requiring that a specified percentage of a waste stream be recovered or the prohibition of mixed wastes entirely in order to facilitate recovery.

The third goal of the act in relation to protection of public health and environment is the prohibition of open dumps. This will be evidenced as an affirmative, direct aggressive program of enforcement to identify, close or upgrade undesirable disposal options. However, a less apparent consideration is whether or not in developing regulatory provisions such degree of control is mandated; thereby, resulting in severe financial impact on acceptable disposal alternatives that open dumping is indirectly fostered as a viable option.

In the development of a regulatory program and its components - rules, standards, regulations, permit process, inspection and enforcement -- the maximum protection of human health and the environment, conservation of resource, and the closing of improper disposal methods will predominate in the selection of regulatory options.

Criteria

Criteria for determining whether or not a waste is hazardous should be based upon the characteristics of a waste rather than its functional origins. That is, a waste is hazardous because it is carcinogenic (characteristic) rather than its generation by a commercial/industrial activity (origin). The identification of waste by source is an inventory method, not a sole criteria for determination of degree of hazard. The conscious decision to solely regulate waste stream from commercial/industrial should be based upon the known volume and types of hazardous waste from those sources as a percentage of the total volume of hazardous wastes and the degree of hazard evidenced existing budgetary and staffing limitations must also be reflected in determining the level of enforcement program feasible. That is, if only given number of hazardous waste sources can be monitored and regulated, selection should based upon the type sources proportion to overall volume of hazardous waste generated and the degree of hazard in specific waste stream type. An example, several sources may generate a particular type waste (e.g. "sludge"). The sources may be commercial, industrial, or institutional facilities. Based upon a given criteria for determining a hazardous waste, only a few waste streams may be classified as hazardous, some of which may be industrial and/or institutional.

Regulations should be based on criteria for waste characteristics with established thresholds as in given LD_{50} -mg/ky body weight. This regulatory alternative will narrow and focus enforcement capabilities. This alternative is preferable rather than a process of elimination based on function, size or type of industry.

The development of criteria should consider -- oral toxicity, dermal toxicity, acidity, alkalinity, inhalation toxicity, bioaccumulation, genetic effect, aquatic toxicity, phytotoxicity, infectious, corrosivity, flammability, and reactivity. While data may not be available for all waste types, the criterium should not be eliminated but developed. Different levels of hazard can be determined on the basis of

- o direct exposure;
- o dilution-waste, leachate;
- o existing standards-air, water, transport.

The level of hazard should not solely focus on the impact of land disposal of hazardous waste. The law requires Environmental Protection Agency to develop and promulgate criteria for hazardous waste determination as well as listing hazardous wastes. Consequently, regulatory programs in the long term can be expected to develop based upon waste characteristics rather than solely upon point of generation of a waste.

The permit process can be responsive to this development and may provide exemptions based upon level of toxicity, etc., volume, rather than by specific identity of a source type. Options may be available in determination of numeric levels for each characteristic dependent upon a specific methodology testing such as standard leaching test, standard attenuation procedure and NIOSH documentation. Two generic approaches can be taken in selecting numeric criteria for designating hazardous waste--

- o compatibility with existing definitions and
- o use of a reasonable scenario describing a manner in which a waste may pose a hazard.

If the latter generic approach is utilized, criteria may develop on the degree of hazard posed by a waste characteristic at a point in time in the management program. Permit and licensing requirements may reflect that difference in degree of hazard, in transport, storage, processing and disposal. Regulatory standards based upon criteria will be different than those based solely upon point of origin since no differentiation in degree of hazard may be made.

Options in implementation of criteria-based regulatory program--

- o who shall apply criteria? generator? transporter? disposer?
- o who incurs the expense of applying criteria?
- o how often must waste be tested? Each load? Only when a change in Stream occurs?
- o what if cost of testing is prohibitive?

Inventory Methods

Inventory methods based on criteria system will vary from currently practiced survey methodologies. How a question is asked and to whom is crucial. Questions usually are volume oriented and perhaps should be weight oriented (weight of metals in solution versus gallons generated). All possible sources of hazardous waste should be inventoried rather than a selected SIC manufacturing population. Most surveys previously conducted are industrial surveys - not hazardous waste surveys. The results of the surveys determine the size, scope of program required, whether or not environmental program coordination is required, type and priority of regulation. Program levels should be given priority on degree of hazard rather than by category of industry. Methods of listing wastes on an inventory questionnaire may be by source, common or generic name. The usage of uniform waste listing approaches is crucial in the comparison of information gathered in a survey compilation to information received through a manifest system.

Regulations

Currently, most existing state programs place primary responsibility and regulatory control on the disposal site operator. Frankly, this is the weakest link in the decision-making chain. By the time a waste has reached a disposal site all major economic decisions have been made. The generator's, hauler's, storage facility operator's decisions override those possible economic options which may be available to the disposer. In effect, he has no economic recourse but to dispose of the material in most cases. While this scheme places full weight of responsibility upon a landfill operator, since his capability to respond is limited, the hazardous waste management program - especially enforcement-is weakened and possibly rendered ineffective. The new Federal law clearly sets forth responsibilities of the generator, transporter, and disposer. But regulations to be developed will determine degree of responsibility with the expectation that the responsibilities of the generator will expand significantly. Alternatives also exist in regulatory process in developing permits, providing for exemptions and variances, degree and frequency of inspection. The alternatives break-down into two categories - administrative and technical. In most cases administrative procedures for review are addressed in already enacted Federal and state laws. However, a degree of consistency in administrative processes is hoped for, especially in those situations where several environmental permits are required. For example, Washington State has provided for a "one stop" permitting process and the Minnesota Environmental Quality Council is reviewing such a proposal. The EPA should be cognizant of this procedure in reviewing state's application for interim and permanent authorization.

Technical: decide actual economic impact to applicant,especially if best available technology is considered as a criteria in facility design review and applied to monitoring, leachate collection, site selections, emission control requirements. The purchasing of materials, system design, service provisions will be affected and costs significantly increased. Stress should be placed on performance rather than operating standards. That is, a level of protection rather than specific method of accomplishment should be considered in the permit review process. Technical determinations can be applied to--

--definition determine scope of program, and level of enforcement

--permit requirements, length of time of permit

--financial responsibility and establishing degree of liability of unanticipated damage

--manifest requirements

<u>Time Frame</u>

The scope of hazardous waste program is also dependent on time frame for development and implementation. The time frame of Federal law appears to be 3 years. The time frame of reference varies for administrator, operator, generator. Administrator may determine - 18 months intervals - 3 year with review. However, hazardous waste facility operator makes determination on 10 year intervals. An administrative planner may think of two stage program - 18 months develop regulatory program, 1 year for implementation, and 3 year review schedule. All involved parties must recognize the impact on program planning of a start versus long time frame.

Interstate Compacts

The law provides for "establishment of such agencies, joint or otherwise, as they may deem desirable for making effective agreements or compacts."

While compacts for air and water programs are contiguous, hazardous waste management occurs in economic corridors which are not necessarily contiguous or encompassed by geographic region. Therefore, compacts between states which are not contiguous may be expected, especially in the enforcement of a manifest program.

The Role of 208 Regional Planning
Organizations in Solid Waste Management

by

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When the Federal Water Pollution Control Act (FWPCA) was passed in 1972, Section 208 called for areawide water planning, and implementation programs to carry out these plans. The objective of this section was to provide adequate State and regional planning to protect the ground and surface waters of this Nation.

The complexity of the problem is that major metropolitan areas discharge millions of tons of industrial and municipal wastes each year into the ocean, inland waterways and on the land. Only some of these wastes are discharged into sewers for primary and secondary treatment. The balance is dumped, untreated, into these three sinks: the ocean, inland waterways, and on the land. Even the wastes which reach treatment plants are only regulated with respect to the water effluent; the solid portion, which contains many potentially hazardous materials, is disposed in many cases, without adequate regulation.

Each year, this Nation generates 135 million tons of municipal waste, 270 million tons of industrial wastes, and 40 million wet tons of sewage sludge — and these quantities are growing every year. Approximately 90% of the municipal wastes, and over half of the industrial wastes and sewage sludge are deposited on the land. If not disposed of properly, leachate from these wastes reaches ground water which, at best, is left discolored and odorous, and at worst, is rendered non-potable. Approximately 90 million gallons of leachate is generated nationally each year, an unknown portion of which reaches ground water. Once ground water is contaminated it is too costly to attempt to clean it up and it must be abandoned as a drinking water supply. Alternatives may mean transporting water great distances, also a costly remedy. Since 50% of the Nation uses ground water for drinking, this is potentially a serious nationwide problem, and one which cannot be ignored.

An implicit part of the 208 water planning and management program is the development of a residual management plan which can be implemented. Specifically, sewage sludge processing and disposal was to be covered by Section 208 according to the legislative intent of the Act. However, since many localities and regions currently combine sewage sludge and municipal wastes (garbage and trash), and since, in the absence of pretreatment regulations, many industrial wastes empty, untreated, into sewage treatment systems, the residuals problem cannot easily be segmented.

Section 208 of the FWPCA defines residuals as any solid or semi-solid waste material which may result in ground or surface water contamination if disposed of improperly on the land. As you can see, the definition is very broad, and does include mixed municipal wastes. Like most laws, the language of 208 is broad in its scope and leaves to the states and local government a narrowing of the definition according to their priority needs.

A major question that has arisen in the progress of 208 is "what is the role of existing local, regional, and State solid waste planning agencies"? It is the intent of the 208 program to involve these agencies as an integral part of the process. They have the solid waste or residuals expertise, and in many cases have developed or are developing a residuals plan. These plans contain the basic data and analysis for good decision making, and if utilized, should accelerate the achievement of 208 goals. It is the intent of EPA to insist that these agencies be used and not ignored. Guidance to this effect has been given to all 208 agencies in a series of ten regional seminars over the past six months.

However, in spite of these efforts to include existing solid waste management planning agencies and service companies, some may be overlooked by the 208 agencies. In most cases this will be through an oversight — not being aware of the work that is already being done to insure proper solid waste disposal. All of you who are a part of an existing solid waste planning department, or a member of a local association of NSWMA should find out from the Water Planning Division of EPA, the name and address of the 208 agency in your area, and contact them directly with your information concerning current solid waste management activities in your region.

Another difficulty is the variability in level of involvement at the State level. In all cases, the Governor has the authority to designate regional 208 agencies. In regional areas which are not so designated (and, in the extreme, this may be the entire State) a State agency, also designated by the Governor, assumes the 208 planning and management function. So some states have chosen to engage in an active role, while others pass the responsibility (and the funds) to the regional agencies.

The operational system for dealing with residuals is in place, to some extent, in every community. Private companies and government agencies are collecting, processing, and disposing of municipal wastes already. Many are performing these tasks in an economical and environmentally-sound manner. In the case of sewage sludge and industrial wastes, there is less public visability, so, to date, only the most responsible companies and agencies have been concerned with the environmental impacts of its methods of waste disposal.

The 208 program is more than a planning program, which is a fact that has escaped many in trying to understand the goals of the program. It is the intention of the program to develop a residuals plan and implement it through "an appropriate management agency". Herein lies additional opportunity for misinterpretation by the 208 agency. In many parts of the country, regional or local management agencies already exist for residuals.

Such management agencies might reside in a COG, a public works department, a sanitary district, etc. In the case of private sector performance of services, the management agency might be the one that develops the bid specification, and issues the contract for services. In any event, 208 intends for there to be implementation of its plans, otherwise the entire process will have been a waste of time and money.

Regional agencies which do not have management authority, will need to form a new agency, with the political and financial backing of the local governments in the region. Since bonding authority is frequently required for capital-intensive solutions, it is important for the management agency to have this authority. An example of how this has worked successfully is the Southeast Oakland County (Michigan) Incinerator Authority. In this case, fourteen communities formed an authority to purchase, own, and operate an incinerator. Moreover, they agreed to share cost and performance data on their waste collection systems in an effort to work toward more efficient systems. Some communities performed waste collection themselves while others decided to contract to private haulers; but all used the incinerator for volume reduction and subsequent disposal.

If a cognizant management agency does not currently exist, it would be appropriate for 208 agencies to begin the process of developing a management agency early in the planning cycle since it will take some time and political effort to develop such an institution, and the plan can then be better tailored to meet the realistic authority and financial capability of the management agency.

Finally, the latest information on the additional monies available in the 208 program is as follows: $137 million dollars will be available to Regional Offices by the end of December. Some portion of this money will be used to raise the federal share of existing grants from 75% to 100%. Additionally, some portion will go directly to states. Finally, a great deal of discretion will be exercised by regional offices on how this money is spent. Therefore, the amount of new funds to be spent on residuals will be up to each region, with some guidance provided by EPA headquarters.

THE ROLE OF THE PRIVATE SECTOR IN REGIONAL SOLID WASTE MANAGEMENT PLANNING

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To date, there has been little participation by the private solid waste management sector in regional solid waste management planning. This is partially because legislative initiatives for regional solid waste management planning are just now getting underway. While states such as Michigan, Missouri, California and Florida provide for county plans, the recently enacted Federal "Resource Conservation and Recovery Act of 1976" is the first requirement for states to consider comprehensive regional planning for solid waste management, including hazardous waste management and resource recovery.

Under the new Federal law, the U.S. Environmental Protection Agency is required to publish guidelines by April 1977 for identifying regional solid waste management areas. The States with the help of municipal and local officials are responsible for designating regional planning areas and agencies, as well as determining which functions will be conducted on a state level and which functions will be conducted on a regional or local level. The law specifically requests that consideration be given to designating existing 208 wastewater treatment agencies.

It is unclear, however, whether designation of existing 208 agencies will be for both planning and implementation. Under the

Federal Water Pollution Control Act of 1972, there are two separate designation processes, one for planning and one for implementation. The majority of 208 planning agencies designated to date have been general purpose units of government who have responsibilities in other areas as well, such as in transportation and in housing and community development. In general they do not have the authority necessary to implement these plans. This authority is provided by the second designation process for 208 wastewater treatment management agencies. To be designated as a management agency an agency must have the authority to directly or by contract design, construct, own and operate new and existing facilities, incur indebtedness, and raise revenues.

The new Federal "Resource Conservation and Recovery Act of 1976" combines the designation process for both planning and implementation without defining the criteria of either. The concern of the private solid waste management industry is that while designation of existing 208 planning agencies may be appropriate for solid waste management planning, designation of 208 management agencies may be very inappropriate. Local or municipal wastewater treatment agencies are likely to be designated as the implementation agencies. These agencies are largely unfamiliar with solid waste management issues or problems, or with the private sector involvement in this field. Unlike the solid waste industry which is predominantely serviced by the private sector, municipal wastewater treatment facilities are generally publically owned and operated.

EPA's Office of Water Planning and Standards and Office of Solid Waste recognized the low priority being given by the 208 agencies to land disposal problems, particularly the problems of potential migration of leachate into ground waters. In response the agencies made a formal agreement to allocate both funds and technical expertise to these problems. As mentioned earlier, EPA has conducted 10 regional seminars this year to encourage the 208 planning agencies to become aware of residual management planning, including solid waste, hazardous waste and resource recovery planning. For the first time, many of these 208 agencies began thinking about solid waste management planning. EPA has also outlined a suggested minimum level of study by 208 agencies for residual management. The agencies are asked to estimate landfill capacity in the area, examine soil conditions, locate existing surface and groundwater supplies. The agencies are also asked to determine if existing sites have adequate life and are in compliance with regulatory policies, and if they are not, the agencies are asked to include in their plan suggestions for new site locations. Clearly the public and private solid waste management sector needs to become involved in providing these agencies with the necessary input to insure that all alternatives have been considered. The Association and industry members have attended many of the regional seminars in an attempt to become more familiar with the agencies and their problems and to illustrate the concern of this industry in addressing these problems. However, there are over 149 designated 208 planning agencies in various stages of their planning process. Therefore it will require a major undertaking by the solid waste management industry to develop a working relationship with each of these agencies in addition to any new agencies designated under the "Resource Conservation and Recovery Act." I might add that this is only the first stage of involvement. The Act clearly intends for these plans to be implemented. Who implements, and how they are implemented will be equally important and will shape the operational capability of the private solid waste management industry in the future.

There are several ways for the private sector to become involved. Most 208 agencies use advisory committees in developing their plans. Membership on an advisory committee will be governed by their Administrative Procedure Regulations. But clearly the first step is getting involved and requesting it. The agencies also seek public involvement through public hearings, meetings and newsletters. The Association on behalf of the solid waste management industry has requested to be placed on the newsletter mailing list by all 208 agencies, and in return will provide technical and planning information to these agencies.

In addition to becoming involved in the planning process of the existing 208 planning agencies, the private sector needs to become actively involved in the implementation of the new Federal act. The new Federal act specifically requires public participation in the development, revision, implementation and enforcement of the regulations and enforcement of the act. Federal guidelines are required to be designed to foster cooperation among Federal, State, and local governments and private industry. Agencies receiving Federal financial assistance are requested to consider existing solid waste management services as well as facilities proposed for construction. However, while the mechanisms have been outlined by the legislation to allow for public participation, the private sector must take the initiative in getting involved.

Involvement needs to be on several levels, Federal, state, regional and local. On the Federal level, private industry needs to be first involved in providing input to EPA on factors to be considered in establishing guidelines for identification of regional planning areas. These guidelines are already being drafted and, will be promulgated next April. Information is necessary on the size and location of appropriate areas for solid waste management areas, including resource recovery and hazardous waste management, the volume of solid waste which should be included, and the means of coordinating regional planning with other related planning in the area and with the overall state plan. These guidelines must be flexible if they are to deal effectively with the existing services and facilities. EPA will recommend usage of existing 208 unless they receive information illustrating where an existing 208 is not appropriate.

The second area of involvement is on the state level. The state, in cooperation with local governments will not only designate the areas and agencies, but also will identify what areas of solid waste management will be handled on a state level and what will be done on a regional or local level. The process is designed to give maximum flexibility to state and local governments. Therefore, the number of regional and local planning agencies and the level of planning delegated to each agency will vary from state to state. Several states such as Alabama, Tennessee, Arkansas and Indiana have already passed legislation authorizing local authorities to expand their jurisdiction to include solid waste. Alabama, for example, recently passed legislation authorizing sewer districts to provide solid waste collection and disposal systems. The relationship between local and county plans with the new overall regional plans to be developed will have to be defined state by state. California, has been the first to my knowledge in defining this relationship.

The State Solid Waste Management Board in California has already passed a resolution stating that the state approved county solid waste management plans will be recognized and adoped as the solid waste management component of the 208 plans.

Finally, on a local and county level industry will have to continue its involvement in the planning process, while a regional level industry will need to become involved in providing information to be utilized in the formulation of the plans, such as demographic data, statistical data on the amounts of waste generated and other information necessary to determine what functions can best be handled on the regional level.

In conclusion, regional planning has expanded the areas in which industry must become involved. Participation in each area will vary according to the agency involved, states and regional and local agencies will develop individual schedules and procedures for preparing plans and participating in the formulation of those plans. There are potential benefits of regional planning, given the proper guidance, assistance and support. Whether the private solid waste management industry shares in those benefits will depend on their ability to become involved in both the planning and implementation process.

LINERS - VIABLE OPTIONS AND THEIR APPLICATIONS

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We are all well aware of the vast quantities of wastes that are discarded by our highly technological and urban society. In spite of the many efforts to develop new methods of disposing of these wastes or utilizing them, we can expect that the storage and disposal of wastes on land will continue to rise for many years. At the same time, we can also expect an increasing potential for pollution of the ground and surface water by these wastes or by leachate being generated in the wastes, percolating through, and carrying with it dissolved and suspended biological and chemical products.

Proper selection, design, construction, and operation of waste storage and disposal sites can minimize pollution. However, the availability of acceptable disposal sites is decreasing because of environmental and economic impact. Furthermore, there are geographic areas of high humidity and rainfall or high water tables which pose special problems.

The concept of lining a disposal site with impervious barriers is being considered as a means of controlling leachate from wastes and preventing it from entering the ground water system. A wide variety of impervious materials has been used to line ponds, lagoons, canals, and small lakes. Materials such as these might also be used to control leachate and hazardous wastes. However, little is widely known about the behavior of these materials on prolonged exposure to landfill leachate and to other hazardous wastes.

In this paper, we discuss the various materials which might be used as impermeable barriers, with particular emphasis on those potentially useful in lining sanitary landfills. We report on progress in two current engineering research projects sponsored by EPA to assess various liner materials exposed to landfill leachate and to hazardous wastes.

LINING A SANITARY LANDFILL

The sanitary landfill is an acceptable and recommended method of disposing of solid wastes when sound engineering principles are followed in site selection, design, construction, and day-to-day operations are highly controlled to minimize odor, vector attraction, fire hazards, blowing of paper, and maintenance of good appearance.

Nonetheless, leachate containing a wide range of chemical and organic constituents, such as shown in Table I, can be generated in a landfill by water entering the fill, dissolving salts and products of the decomposition of the refuse. Such leachates can contaminate and pollute the ground water. It is estimated that more than 60% of the landfills in the United States will produce leachate during their lifetimes.

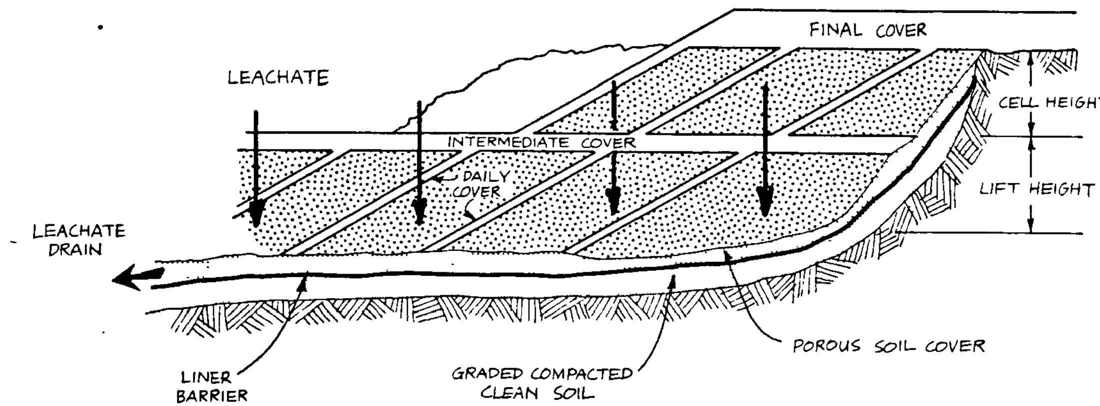
TABLE I - RANGE OF COMPOSITION OF TYPICAL LEACHATES FROM SANITARY LANDFILLS

Constituent	Concentration Range*
Iron	200 - 1700
Zinc	1 - 135
Phosphate	5 - 130
Sulfate	25 - 500
Chloride	100 - 2400
Sodium	100 - 3800
Nitrogen	20 - 500
Hardness (as $CaCO_3$)	200 - 5250
COD	100 - 51,000
Total residue	1000 - 45,000
Nickel	0.01 - 0.8
Copper	0.10 - 9.0
pH	4.00 - 8.5

* All values except that for PH are in mg/l.

To prevent the seepage of leachate, with its high concentration of pollutants, into the surface and ground water, landfills can be isolated from the ground by placing an impervious layer between the landfill and the ground.

The concept of using an impervious barrier as a liner for a landfill is basically simple as is illustrated in Figure 1. An impervious material is placed upon a properly prepared surface that is graded for drainage. The amount of surface preparation depends on the specific type of liner material being installed and on the soil base on which the liner is being placed. This surface must be free of stumps and rocks and should be compacted. The liner can be several feet



CONCEPT OF LINING A SANITARY LANDFILL

Figure 1

in thickness or only a fraction of an inch; it can be compacted native fine-grain soil, clay, asphaltic concrete, polymeric membrane, or other artificial barrier. Porous soil or sand should be placed on the liner through which leachate can flow and on which refuse can be compacted in the manner normally done in sanitary landfills. Leachate percolating through the refuse will be intercepted by the barrier and drain through the porous layer. It can be collected for ultimate disposal in a sanitary sewer system or a leachate treatment system, or be recycled through a landfill to hasten stabilization of the fill.

It is these liners which we will discuss in this paper. Let us consider first the requirement of a liner and the environment in which it must exist.

ENVIRONMENT OF A LINER IN A LANDFILL

The primary purpose and function of a liner is to prevent the passage of pollutants, such as leachate, for extended periods of time. In the case of a landfill, it may mean decades until the fill has stabilized and the potential for leachate generation has fallen to safe limits. To fulfill its function, a liner must be impermeable to water and the contaminants and must maintain its structural integrity.

Liner failures vary with the type of material. A liner can crack, be punctured, fail at a seam or interact with the medium being confined. The usefulness of a liner depends upon the material and the environment in which it is expected to operate.

Some of the environmental conditions at the bottom of a landfill should have little or no adverse effect on a given material, while other conditions may be quite deleterious. Conditions which exist at the bottom of a landfill that probably affect the service life of a liner are:

1) The liner is placed on a prepared surface, which has been graded to allow drainage, compacted, and presumably free of rocks, stumps, etc., but which may settle to cause breaking or cracking of hard material. A brittle or weak material would fail.

2) Anaerobic condition with no oxygen to cause oxidation.

3) No light which normally degrades many organic and polymeric materials.

4) Generally wet-humid conditions, particularly if leachate is being generated regularly, which could result in the leaching of ingredients from a liner.

5) Cool temperatures of 40 - 70°F normally, although higher temperatures are generated within the fill when aerobic decomposition takes place.

6) Generally low pH from acidic leachate.

7) High concentration of ions in the leachate which, in the case of clay, may ion-exchange and flocculate the clay and thus increase permeability.

8) Considerable dissolved organic constituents in the leachate which may degrade some of the liners of organic materials.

9) Only modest head pressure, since drainage above the liner is designed to take place continually through the porous soil placed on top of the liner.

The effects of these environmental conditions will differ on the various barrier materials. However, it appears at present that mechanical failure during installation or during operation of the fill due to settling of the soil may be the most significant source of failure of a liner.

POTENTIAL MATERIALS FOR LINING SANITARY LANDFILLS

Typical of the wide range of materials which have been or are being used as barriers to the seepage of water and hazardous toxic wastes in holding ponds, pits, lagoons, canals, reservoirs, etc., are those listed in Table II. Selection of liner materials for a specific job depends upon the type of fluid or waste being confined, the types of materials which can perform for the lifetime needed and economics. Often several materials can be used and the choice then becomes one of economics and the length of time which the liner should function. At times it may be desirable to use combinations of materials.

Some of the earliest man-made lining materials are those based upon compacted soils, asphalt, and portland cement. These are admixed materials which are generally formed or mixed-in-place at the site. Several of the more well known admixed materials are discussed below:

1. Native fine-grain soil, when available nearby, is imported to the site and compacted as a liner. Permeabilities of 10^{-6} cm/sec. can be achieved. This is often used for containing water.

TABLE II. POTENTIAL MATERIALS FOR LINING SANITARY LANDFILLS

Compacted native fine-grain soils.

Bentonite and other clay sealants.

- Bentonite - polymer sealants.

Asphaltic compositions

- Asphalt concrete.
- Hydraulic asphalt concrete.
- Preformed asphalt panels laid on concrete surfaces.
- Catalytically-blown asphalt sprayed on soil.
- Emulsified asphalt sprayed on soil or on fabric matting.
- Soil asphalt.
- Asphalt seals.

Portland cement compositions

- Concrete with seals.
- Soil-cement with seals.

Soil sealants

- Chemical
- Lime
- Rubber and plastic latexes.
- Penetrating polymeric emulsions.

Liquid rubbers sprayed

- Rubber and plastic latexes.
- Polyurethanes.

Synthetic polymeric membranes

- Butyl rubber.
- Elasticized polyolefin.
- Ethylene propylene rubber (EPDM).
- Chlorosulfonated polyethylene (Hypalon).
- Chlorinated polyethylene (CPE).
- Polyvinyl chloride (PVC).
- Polyethylene (PE).

2) Bentonite and treated bentonite are well known in the petroleum industry and also in the sealing of ponds and lakes. These are expansive clays and can be mixed in or deposited on permeable soils to form adequate seals for water. Water permeabilities of 10^{-7} cm/sec can be achieved with these materials. However, with saline waters these materials will eventually lose impermeability.

3) Conventional asphalt concrete, hot-mixed and hot-laid, is widely used for paving and is readily available. Contractors are experienced in its placement and have the necessary equipment. It presents a hard surface, resistant to traffic and impact forces, and is resistant to acids and to aging, especially in the absence of light and air. As it is designed to have a voids content of about 5% , it is not completely impervious.

therefore, a surface treatment to seal the voids may be needed.

4) Hydraulic asphalt concrete, also hot-mixed and hot-laid, is especially designed to be impervious. Low permeability is achieved by controlling the gradation of the aggregate and the asphalt content to obtain a virtually voidless structure after compaction. Its other properties are similar to those of asphalt concrete. Hydraulic asphalt concrete is mixed, laid, and compacted with the same equipment used for conventional asphalt concrete, but is more difficult to handle.

5) Soil-cement is made by mixing the in-place soil with portland cement and water, and compacting the mixture. As the portland cement hydrates, the mixture becomes a hard, low-strength portland cement concrete. Soil-cement is sometimes used as a surface for pavements with low-traffic volume, and is extensively used for the lower layers of pavements, where it is called "cement-treated base." Strong soil-cement can be constructed with many types of soil, but permeability varies with the nature of the soil; the more granular the soil, the higher the permeability. With fine-grained soils, soil-cements with permeability coefficients of about 10^{-6} cm/sec are achievable. In practice, surface sealants are often applied to the soil-cement to obtain a more waterproof structure. Aging characteristics

of soil-cement are good, especially under conditions where wet-dry and freeze-thaw cycling are minimal. Some degradation of the cement can be expected in an acid environment.

6) Soil asphalt of mixed-in-place asphalt surfacing is made by mixing a liquid asphalt with the in-place soil or with imported aggregate. It is widely used for low-cost pavements for low-volume traffic. Permeability characteristics can be controlled by the amount and type of asphalt added. Soil asphalt is more flexible and resistant to cracking than asphalt concrete or soil-cement, and has good aging characteristics in the absence of light.

7) Catalytically-blown asphalt membranes have been used extensively as linings for canals and reservoirs and to seal off layers of expansive soils under pavements. This type of asphalt is produced by air-blowing in the presence of a catalyst (phosphorous pentoxide or ferric chloride), which produces an asphalt which has a high softening point, yet remains flexible at low temperatures. Membranes are applied to compacted, smooth soil surfaces by spraying the hot (200 to 220°C) asphalt in two successive applications to insure a continuous film free of pinholes and holidays. Aging resistance is good when protected from light. It is usually covered with a protective layer of soil to prevent damage by traffic and deterioration by light.

8) Bituminous seals of asphalt emulsion can be applied on soil at temperatures above freezing. They form continuous films of asphalt after breaking of the emulsion and evaporation of the water. The films are less tough and have lower softening points than films of hot-applied, catalytically-blown asphalt. However, toughness and dimensional stability can be achieved by spraying asphalt emulsions onto a supporting fabric. Fabrics of woven jute, woven or nonwoven glass fiber, and nonwoven synthetic fibers have been used with various anionic or cationic asphalt emulsions to form linings for ponds and canals.

Polymeric membranes are assuming increased importance as liner materials because of their very low permeability to many fluids and water. These membranes are made in the plastics and rubber industry and are manufactured in the form of sheeting of 10 to 125 mils thickness and widths up to 20 feet. Compounds based on the same polymers can vary considerably among liner manufacturers, depending upon the grade and price. They are made both with and without fabric support. Generally, the sheeting is made by calendering of two plies and fabric, if desired. The two plies are used to avoid pinholes through the sheeting. Both vulcanized and nonvulcanized or thermoplastic polymers are used. The liners are brought to the site in the form of preassembled panels which are then seamed in the field. Field seaming is one of the major problem areas in the use of polymeric liners. Heat sealing, cementing and solvent welding are used both in the factory and in field seaming. Vulcanized sheetings have presented the most problems, particularly on the field. Cold-curing adhesives usually are required to make the seams.

The polymers which are being used for the manufacture of liners, or show particular promise, are discussed below:

1) Butyl rubber is a copolymer of isobutylene and isoprene, usually supplied as a vulcanized compound. This rubber is well known for its impermeability, both to air and water. A butyl rubber sheeting was the first polymeric material to be used for pond lining and an installed liner has shown no degradation after more than 20 years of service.

2) Chlorinated polyethylene (CPE) is a thermoplastic material produced by the chlorination of polyethylene. As a completely saturated material, it is not susceptible to ozone and has good crack and low temperature resistance.

3) Chlorosulfonated polyethylene is a saturated rubber having excellent weathering, ozone, and sunlight resistance. When vulcanized, it is highly resistant to a wide range of chemicals, but is generally supplied in an unvulcanized form which swells in oil and some chemicals.

4) Elasticized polyolefin is a recently developed material which is furnished in a thermoplastic form. It has excellent chemical and weathering resistance.

5) Ethylene propylene rubber is a terpolymer of ethylene propylene with a minor amount of diolefin to allow it to be vulcanized. It has excellent weathering and ozone resistance and is sometimes used in blends with butyl.

6) Polychloroprene, or neoprene, is supplied as a vulcanized rubber compound. It features oil and chemical resistance; however, it is relatively expensive and is usually used in special applications.

7) Polyethylene is well known as a film in construction and has high chemical and weather resistance if supplied in black compounds. It is easy to puncture during installation.

8) Polyvinyl chloride is the most widely used polymeric liner. The PVC compound is thermoplastic, containing 30 to 50% plasticizer and about 2% stabilizer. Because of plasticizer volatility, these materials are generally covered to avoid loss of plasticizer and to furnish protection from light.

CURRENT RESEARCH IN THE EVALUATION OF LINERS

The Municipal Environmental Research Laboratory of EPA is sponsoring two engineering research projects which are being conducted by our laboratories with the assistance of the Sanitary Engineering Research Laboratory of the University of California, Berkeley:

- Evaluation of liners for sanitary landfills.
- Evaluation of liners for impounding hazardous wastes.

The overall objectives of these studies are to determine the present state of liner technology as it might be applied on a practical scale to confining wastes. Specifically, we are evaluating a variety of liner materials, exposed over a 3 to 3½ year period, to leachate generated in municipal refuse, and to a range of hazardous wastes. These projects are now scheduled for completion in mid-1978, at which time we expect to be able to make an assessment of the performance of the different liner materials and to estimate their service lives, based upon the changes in their properties and permeabilities during the exposure period. Ultimately, we expect to be able to write specifications for liner materials based upon performance.

We shall concentrate our discussion on the first of these projects, liners for sanitary landfills; however, much that is said about this project is also pertinent to the second.

9) To determine the composition of the shredded refuse from a blend of grab samples taken during the loading of the cells.

10) After the refuse in the cells is saturated, i.e. brought to "field capacity", to generate leachate by adding one inch of tap water every two weeks (26 inches per year) and allow leachate to pond on the liner at a depth of about one foot.

11) To monitor the simulated landfills, characterizing the leachate during exposure period to insure proper conditions exist in the refuse.

Experimental Program -

To simulate the actual conditions which exist at the bottom of a landfill, 24 generators were constructed, as shown in Figure 2. Each consists of a 10-foot steel pipe, 2-feet in diameter, mounted on a concrete base in which a liner approximately 2-feet in diameter is sealed in position with epoxy. Two specimens of each of the 12 primary liner materials were mounted; one group of 12 to be exposed for one year and the second group for two years. Draining can be performed above and below the liner to measure the permeability of the liner. The pipes were lined with a polyethylene sleeve and the interiors of the concrete bases were coated with a chemically-resistant epoxy resin. The pipe was sealed to the base with a neoprene sponge gasket and mastic seal to insure airtightness.

Each pipe was filled with 24 cubic feet of shredded municipal refuse compacted to 1240 pounds per cubic yard at a water content of 30%; a soil cover of 1.75 feet was then placed on the refuse, followed by three inches of drain rock. This design simulates approximately one lift of refuse in a sanitary landfill.

For our tests, we selected 12 primary liner materials, six of them admixed materials:

Paving asphalt concrete
Hydraulic asphalt concrete
Soil cement
Soil asphalt
Bituminous seal
Emulsion asphalt on fabric

and six polymeric liner membranes:

Polyethylene
Polyvinyl chloride
Butyl rubber
Chlorosulfonated polyethylene
(nylon scrim reinforced)
Ethylene propylene rubber
Chlorinated polyethylene.

Elasticized polyolefin had not been developed when the selection was made. Therefore, it was not included in the initial program.

LINERS FOR LANDFILLS -

General Approach -

Considering the wide diversity in the types of materials which are candidates for lining landfills and the urgent need for information regarding their performance and durability in a landfill environment, our overall plan has been:

1) To expose a variety of representative liner materials to typical landfill leachate under conditions simulating real-life and measuring the physical properties as a function of exposure time, for a period of 3 to 3½ years.

2) To select for exposure testing 12 types of liner materials from among those which have been successfully used in lining pits, ponds, lagoons, canals, etc., to prevent seepage of water or various wastes and which appear suitable for lining sanitary landfills.

3) To accelerate the possible effects of the leachate by selecting thinner liners than normally used in the field.

4) To expose liner specimens to leachate on a pilot scale which simulates, as closely as possible, those conditions that a liner would encounter at the bottom of a real landfill.

5) To expose specimens of sufficient size so that physical tests can be made to measure the effects of exposure to leachate and, if appropriate, a typical seam can be incorporated for testing.

6) To subject the liner specimens to appropriate tests for the specific type of liner. Properties would be measured which could be expected to reflect on the performance of the respective liners in sanitary landfills.

7) To seal the liner specimens in individual simulated landfills so that whatever seepage might come through can be collected and tested. This cell and generator would perform as a large permeameter.

8) To create equal conditions in all simulated fills, so that valid comparison between liners can be made.

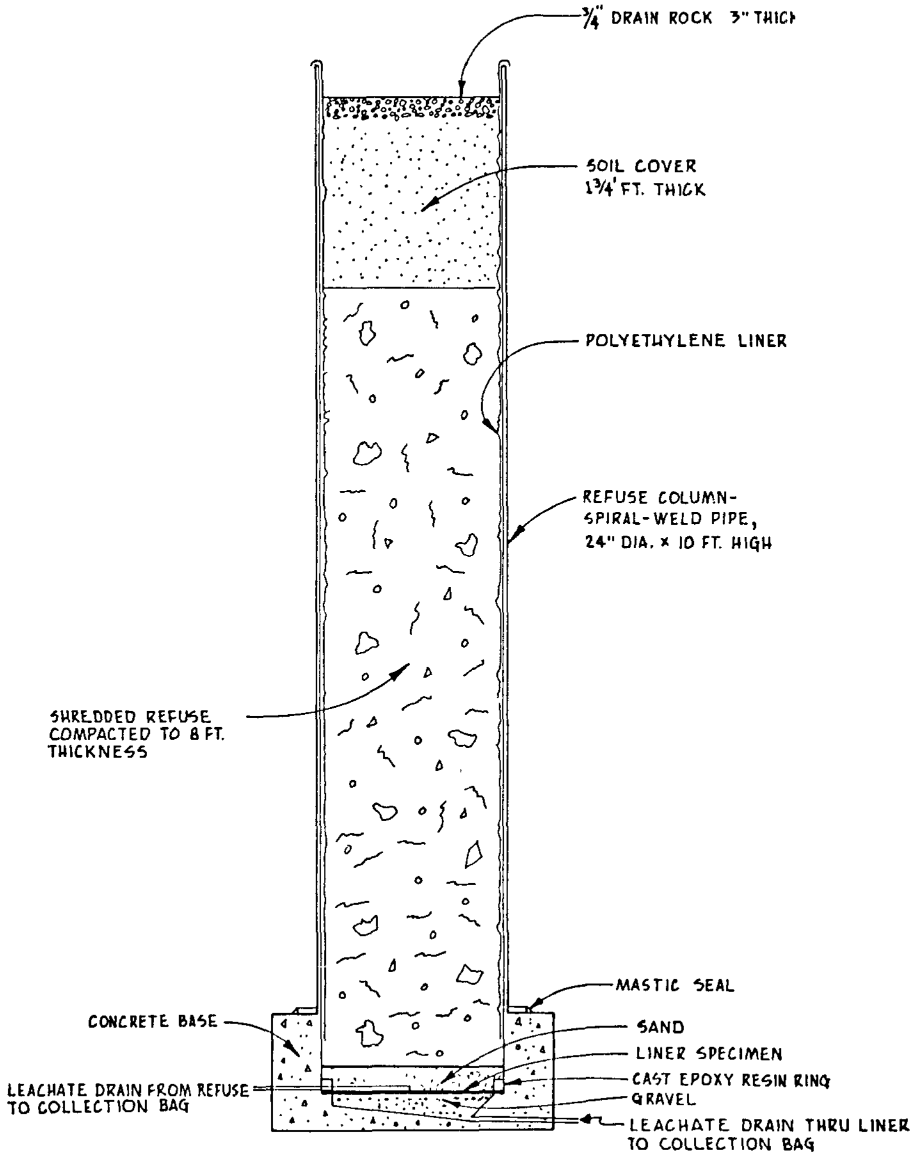


Figure 2 - Schematic Drawing of Leachate Generator and Cell in Which the Liner Materials are Being Exposed to Leachate Under Conditions Simulating Sanitary Landfills.

Soils and clays were specifically excluded by EPA from this study as they were included in other investigations, such as that being carried on by Dr. Wallace Fuller at the University of Arizona.

After loading the cells with ground refuse, they were brought to field capacity by incremental additions of tap water over a month. Afterwards, two gallons of water were added biweekly to equal 26 inches per year of water entering the fill. One foot of leachate was allowed to pond on the liners.

The 24 cells operated satisfactorily, yielding consistent leachate among the generators. The leachate compositions were measured on a regular basis. They showed a relatively high amount of organic acids, particularly butyric acid, a chemical which swells many rubbers.

During the first few days after the cells were loaded there was a slight rise in temperature after which the temperature fell to ambient and remained at that temperature, approximately 15 to 20°C. During this time conditions in the cell went from aerobic to anaerobic.

The tests which were selected for the polymeric membrane liners and the admixed liners are shown in Tables III and IV. These tests were performed on both unexposed and exposed specimens.

The tests used in the monitoring of the refuse and leachate are given in Table V. Most of these were performed on a monthly basis, although the tests for the individual organic acids were performed on a quarterly basis.

Results of one year's exposure to leachate -

After one year of exposure to leachate, the first group of 12 liners was recovered from the leachate generators and their properties measured. Overall, the effect of this exposure upon the physical properties was minor. There were small losses in the tensile strengths of all liners, except polyethylene and EPDM, neither of which lost strength. The elongation at break increased in all cases; the modulus, or stiffness, generally dropped, except in the case of polyethylene, ethylene propylene and butyl rubbers, where it remained essentially the same. In all cases, the liners softened. The tear strength and puncture resistance increased, undoubtedly due to the increase in elongation. In seam strength there were some major losses; however, those seams which had been heat sealing retained their strengths best.

TABLE III. TESTING OF POLYMERIC MEMBRANE LINERS

Water vapor permeability, ASTM D96, procedure BW.
Thickness and weight per square foot.
Tensile strength and elongation at break, ASTM D412.
Hardness, ASTM D2240.
Tear strength, ASTM D624, Die C.
Water absorption or extraction at RT and 70°C, ASTM D570.
Splice strength, in peel and in sheer, ASTM 413.
Puncture resistance - Fed. Test Method Std. No. 101B, Method 2065.
Density, ash, and extractables.

TABLE IV. TESTING OF ADMIXED LINER MATERIALS

Permeability	Back pressure permeameter
Density and voids	ASTM D1184 and D2041
Water swell	Calif. Div. of Highways 305
Compressive strength	ASTM D1074
Sliding plate viscosity of asphalts	Calif. Div. of Highways 348
Microductility of asphalts	Calif. Div. of Highways 349

TABLE V. TESTING OF REFUSE AND LEACHATE DURING MONITORING

- Temperature
- Amount of leachate
- Total solids
- Volatile solids
- pH
- Chemical oxygen demand (COD)
- Total volatile acids (as acetic acid)
- Individual organic acids
    - Acetic
    - Propionic
    - Isobutyric
    - Butyric
    - Isovaleric
    - Valeric
    - Caproic

As for the permeability of the liners, during the first year none of the polymeric membranes allowed leachate to pass. There was, however, leakage through the soil asphalt and asphalt concrete liners. The epoxy seal around the hydraulic asphalt disintegrated, allowing the leachate to bypass the liner.

As the absorption of leachate by the liner material is an indication of its permeability, the leachate absorption of each liner was determined and the results are shown in Table VI.

TABLE VI. WATER AND LEACHATE ABSORPTION BY POLYMERIC LINERS

Data in percent absorbed by weight

Polymeric Liner	Water 1 year	Leachate 1 year
Butyl rubber	1.60	1.78
Chlorinated PE	13.10	9.0
Chlorosulfonated PE	17.40	20.0
Ethylene propylene rubber	1.40	5.95
Neoprene	22.7	8.73
Polybutylene	0.25	0.33
Polyethylene	0.20	0.25
Polypropylene	0.28	0.40
Polyvinyl chloride	1.85	6.72

The column on the right is the absorption in leachate the first year for the same material. As can be seen, there is not a one-to-one relationship between the water and leachate absorption. This reflects the dissolved solids content of the leachate, both inorganic and organic. In the case of the materials which are highly hydrocarbon in character, the swelling of both in water or leachate is very similar. However, in the case of the chlorinated materials, there is a substantial amount of water absorption, particularly in the case of the chlorinated polyethylene, chlorosulfonated polyethylene and neoprene. The PVC had rather low absorption in water but, in leachate, the absorption may be significant.

In view of the relatively small changes in the liner materials which occurred during the first year of exposure, the EPA has increased the total exposure time for the remaining specimens from two years to about three and one-half years. Certainly two years would be insufficient to establish long-term trends as to the service life of these liners.

LINERS FOR CONTAINING HAZARDOUS WASTES

Our second project deals with the evaluation of liners exposed to nonradioactive hazardous wastes. As in the case of leachate from landfills, the impoundment of the hazardous wastes on land can also present the potential for pollution of ground and surface water. Barriers, such as membrane liners, have been used for this purpose for approximately 25 years. However, information as to relative performance and service lives of various liners in highly characterized hazardous wastes is meager.

Our general approach was:

1) To expose at least 12 different liners in six or more wastes, under conditions which simulate real-life, and determine their properties as a function of time.

2) To select liner materials which are, or potentially could be, used for lining ponds containing hazardous wastes.

3) To design and construct exposure cells which would simulate the condition under which the liner would exist in a pond.

4) To select a range of hazardous wastes of various types which would be encountered in industry.

5) To highly characterize these wastes so that the liner behavior can be predicted for confining actual wastes in a given installation.

The design of the exposure cell for this study is shown in Figure 3. It is made of sheet steel coated on the interior with a chemically-resistant epoxy resin. It features:

1) Specimens of one square foot area, with field type seam.
2) A depth of waste of one foot.
3) It can be used for liners of various thicknesses.

The materials which were selected for this project are shown in Table VII, and represent a broader group than were used in the landfill project. Bentonite and fine-grain soil are included. As for the polymeric materials, we included the same types of materials as were used in the sanitary landfill project, and added three additional, (1) neoprene, (2) an elasticized polyolefin, and (3) an experimental polyester film, all of which feature oil resistance.

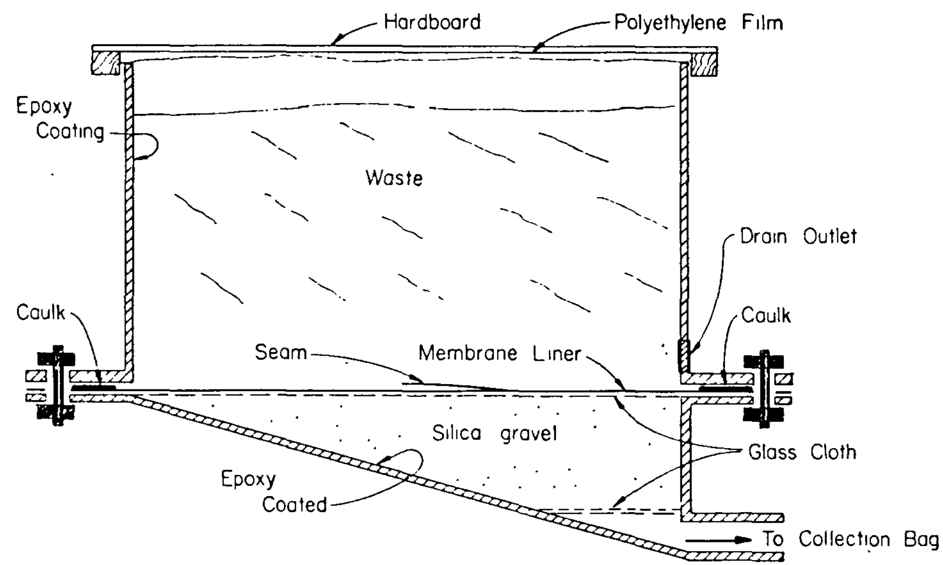


Figure 3. Schematic drawing of exposure cell for membrane liners. Exposed area of liner is 10 in. by 15 in. and depth of the waste is 1 foot.

TABLE VII. LINER MATERIALS FOR HAZARDOUS WASTES

SOIL AND ADMIXED MATERIALS	Thickness in inches
Asphalt emulsion on nonwoven fabric	0.3
Compacted native fine-grain soil (from Mare Island, California)	12.0
Hydraulic asphalt concrete	2.5
Modified bentonite and sand	5.0
Soil-cement with seal	4.5
POLYMERIC MEMBRANES	**Thickness in mils**
Butyl rubber-reinforced	34
Chlorinated polyethylene (CPE)	32
Chlorosulfonated polyethylene - reinforced	34
Elasticized polyolefin	25
Ethylene propylene rubber (EPDM)	50
Polychloroprene (neoprene) - reinforced	32
Polyester (experimental)	7
Polyvinyl chloride (PVC)	30

The six types of hazardous wastes selected for use in this project are:

- Acidic wastes
- Alkaline wastes
- Pesticide wastes
- Oil refinery tank bottom wastes
- Lead wastes from gasoline tanks
- A cyclic hydrocarbon waste

So that the length of exposure time would be practical, we made the final selection of combinations of liners and wastes after we had performed a series of preliminary bench tests of liners in the various wastes. We did not select asphaltic liner materials for confining oily wastes, nor did we use clays to confine briney and acidic wastes. Where a polymeric liner swelled badly in aromatic waste, we deleted that combination.

These exposures have been underway for about 10 months. At 12 months the cells will be dismantled and the liners recovered and tested.

In addition to the primary liners, we have:

1) Suspended additional small specimens of liners in the wastes.

2) Lined 12 small tubs with various membrane liners and filled them with hazardous wastes for exposure to the weather.

3) Mounted a variety of liner specimens on a rack for outdoor exposure.

FIELD EXPERIENCE IN THE USE OF LINERS FOR WASTE DISPOSAL SITES

The experimental work which has been described is on a laboratory or, at best, pilot scale only. We have attempted to simulate the actual conditions encountered in full scale service but we recognize the many limitations of the exposure conditions compared with the complexity and diversity of actual field disposal sites. Each waste disposal or storage installation has its own unique characteristics as to the materials being confined, the geology of the site, the weather, etc.

The ultimate functioning of a liner in a given landfill will depend upon proper site selection, design of the disposal installation, and proper construction and operation of the disposal site. Of particular importance is the construction and field seaming when membrane liners are used. We start with highly impermeable materials which, in order to function properly, should be placed intact and with impermeable seams.

There is considerable experience in the use of liners for impounding water, industrial fluids, and wastes in the chemical, petroleum, and metals industries. Their use in lining sanitary landfills is recent and field experience is very limited. A few experimental installations are about 10 years old, but the first full-scale lined sanitary landfill is only five years old. There are now several landfills lined with asphalt concrete and bentonite clay and three with polyvinyl chloride. A butyl rubber liner has been used to line a disposal site for incinerator residue; chlorosulfonated polyethylene and chlorinated polyethylene liners have been used in two small pilot landfills. Polymeric liners are presently being considered for a number of new installations.

CONCLUSIONS

Lining land waste storage and disposal sites shows great promise of alleviating and, hopefully, solving potential environmental problems of ground water pollution arising from disposal of solid and liquid wastes on the land. The concept of using impervious liners to isolate and control leachate from solid wastes appears to be feasible and is now being put into practice. There is a wide range of materials which are suitable for this use and more are being introduced by industry.

The results being obtained in the two ongoing engineering research projects, which are sponsored by the EPA, should ultimately yield information as to the performance of different liner materials under various conditions and as to their anticipated service lives. These results should be useful in designing waste disposal installations and in the selection of proper materials for their construction.

The ultimate service lives cannot now be established on an absolute scale; the indications are that long lives can be expected. Certainly, there are lining materials available now which can reduce the potential of ground water pollution.

The long-term effectiveness of liners for containing leachate from sanitary landfills and other hazardous wastes will depend upon the correct selection of materials and the use of good engineering practice in the design, construction, and operation of the lined disposal sites.

ACKNOWLEDGEMENT

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THE IMPORTANCE OF SOIL ATTENUATION FOR LEACHATE CONTROL[1]

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INTRODUCTION

Almost all of man's waste now ends up on land. In fact, reliable estimates place the amount that reaches the soil at about 90 percent, U.S. EPA (1973),Hershaft (1972). Air and streams are only transport systems to the soil, and dumping in the ocean has become very unpopular, even to the extent of enactment of legislation prohibiting such action, U.S. Congress (1972). The soil, thus, stands between life and lifelessness, not only in food production but in biodigestion of waste, destruction of disease, and retention of hazardous pollutants. It is a unique body. It is this uniqueness which attracts our attention today. It is this uniqueness that has protected us in the past from the polluting hazards of our wastes, which now is threatened by point-source overburden of today's wastes.

By understanding how the chemical, physical and biological characteristics of the soil and geologic material interact with wastes, we can begin to develop practical management methods for safe disposal, Fuller, et al. (1976).

The soil must now be considered for its role as a waste treatment/utilization system, Figure 1. The economic shift with time will be from soil as a treatment to soil as a utilization system. This shift, of course, will not be sufficient to relieve the soil from the burden of waste disposal. Yet certain constituents (such as paper, landscaping trash, food residues and other natural organics) will be utilized for soil building and not merely

[1]This research is supported in part by the U.S. Environmental Protection Agency, SHWRD, Cincinnati, OH.

referred to disposal. Further, a certain limited proportion of solid waste can go into relief for energy sources as methane, Figure 2. Yet there is waste (sludge), even in this system, that will require disposal on land (or soil).

The soil must be regarded as a permanent resting place for all potentially hazardous pollutants. The shift in thinking here is from classic soil science for food production where plant nutrients are stored in the soil in an "available", temporary or transient form (cation and anion exchange) to permanently fixed forms.

OBJECTIVE

Management of wastes to minimize their potential for long-range pollution requires the manipulation of the components of disposal habitats based on a thorough knowledge of the way these components interact toward element migration and attenuation. This is the theme or objective of the presentation today.

MAIN COMPONENTS OF DISPOSAL HABITATS

To understand what keeps potentially hazardous pollutants from migrating into underground water sources and other locations where they might enter the food chain, there are 3 systems which require examination and study. They are the 3 main components of waste habitats:

1) the porous medium through which the constituent is being transported,
2) the solution carrying the pollution constituent, and
3) the constituent itself, i.e. the soluble element involved.

The characteristics of each component markedly influences attenuation in soils. The characteristics of each component that have been found to influence migration and attenuation will be discussed separately.

The porous medium or soil -- Some prominent physical soil factors in attenuation are listed in Table 1. Texture refers to particle size distribution and therefore represents gravel, sand, silt, and clay. Sand is found to be negatively correlated to attenuation and clay positively. Sands and gravels retain solubilized polluting constituents very poorly to not at all. Structure refers to arrangement of soil particles and controls rate of solution flow through the soil, water-holding capacity, solution flow rate, and may not be favorable if too stable. For example, Molokai is highly structured even though it is a clay. It most often acts like a sand. Solutions pass through so rapidly, the polluting constituents may not diffuse into the clay and have contact time sufficient to react to attain maximum attenuation.

Stratification defines the layering of soil and geologic material into horizontal lenses of sand, silt, and clay, or gravel. Flux is a term better described as rate of low through a porous medium. Compaction defines the density. A compact soil may or may not favor attenuation depending on its extent. Excessive compaction may perch water and prevent necessary flow downward and may encourage lateral movement or seepage to the surface just as will cementation layers. Wetting and drying influences the migration potential of pollutants both favorably and unfavorably; for example, dehydration (a) favors retention of constituents in the leachate by lowering the solubility as a result of precipitation while at the same time (b) opens the soil for more rapid downward migration through the shrinking and cracking processes. Rehydration again puts some of the constituents back into solution but also closes the cracks. The overall effect of wetting and drying of disposal materials and particularly landfill leachates, however, is believed (from our experiences with soils) to favor retention of pollutants in place. Specific research on this factor for waste leachates is yet in its infancy.

Some prominent factors in attenuation according to Fuller (1976), Fuller and Korte (1975), and Korte, et al. (1975), relate to chemical characteristics of soils, Table 2. They may be grouped into the three broad areas; (a) surface area and clay content, (b) lime and pH (or acidity and alkalinity) and (c) content of the hydrous oxides of Fe, Al, and Mn. Attenuation in soils has been positively correlated with soil surface area and clay content, and is negatively correlated with sand. The more alkaline soil pH values favor precipitation of most heavy and trace elements and therefore attenuation. Lime favors the development of a less acid soil and more alkaline pH soil habitat. The abundance of hydrous oxides in soils also favors attenuation, particularly Fe and Mn. How practical it is to alter the hydrous oxide content in soils remains to be demonstrated.

Leachate Components -- Prominent leachate characteristics affecting attenuation, according to our ongoing research, Table 3, include the concentration of (a) organic constituents (TOC), (b) soluble salts, (c) acidity and alkalinity of the solution (pH), (d) specific heavy and trace elements, (e) soluble Fe. In general, when the leachate or leaching solutions passing through the soil are relatively high in TOC, soluble salt, specific polluting element, and acidity less are the chances for attenuation. Soluble Fe content is positively correlated with attenuation. The mechanism(s) for this interrelationship is (are) not known at this time.

Specific element factors -- Prominent factors in specific element attenuation reported in Table 4 relate to elements selected by the U.S. EPA as As, Be, Cd, Cr, C8, Fe, Pb, Ni, Hg, Se, Zn, and V as possessing potentially hazardous characteristics as pollutants. The elements differ greatly with respect to migration rates through soils and geologic materials depending on their (a) capacity to form anions or not, and (b) indiviudal chemical characteristics in reacting to form soluble and insoluble compounds with their environmental constituents at the various pH and Eh habitats available. Lead, for example, migrates very slowly through most soils, whereas Cd moves comparatively rapidly.

RANKING ELEMENTS AND SOILS FOR ATTENUATION

Recognizing the pitfalls of ranking elements and soils for attenuation, Korte et al. (1976), felt their research with 10 soils representing the 10 major orders of soil in the U.S. provided a rare opportunity to do so. The data presented in Figures 3 and 4 display quantitatively the relative mobility of the elements (As, Be, Cd, Cr, Cu, Ni, Pb, Hg, Se, Zn and V) and the relative effectiveness of the soils in attenuating them. The elements naturally separated into cations and anions as previously discussed. The soils represent all ranges of physical and chemical characteristics described earlier. By knowning the characteristics and climatic location of these soils and comparing them with one's own, these figures can be useful in the selection of the most favorable disposal sites depending on the kind(s) of metals present.

The divalent Cu and Pb may be found to be the least mobile while Hg only weakly attenuated, Figure 3. Molokai (tropical clay), Nicholson (temperate-humid, clayey loam), Mohave (arid, calcareous, clayey) soils were the most effective in attenuating the metallic elements. Wagram (temperate-humid sand) and Anthony (alluvium) soils were the least effective for attenuation.

The metals that form anions, Figure 4, in the leachate reorder from Figure 3 based largely on pH and abundance of the hydrous oxides of the soils. Thus, attenuation is more efficient for soils lower in pH and/or higher in free oxides of iron. Free lime may or may not significantly decrease their mobility, Fuller, et al. (1976).

Among the most outstanding soil parameters that influence attenuation of the heavy and trace elements are clay content, lime, pH, and hydrous oxides, Table 5. With these and other known parameters certain low-cost liners for disposal sites are suggested, Table 6. Disposal excavations, typified by landfill sites, may be lined easily to various thicknesses of lime, clay, and other natural soil and geological material. All sites require modification if migration of pollutants is to be retarded because all in situ land materials permit migration of at least some polluting constituents found in waste leachates and waste solutions.

Agricultural Limestone - Limestone occurs abundantly throughout the U.S. Moreover, the agriculture industry uses large quantities of lime for crop nutrient control and acid abatement of soils. The agricultural sieve sizes have proved suitable for land-sit liners, Fuller, et al. (1976). Certain heavy metals (Pb, Cu, Al) were found to be absorbed by limestone to a greater extent than others (Ni and Zn). Limestone may act to (a) adsorb the metal ion directly, (b) react to form less soluble compounds as carbonate and/or (c) raise the pH level of the leachate as it passes through the liner barrier so precipitation may take place due to reduced solubility.

Lime-slurries containing sulfur oxides from air pollution control may be expected to react the same way since they contain unspent limestone. The sulfur compounds may add an additional attenuating dimension to these slurries.

Hydrous Oxides - Although the research with hydrous oxides of Fe shows them to be highly reactive with certain metal ions, and earlier research indicates attenuating possibility, Korte, et al. (1975), the technique of managing the iron sulfate mining waste residue for liner purposes yet needs to be worked into a practical liner program. Documented laboratory evidence for the attenuating influence of the hydrous oxides of Fe for certain metallic pollutants is provided also by Fuller, et al. (1976).

Organic Wastes - The abundance of nutshells (pecan, walnut, etc.) which are highly resistant to biodegradation appear to have great capacity to adsorb metallic ions. Lining disposal sites with ground nutshells can reasonably be expected to initiate fixation of certain heavy metals at the disposal sites.

Natural Soil as Sealant - The author has had considerable practical experience in the area of completely sealing artificial lakes using natural clayey materials taken from the lake-bed excavations. Partial and complete sealing against leaking may be achieved depending on (a) compaction technique, (b) clay content of soil, (c) dispersion of clay with sodium, (d) and thickness of the liner, Fuller, et al. (1976).

Flux - In addition to liners the density of the floor and sides of the disposal sites can be modified to control the rate of flow (flux) of the liquid vehicle carrying the pollutant. Thus the natural soil material can be altered in such a way as to act as a liner by permitting the soluble constituents more time to linger in the vicinity of the soil constituents responsible for attenuation.

RESIDUAL MANAGEMENT: SOILS

In addition to the use of natural soil liners and soil modification for pollution control, wise site selection and management must become an essential part in the attempt to achieve maximum retention of potentially hazardous pollutants. Some such residual management practices are outlined in Table 7.

Perhaps one of the most critical practices in site selection is to avoid disposing of wastes in river bottoms, sand and gravel pits where there is no hope for retention and attenuation. Most of these locations feed directly into aquifers and underground water storage. Equally undesirable are locations where impervious "gumbo till" or clay stratifications impede water leakage downward. If such layers traverse the disposal site lateral flow can take place and seepage may bring leachates and hazardous pollutants to the surface slopes. Surface contamination associated with the usual erosion of rainfall offers serious hazards to water pollution and food chain entry.

RESIDUAL MANAGEMENT: LEACHATES

At least two prominent characteristics of leachates (municipal solid waste landfill leachates, in particular) may be managed to aid in the control of migrating metals through soils. They are (a) mixing of organic and inorganic and inorganic source materials and/or solutions, and (b) aeration, Table 8. Certain inorganic soluble metal compounds found in leachates migrate more rapidly through soils when associated with organic substances. Mercury, lead, and copper compounds are notable in this respect. Chelation or sequestering mechanisms protecting the metals are thought to be operative more extensively than precipitation and absorptive mechanisms. Attenuation of some elements appear to be negatively correlated with total organic carbon (TOC) content of leachates.

Aeration of leachate solutions (anaerobic) results in precipitation development, Korte, et al. (1975). The precipitate is readily detected by the dark coloration of the solution during exposure to air directly or by aeration techniques. If landfill or excavation sites were lined at the bottom with plastic pipes perforated to permit pumping of air through the leachates, retention of organic and inorganic constituents may be encouraged.

ACKNOWLEDGEMENT

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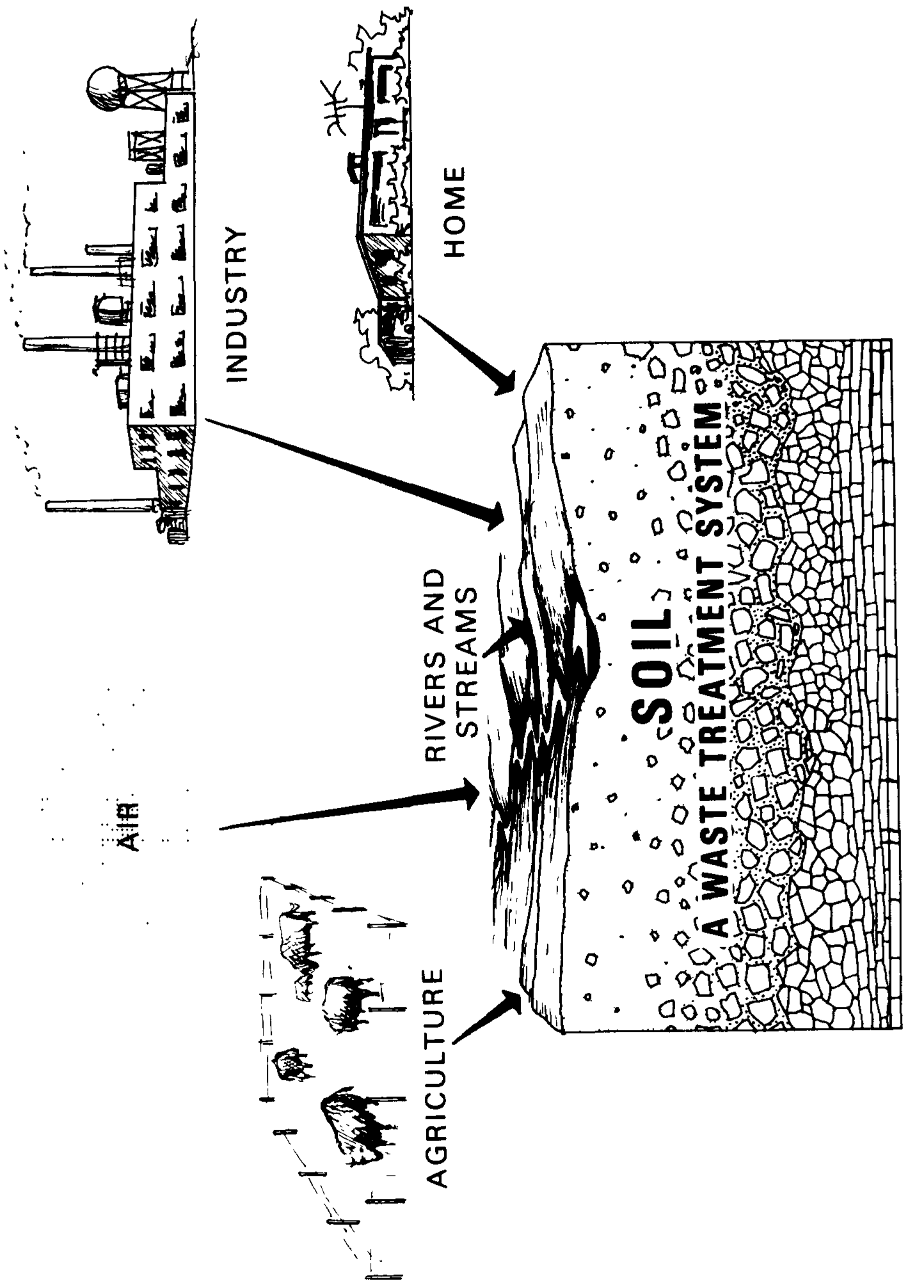
FIGURES

Figure 1. Soil: A waste treatment system.

Figure 2. Methane production from solid organic wastes.

Figure 3. Relative mobility of Cu, Pb, Be, Cd, Ni, and Hg through ten soils.

Figure 4. Relative mobility of Se, V, As, and Cr through ten soils.


INDUSTRY
HOME
AIR
RIVERS AND STREAMS
AGRICULTURE
SOIL
A WASTE TREATMENT SYSTEM

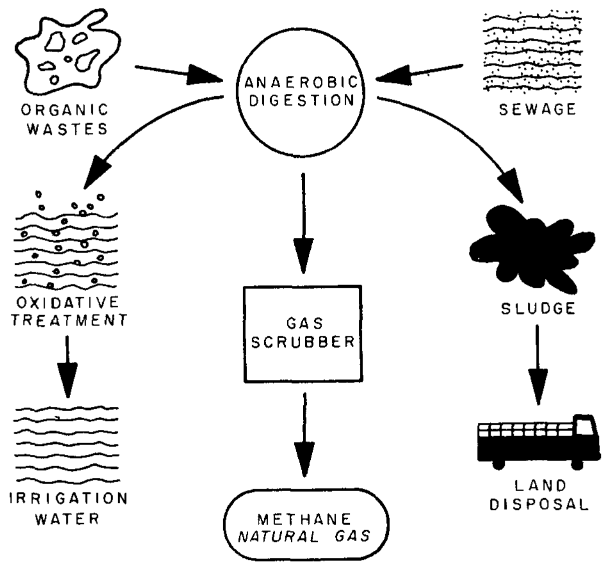


Fig. 2. Methane production from solid organic wastes

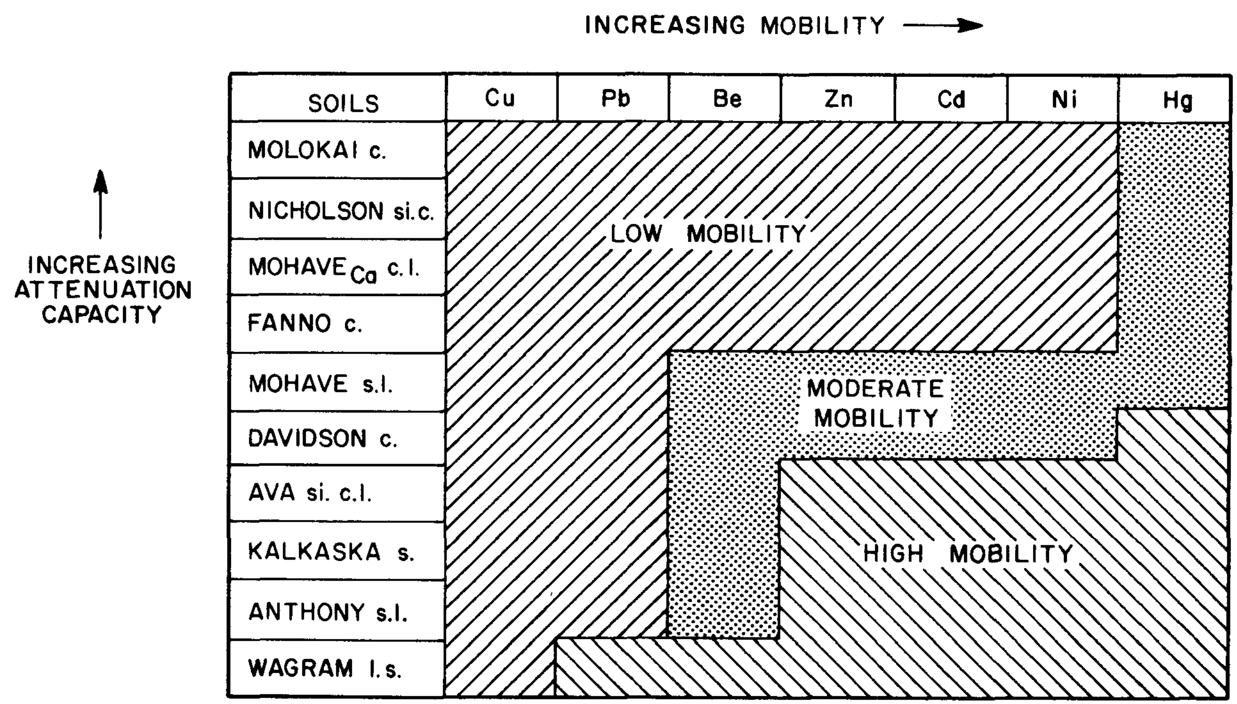


Figure 3. Relative mobility of cations in soils used in the University of Arizona Study.

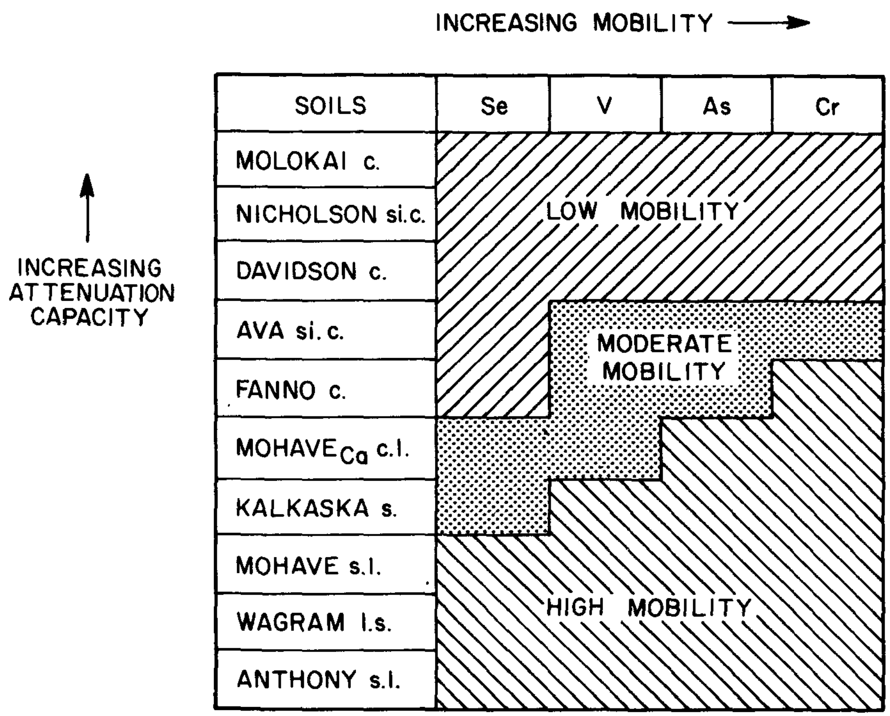


Figure 4. Relative mobility of anions used in the University of Arizona Study.

TABLES

Table 1. Some prominent physical soil characteristics influencing attenuation of metals.

Table 2. Some prominent chemical soil characteristics influencing attenuation of metals.

Table 3. Some prominent waste leachate characteristics influencing attenuation of metals.

Table 4. Some prominent factors in specific element (metal) attenuation in soils.

Table 5. Some soil characteristics associated with attenuation.

Table 6. Suggested low-cost soil liners for disposal excavations that aid in attenuation.

Table 7. Residual management of soils for pollution retention.

Table 8. Residual management of leachates as an aid in attenuation.

TABLE 1. SOME PROMINENT PHYSICAL SOIL CHARACTERISTICS INFLUENCING ATTENUATION OF METALS

1. Texture
2. Structure
3. Stratifications
4. Flux
5. Compaction
6. Cementation - Fe, Caliche, lime, clay
7. Wetting and drying
   (hydraulic conductivity)

TABLE 2. SOME PROMINENT CHEMICAL SOIL CHARACTERISTICS INFLUENCING ATTENUATION OF METALS

1. CLAY CONTENT
2. SURFACE AREA - REACTION SITES
3. LIME CONTENT
4. HYDROUS OXIDES - Fe, Mn, Al
5. pH-ACIDITY & ALKALINITY
6. TOTAL DISSOLVED SOLIDS - (SALTS)

TABLE 3. SOME PROMINENT WASTE LEACHATE CHARACTERISTICS INFLUENCING ATTENUATION OF METAL

1. TOTAL ORGANIC CARBON COMPOUNDS (TOC)
2. TOTAL SOLUBLE SALTS (Elec. Cond.)
3. ACIDITY AND ALKALINITY (pH Values)
4. SPECIFIC HAZARDOUS ELEMENT CONCENTRATIONS (As, Be, Cd, Cn, Cu, Pb, Ni, Hg, Se, Zn, V)
5. TOTAL SOLUBLE IRON CONTENT

TABLE 4. SOME PROMINENT FACTORS IN SPECIFIC ELEMENT (METAL) ATTENUATION IN SOILS

ELEMENTS

As, Be, Cd, Cn, Cu, Pb, Ni, Hg, Se, Zn, V, Fe

1. AN IONIC REACTION

   As, Cn, (Hg), Se, V

2. CATIONIC REACTIONS

   Be, Cd, Cu, Pb, Ni, Zn (Fe)

3. SPECIFIC ION CHARACTERISTICS

   e.g. Pb vs Cd

TABLE 5. SOME CHARACTERISTICS OF THE SOILS USED IN RESEARCH AT THE UNIVERSITY OF ARIZONA

Series	Order†	Soil Paste pH	Cation exchange capacity	Electrical conductivity of extract	Column bulk density	Surface Area	Free Iron oxides	Total Mn	Texture* Sand	Texture* Silt	Texture* Clay	Major Clay Minerals**
			meq/100g	μmhos/cm	g/cm^3	m^2/g	%	ppm	%	%	%	
Wagram	Ultisol	4.2	2	225	1.89	8.0	0.6	50	88	8	4	Kaolinite, Chlorite
Ava	Alfisol	4.5	19	157	1.45	61.5	4.0	360	10	60	31	Vermiculite, Kaolinite
Kalkaska	Spodosol	4.7	10	237	1.53	8.9	1.8	80	91	4	5	Chlorite, Kaolinite
Davidson	Ultisol	6.2	9	169	1.89	51.3	17.0	4100	19	20	61	Kaolinite
Molokai	Oxisol	6.2	14	1262	1.44	67.3	23.0	7400	23	25	52	Kaolinite, Gibbsite
Chalmers	Mollisol	6.6	26	288	1.60	125.6	3.1	330	7	58	35	Montmorillonite, Vermiculite
Nicholson	Alfisol	6.7	37	176	1.53	120.5	5.6	950	3	47	49	Vermiculite
Fanno	Alfisol	7.0	33	392	1.48	122.1	3.7	280	35	19	46	Montmorillinite, Mica
Mohave	Aridisol	7.3	10	615	1.78	38.3	1.7	825	52	37	11	Mica, Kaolinite
$Mohave_{Ca}$	Aridisol	7.8	12	510	1.54	127.5	2.5	770	32	28	40	Mica, Montmorillonite
Anthony	Entisol	7.8	6	328	2.07	19.8	1.8	275	71	14	15	Montmorillonite, Mica

† U.S. Department of Agriculture Comprehensive Soil Classification System.
* U.S. Department of Agriculture System: Sand, 2mm-0.05mm; Silt, 0.05mm-0.002mm; Clay, <0.002mm diameter
**The dominant mineral is listed first

TABLE 6. SUGGESTED LOW-COST SOIL LINERS FOR DISPOSAL EXCAVATIONS THAT AID IN ATTENUATION

1. AGRICULTURAL LIMESTONE
2. LIME-WASTE SLURRIES
3. HYDROUS OXIDES OF Fe, Mn, and Al.
4. ORGANIC WASTES
5. SOIL MATERIALS AS SEALANTS

TABLE 7. RESIDUAL MANAGEMENT OF SOILS FOR POLLUTION RETENTION

1. TEXTURE -- Choose finer textured soils (Clays, loams). Avoid heterogeneous mixtures
2. DEPTH -- Choose deep rather than shallow soils.
3. DRAINAGE -- Choose good drainage but not aquifers
4. REACTION -- Choose the least acid soils, and
5. HYDROUS OXIDE CONTENT -- Choose soils highest in Fe, Al, and possibly Mn.

TABLE 8. RESIDUAL MANAGEMENT OF LEACHATES FOR POLLUTION CONTROL

1.	SOURCES OF LEACHATE -- Avoid mixing non-compatible leachates, e.g. Organic and Inorganic: Municipal Wastes with Industrial Wastes.
2.	AERATION -- Aeration precipitates organic as well as inorganic constituents and thus retards migration.

THE APPLICATION OF SEWAGE SLUDGES TO LAND[1/]

E. Epstein and J. F. Parr[2/]

Interest in the appliction of sewage sludge on land in the United States as a viable means of disposal and/or utilization has increased because of certain legislative actions and economic considerations (Colacicco et al., 1977). Legislative actions have imposed strict limitations on sewage disposal by incineration (Air Quality Act of 1967), by fresh water dilution (Water Pollution Control Act Amendments of 1972), and by ocean dumping (Marine Protection, Research, and Sanctuaries Act of 1972). Moreover, the costs for certain methods of sludge disposal, e.g., trenching, landfill, and incineration, have increased tremendously in recent years (Colacicco et al., 1977). The situation is further intensified by the dramatic increase in sludge production resulting from implementation of more advanced wastewater treatment methods. Based on current trends, the present annual U.S. sludge production of approximately five million dry tons is expected to exceed ten million tons by 1985.

Composition and Properties

Sludge is predominately organic matter (40 to 60 percent) and, thus can be a valuable resource when applied to the land. Its potential use on land will be limited by the level of contamination from toxic chemicals and pathogens.

Sludge can be applied to land as a liquid (2 to 10 percent solids), as dewatered filter cake (18 to 25 percent solids), as a compost (40 to 70 percent solids), or as a heat dried product (94 to 99 percent solids).

1/ Research on composting of sewage sludge reported herein was partially supported by funds from the Maryland Environmental Service, Annapolis, Maryland, and the United States Environmental Protection Agency, Cincinnati, Ohio.

2/ Soil Scientist and Microbiologist, respectively, Biological Waste Management and Soil Nitrogen Laboratory, Beltsville Agricultural Research Center, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Maryland.

Table 1 shows the composition of sludge from eight North Central States (Sommers, 1977). The composition varies depending on the extent of treatment and industrial contamination.

The composition of composted sewage sludge depends on the characteristics of the sludge (raw or digested), its source (industrial or domestic), and the composting process technology which concerns the nature and amount of bulking material that is used (e.g., refuse or woodchips), and whether the compost is cured, screened, and stored before use. Table 2 shows the properties of raw and digested sludge composts. The sludges were obtained from the Washington, D.C., Blue Plains Wastewater Treatment Plant and composted with woodchips. These sludges are essentially from domestic sources and, thus, relatively low in trace metals.

Potential Problems

Odors

Odors can be a major problem in land application of sludge. Hydrogen sulfide (H_2S), ammonia (NH_3), indoles, skatoles, and mercaptans produced during sludge treatment are malodorous. Avoidance of odors during land application requires immediate incorporation of sludge into the soil. Sites must be selected with respect to population density, soil and drainage characteristics, and the prevailing wind direction. Composting of sludge under proper conditions eliminates putrefying odors so that land application of compost does not require special precautions (Epstein and Willson, 1975).

Heavy Metals

Land application of sewage sludge can result in soil enrichment of toxic trace elements (often referred to as heavy metals). It has been shown that such enrichment can cause direct phytotoxic effects on plants resulting in repressed growth and yield. Heavy metals may also accumulate in plant tissues which could then enter the food chain through direct ingestion by humans or indirectly through animals (Page, 1974; Chaney and Giordano, 1977). The elements in sludge of greatest concern are Zinc (Zn), Copper (Cu), Nickel (Ni), and Cadmium (Cd). The first three are important because sufficiently high levels of these elements in soil can cause direct phytotoxic effects on plants, resulting in repressed growth and yield. The element of greatest concern to human health where sewage sludges and sludge composts are applied to land is Cd. While Cd is not usually phytotoxic it is readily absorbed by plants, can accumulate in edible parts, and enter the food chain. Most human exposure to Cd comes from food (principally grain products, vegetables, and fruits). High levels of Cd in foods can be toxic to humans (Sandstead et al., 1974). Dietary Cd accumulates primarily in the liver and kidney and at high concentrations can result in liver damage and kidney failure. Environmental pollution of soils with Cd and subsequent accumulation of Cd in rice resulted in the itai-itai ("ouch-ouch") disease which occurred in the Jiatsu River basin of Japan (Yamagata and Shigematsu, 1970). The World Health Organization has established that the maximum permissible level of dietary Cd should not exceed 70 μg/person/day. The United States Food and Drug Administration "Total Diet Study" (Duggan and Corneliussen, 1972) shows that we are already approaching this level and consequently a further increase in our dietary intake of this element would not be acceptable.

A second source of human exposure to Cd is from smoking tobacco which usually contains 1 to 6 ppm Cd. In this case, Cd is absorbed by the lung and can contribute significantly to the total body burden.

The availability of heavy metals to plants, their uptake, and accumulation depend on a number of soil, plant, and miscellaneous factors listed in Table 3.

For example, toxic metals are more available to plants when the soil pH is below 6.5. Thus, the practice of liming soils to a pH range of 6.0 to 6.5 is recommended to suppress the availability and toxicity of heavy metals to plants. Soil organic matter can chelate or bind metal cations making them less available to plants. The application of organic amendments such as manures and composts can also lower the availability of heavy metals through chelation and the formation of complex ions. Soil phosphorus can interact with certain metals thereby reducing their availability to plants.

The cation exchange capacity (CEC), an expression of the soil's capacity to retain metal cations, is important in binding heavy metals which decreases their availability to plants. Generally, the higher the clay and organic matter content of soils, the higher their CEC value. Heavy metals are relatively less available to plants in high CEC soils (clays or clay loams) than in low CEC soils (sands or sandy loams). Soil moisture, temperature, and aeration are factors which interact to affect plant growth, uptake, and accumulation of metals. For example, increasing the soil temperature can increase plant growth and the availability and uptake of heavy metals as well.

Plant species, and varieties as well, vary widely in their sensitivity to heavy metals. For example, some vegetable crops are very susceptible to injury by heavy metals; corn, soybeans, and cereal grains only moderately susceptible, while forage grasses are relatively tolerant. Generally, the older leaves of most plants will contain higher amounts of heavy metals than the younger tissues. Moreover, the grain and fruit of plants accumulate lower amounts of heavy metals than the leafy tissues. This observation is illustrated in Table 4 which shows the effect of sludge application rates on the Zn and Cd content of corn grain and leaves. As the sludge rates increased, both the Zn and Cd concentrations increased in the plant tissues. However, considerably lower amounts of these metals were accumulated in the grain than in the leaves.

It is noteworthy that heavy metals differ in their relative toxicities to plants and in their reactivity in soils. For example, on an equivalent basis, Cu is generally more phytotoxic than Zn, while Ni is considerably more phytotoxic than either Zn or Cu. For reasons as yet unexplained, heavy metals can revert with time to unavailable forms in soil.

USDA Guidelines to Limit Heavy Metal Loadings on Agricultural Land

In 1976 USDA recommended certain guidelines[3/] to limit the application of heavy metals on agricultural land from either the landspreading of sewage sludges or sludge composts. These guidelines are based on the best available knowledge from scientists at a number of State Agricultural Experiment Stations as well as USDA. Two categories of land were delineated: (1) privately owned land, and (2) land dedicated to sludge application, e.g., publicly owned or leased land.

Table 5 shows the maximum allowable cumulative sludge metal applications for privately owned land. It is suggested that sludges having cadmium contents greater than 25 mg/kg (dry weight) should not be applied to privately owned land unless their Cd/Zn is $\leq$ 0.010. That is, the Cd content of the sludge should not exceed 1% of the Zn content, so that Zn will accumulate to phytotoxic levels before sufficient Cd can be absorbed by the plant to endanger the food chain. Annual rates of sludge application should be based on the nitrogen requirements of crops. Cadmium loadings on land should not exceed 1 kg/ha/year for liquid sludge and not more than 2 kg/ha/year for dewatered sludge. The soil should be limed to a pH of 6.5 when the sludge is applied and maintained at a pH of 6.2 thereafter.

On publicly controlled land up to five times the amounts of sludge-borne metals listed in Table 5 may be applied if the sludge is mixed into the 0 to 15 cm

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3/ Copies of the draft document are available from the Office of Environmental Quality Activities, USDA, Washington, D.C. 20250.

of surface soil. Where deeper incorporation is practiced, proportionally higher total metal applications may be made. These metal applications apply only to soils that are adjusted to pH 6.5 or greater when sludge is applied.

Pathogens

Sewage sludge contains human pathogens, many of which are destroyed or reduced in number during sewage treatment. Further reduction can be accomplished by heat drying, composting, lime stabilization, or pasteurization. Data indicate that disease problems related to soil application have been caused primarily by use of raw sewage effluent, raw sludge, and night soil (Sepp, 1971; Parsons et al., 1975). Parsons et al. (1975) summarized various data (Table 5) on the survival of certain pathogens in soils and on plants. While most pathogens survive in soil only for several days or a few weeks, the eggs of intestinal worms such as Ascaris lumbricoides can survive for a number of years.

Soil moisture, pH, and temperature greatly influenced the survival of pathogenic organisms. Adsorption and movement of pathogens in soil is affected by the clay and organic matter content. Movement of bacteria through soils was generally restricted to the upper few centimeters (Romero 1970). However, Bouwer et al. (1974) showed that in porous soils subjected to high flow rates of sewage effluents, bacterial movement can occur to a depth of several meters.

Bitton (1975) cites several references regarding adsorption of viruses on soil particles and their movement through soils. Migration of viruses through soils was generally limited to the upper 50 cm. However, in porous media or where fissures, fractures, or cracks in the substratum occur, movement of viruses to groundwater is possible (Hori et al., 1970). Epstein et al. (1976), Burge et al. (1977), and Kawata et al. (1976) showed that sewage sludge composting can effectively destroy coliforms, salmonella, and enteric viruses when composting temperatures exceed 55°C for several days. Recent stuides at

Beltsville, using an aerated pile method for composting raw sludge, showed that f_2 bacteriophage, a virus similar to some animal viruses but far more resistant to destruction by heat, was completely destroyed during the first 2 weeks of the composting period.

Miscellaneous Problems

Application of sludge to land can result in excess salts since ferric chloride, alum, and lime are added during wastewater treatment to flocculate and precipitate the suspended solids. There are a number of concerns associated with the use of sludge on land; e.g., lack of public acceptance, adverse environmental effects from odors and runoff, storage and distribution problems, and climatic constraints. Public opposition to hauling and surface application of sewage sludge can be a major problem. Residents along hauling routes near application sites often object to the use of sludge on land. Improper soil or site management can cause excessive runoff of effluent, nitrate pollution of ground or surface waters, odors and other environmental problems. Sludge application to land may have to be curtailed during winter months necessitating costly storage. Land application usually requires immediate incorporation into the soil to avoid runoff and odor problems and is, thus, dependent on weather conditions. The costs of land spreading will also be dictated by land values near urban areas, and the probable future limited use of the land where sludges containing high quantities of heavy metals or persistent organic constituents are applied.

Benefits

The major benefits from use of sludge on land is from the macro- and micronutrients it contains and from improvement of soil physical conditions. Sewage sludge can provide nitrogen (N), phosphorus (P), Calcium (Ca), sulfur (S) and other essential plant micronutrients. Larson (1974) estimated that sewage sludge produced in the United States could provide 2.5% of the nitrogen, 6% of the phosphorus, and 0.5% of the potassium sold as commercial fertilizers in 1973. Most of the nitrogen in sewage sludge is in the organic form and not readily available for crop growth. Epstein (1976) indicated that 65 and 44 percent of the organic N fraction in raw and anaerobically digested sludge, respectively, was mineralized after 5 weeks of incubation in soil. Sludge application to land often produces higher yields than comparable applications of commercial fertilizers based on N content (Dowdy et al., 1976). This increase is most probably due to improved soil physical properties. The addition of organic matter such as sludge, green manure, animal manures, and composts are known to improve soil physical properties as evidenced by increased water content, increased water retention, enhanced aggregation, increased soil aeration, greater permeability, increased water infiltration, and decreased surface crusting. Addition of sludge to sandy soils will increase their ability to retain water and render them less droughty. In clay soils the added organic matter will increase permeability to air and water, and increase the infiltration of water into the soil profile. The improvement of soil-water relationships in clay soil will provide more available water for plant growth. The added organic matter, particularly to clay soils, improves tilth, reduces compaction, and increases soil aeration and rooting depth.

Land Application

Wastewater treatment can be primary (sedimentation), secondary (anaerobic digestion or extended aeration), or tertiary (chemical treatment) and, accordingly, produces primary, secondary, and chemically stabilized sludges. Untreated effluent is not recommended for land application since it may contain human pathogens. Treated effluents or liquid sludge (1 or 10% solids) can be applied by standard irrigation equipment (Dowdy et al., 1976). Two projects utilizing liquid effluents for both irrigation and nutrient supplementation of crops are the EPA-Muskegon County Project in Michigan and the Chicago-Fulton County Project in Illinois. Liquid sludge may also be injected into soil with specialized equipment including, chisels and sweep injectors, and disc and moldboard plows. Surface application systems consist of tank vehicles either tractor-drawn or truck mounted which spray the liquid sludge directly on the soil or crop. Filter cake sludge (20 to 23% solids) can be spread with a bulldozer or a tractor-drawn manure spreader. Heat-dried sludge may be applied with a fertilizer spreader.

Composting of Sewage Sludge

There are at least four reasons for composting organic wastes such as sewage sludges. These include (a) abatement of odors through sludge stabilization; (b) destruction of pathogens by heat generated during the composting process; (c) production of a hygienic material that can be uniformly applied to land; (d) and narrowing the C/N ratio of the biomass being composted.

Several years ago the Agricultural Research Service of the U.S. Department of Agriculture at Beltsville, Maryland, developed a windrow method that has proved to be suitable for composting digested sludge (Epstein and Willson, 1974). This method, however, was not acceptable for composting undigested (raw) sludge because of the greater level of malodors associated with undigested sludges. This same research group has now developed a method for composting undigested sludges (Epstein and Willson, 1975; Epstein et al., 1976). The method is widely referred to as the Beltsville Aerated Pile Method, wherein undigested sludge (22% solids) is mixed with woodchips as a bulking material, and then composted in a stationary aerated pile for a period of 3 weeks. Other bulking materials such as paper, leaves, or agricultural residues can be used in lieu of woodchips. Sufficiently high temperatures are attained (above 60°C or 140°F) to effectively destroy pathogens. During composting the pile is blanketed with a layer of screened cured compost for insulation and odor control. Aerobic composting conditions are maintained by pulling air through the pile by means of a vacuum system. The effluent air stream is conducted into a small pile of screened compost where odorous gases are effectively absorbed.

The finished compost can be used as both a fertilizer and soil conditioner. Large quantities have been used as a top soil substitute by the National Capitol Park Service and Maryland State Park Service in land reclamation and development projects. Other uses for the compost include stripmine and gravel pit revegetation and reclamation projects, turfgrass production, tree nurseries, and the production of field crops. Recent research at Beltsville suggests that on a total metal basis, heavy metals are less available to plants in composted sewage sludges than they are in uncomposted raw and digested sludges[4/]. The exact reason for this is not known but it is the subject of continuing research.

The Beltsville Aerated Pile Method has been adopted by a number of municipalities, including Bangor, Maine; Durham, New Hampshire; and Camden, New Jersey; and more are likely to follow, since sludge stabilization by composting and subsequent utilization of the compost on land is a more viable alternative to such environmentally unacceptable disposal methods as ocean dumping, landfill, and incineration.

Conclusions

Intensive cropping systems often accelerate the depletion of soil organic matter thus causing the deterioration of soil physical properties which in turn leads to increased runoff and erosion, increased nutrient losses and decreased soil productivity. Both heavy (clays) and light (sands) soils could greatly

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4/ R. L. Chaney and E. Epstein, unpublished data.

benefit from the application of sludge or sludge composts as a result of improving their chemical and physical properties. The continuing high costs of inorganic fertilizers has caused developing countries to consider the utilization of urban and municipal organic wastes as fertilizers to sustain crop production. Pathogen problems can be minimized with improved sanitary conditions, development of appropriate process technology for composting sludge, and restriction in the use of raw sludges on crops that are eaten raw.

Where sludges and sludge composts are applied to land, steps should be taken to prevent the accumulation of heavy metals in food chain crops. In cases where industries are utilizing sanitary sewers to discharge effluents containing heavy metals, abatement and/or pretreatment methods should be implemented. While it is hoped that such action would be voluntary, regulatory agencies should exercise their authority to limit the influx of heavy metals where necessary. Heavy metals in food crops can be minimized by good soil and crop management practices. For example, maintenance of soil pH near 6.5, proper crop selection, and proper management of organic matter can reduce uptake and accumulation. In addition to agronomic crops, sludge and sludge composts can be very beneficial for use in the development of parks, reclamation and revegetation of stripmined lands and gravel pits, and for nursery use in the production of turfgrass, ornamentals, and trees.

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Table 1. Total Elemental Composition of Sewage Sludge from several United States Municipalities (Sommers 1977).[1]

Component	Concentration[2] Minimum	Maximum	Median
	---	% ---	
Organic C.	6.5	48.0	30.4
Inorganic C.	0.3	54.3	1.4
Total N	<0.1	17.6	3.3
NH_4^+-N	<0.1	6.7	1.0
NO_3^--N	<0.1	0.5	<0.1
Total P	<0.1	14.3	2.3
Inorganic P	<0.1	2.4	1.6
Total S	0.6	1.5	1.1
Ca	0.10	25.0	3.9
Fe	<0.10	15.3	1.1
Al	0.10	13.5	0.4
Na	0.01	3.1	0.2
K	0.02	2.6	0.3
Mg	0.03	2.0	0.4
	---	ppm ---	
Zn	101	27800	1740
Cu	84	10400	850
Ni	2	3515	82
Cr	10	99000	890
Mn	18	7100	260
Cd	3	3410	16
Pb	13	19730	500
Hg	<1	10600	5
Co	1	18	4
Mo	5	39	30
Ba	21	8980	162
As	6	230	10
B	4	757	33

1/ Data compiled from over 200 samples from 8 states.

2/ Values expressed on 110°C weight basis.

Table 2. Composition of Raw and Digested Sludges from the Washington, D. C. Blue Plains Wastewater Treatment Plant, and their Respective Composts Processed at the USDA Composting Facility, Beltsville, Md.

Component	Raw Sludge	Raw Sludge Compost	Digested Sludge	Digested Sludge Compost
pH	5.7	6.8	6.5	6.8
Water, %	78	35	76	35
Organic carbon, %	31	23	24	13
Total N, %	3.8	1.6	2.3	0.9
NH_4^+-N, ppm	1540	235	1210	190
Phosphorus, %	1.5	1.0	2.2	1.1
Potassium, %	0.2	0.2	0.2	0.1
Calcium, %	1.4	1.4	2.0	2.0
Zinc, ppm	980	770	1760	1000
Copper, ppm	420	300	725	250
Cadmium, ppm	10	8	19	9
Nickel, ppm	85	55	-	-
Lead, ppm	425	290	575	320
PCB[1/], ppm	0.24	0.17	0.24	0.25
BHC[2/], ppm	1.22	0.10	0.13	0.05
DDE[3/], ppm	0.01	<0.01	-	0.008
DDT, ppm	0.06	0.02	-	0.06

1/ Polychlorinated biphenyls as Arochlor 1254.

2/ The gamma isomer of benzene hexachloride is also called lindane.

3/ DDE results from the dehydrochlorination of DDT.

Table 3. Major Factors Affecting Heavy Metal Uptake and Accumulation by Plants

Soil Factors

1. Soil pH - Toxic metals are more available to plants below pH 6.5.

2. Organic matter - Organic matter can chelate and complex heavy metals so that they are less available to plants.

3. Soil phosphorus - Phosphorus interacts with certain metal cations altering their availability to plants.

4. Cation Exchange Capacity (CEC) - Important in binding of metal cations. Soils with a high CEC are safer for disposal of sludges.

5. Moisture, temperature, and aeration - These can affect plant growth and uptake of metals.

Plant Factors

1. Plant species and varieties - Vegetable crops are more sensitive to heavy metals than grasses.

2. Organs of the plant - Grain and fruit accumulate lower amounts of heavy metals than leafy tissues.

3. Plant age and seasonal effects - The older leaves of plants will contain higher amounts of metals.

Miscellaneous Factors

1. Reversion - With time, metals may revert to unavailable forms in soil.

2. Metals - Zn, Cu, Ni and other metals differ in their relative toxicities to plants and their reactivity in soils.

Table 4. Effect of Sludge on Zn and Cd Content of Corn

Sludge Applied	Zn		Cd	
	Grain	Leaves	Grain	Leaves
Tons/acre[1/]	ppm	ppm	ppm	ppm
0	27	35	0.04	0.41
17.5	41	180	0.11	1.11
35	46	224	0.21	1.74
70	36	168	0.17	1.89
105	45	143	0.20	1.69

1/ Application rates are on a dry weight basis.

Table 5. Maximum Allowable Cumulative Sludge Metal Loadings for Privately Owned Land as a Function of the Soil Cation Exchange Capacity.

Metal	Soil Cation Exchange Capacity (meq/100g)		
	0 - 5	5 - 15	15
	(Maximum metal addition, kg/ha)		
Zn	250	500	1000
Cu	125	250	500
Ni	50	100	200
Cd	5	10	20
Pb	500	1000	2000

Table 6. Survival of Certain Pathogens in Soil and on Plants (Parsons, et al., 1975).

Organism	Media	Survival Time Days
Coliforms	Soil Surface	38
	Vegetables	35
	Grass and Clover	6-34
Fecal streptococci	Soil	26-77
Salmonella	Soil	15->280
	Vegetables and Fruits	3-49
	Grass or Clover	12->42 (and over winter)
Salmonella typhi	Soil	1-120
	Vegetables and Fruits	<1-68
Shigella	On Grass (raw sewage)	42
	Vegetables	2-10
	In Water Containing Humus	160
Tubercle bacilli	Soil	>180
	Grass	10-49
Entamoeba histolytica cysts	Soil	6-8
	Vegetables	<1-3
	Water	8-40
Enteroviruses	Soil	8
	Vegetables	4-6
Ascaris ova	Soil	Up to 7 years
	Vegetables and Fruits	27-35

LONG-TERM CARE AND LIABILITY ISSUE
Related to Hazardous Waste Treatment, Storage, and Disposal Sites

by Michael Shannon*

Introduction

In the period that led up to Earth Day 1970, this country was coming to the realization that maintaining the quality of the human environment was the most important challenge of our age. It was within this context that the Congress enacted the first solid waste legislation in 1965, initiating a concerted effort to improve solid waste management practices, and the course of extensive envrionmental pollution across the Nation.

The Federal solid waste program was organized to carry out provisions of the 1965 Solid Waste Disposal Act and was, at that time, within the Department of Health, Education, and Welfare. With the coming of Earth Day 1970 and the assembly of the main Federal environmental programs into a single agency, the Office of Solid Waste became a part of the U.S. Environmental Protection Agency. The year 1970 also saw an amendment to the Solid Waste Disposal Act -- the Resource Recovery Act, which provided a new emphasis towards recovery of valuable materials and energy from waste residuals. As a result of EPA's 1973 report to Congress, Disposal of Hazardous Wastes, mandated by Section 212 of the amended legislation, a strong thrust to bring some control to the management of hazardous wastes throughout the United States was begun at EPA.

The new law of the land is the Resource Conservation and Recovery Act of 1976 which was signed by President Ford on October 21 and designated as Public Law 94-580. The new law phases out open dumping of solid wastes, upgrades land disposal, provides Federal financial and technical assistance to State and area-wide programs which are environmentally sound and makes optimal use of opportunities for resource recovery. Limited Federal support for resource recovery demonstrations would be provided through the mechanism of loan guarantees. Expanded Federal technical assistance and information efforts would be authorized to assist States, local governments and industry in every aspect of solid waste management. Those who treat, transport, store, or dispose of hazardous wastes will need to obtain permits for their activities. This paper will focus on several non-technical aspects of the hazardous waste management regulations.

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*Mr. Shannon is a program manager with the Implementation Branch, Hazardous Waste Management Division, Office of Solid Waste, U.S. Environmental Protection Agency.

The problems of perpetual or long-term care and liability of hazardous waste management facilities are of vital concern to the public. Facilities as used here include hazardous waste treatment, storage, and disposal operations/sites. In fact, the recently passed 1976 Resource Conservation and Recovery Act contains elements which are adddressed to these issues. Specifically, Subtitle C - Hazardous Waste Management, Section 3004.6 "Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal facilities" states that the standards shall include "such additional qualifications as to ownership, continuity of operation, and financial responsibility as may be necessary or desirable." In order to protect the public and the environment from harm, this Act recognizes that certain measures are necessary to ensure financial responsibility and long-term care of hazardous waste management facilities.

These requirements are included because from a regulatory standpoint, technical standards and record-keeping and reporting requirements must be re-enforced by incentives for good management and complete protection. The requirements give the public the knowledge that persons in the business of hazardous waste management are responsible and can be held accountable for their actions. In addition, financial responsibility and continuity of operations requirements give the owners or hazardous waste management facilities a degree of protection against the financial aspects of pollution incidents and lawsuits. The mere fact that there is a law increases the visibility and responsibility of persons in the industry and simultaneously gives the public a vehicle for comparison and to bring suit.

There are two related approaches that have to be considered in implementing long-term care and liability provisions. The first approach relates to continuity of operation and ownership requirements or to the transfer of site operations from one operator to the next, as well as the final closing and subsequent monitoring, surveillance, and maintenance of the hazardous waste facility. This paper will address the problem of assuring adequate funds for site closure and long-term care at any point in the life of the site. Once such provisions have been established, the financial responsibilities can be transferred with a change in site operators.

THE DILEMMA OF LIABILITY
AND
PERPETUAL CARE ISSUES

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AND
PERPETUAL CARE ISSUES

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Introduction

In the period that led up to Earth Day 1970, this country was coming to the realization that maintaining the quality of the human environment was the most important challenge of our age. It was within this context that the Congress enacted the first solid waste legislation in 1965, initiating a concerted effort to improve solid waste management practices, and the course of extensive environmental pollution across the Nation.

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The problems of perpetual or long-term care and liability of hazardous waste management facilities are realistic and are of concern to the public. Facilities as used here include hazardous waste treatment, storage, and disposal operations/ sites. In fact, the recently passed hazardous waste management legislation contains elements which are addressed to these issues. Specifically, the language of the 1976 Resource Conservation and Recovery Act under Subtitle C - Hazardous Waste Management, Section 3004.6 "Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities" states that the standards shall include "such additional qualifications as to ownership, continuity of operation, and financial responsibility as may be necessary or desirable." In order to protect the public and the environment from harm, this Act recognizes that certain measures are necessary to ensure financial responsibility and long-term care of hazardous waste management facilities.

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There are two related approaches that have to be considered in implementing long-term care and liability provisions. The first approach relates to continuity of operation and ownership requirements or to the transfer of site operations from one operator to the next, as well as the final closing and subsequent monitoring, surveillance, and maintenance of the hazardous waste facility. This paper will address the problem of assuring adequate funds for site closure and long-term care at any point in the life of the site. Once such provisions have been established, the financial responsibilities can be transferred with a change in site operators.

The second approach encompasses the financial responsibility of operators of hazardous waste managment facilities. Here the concern is more with the assessment of liablity for damage occurrences related to hazardous waste. The reouirement of liability insurance is discussed as the means for insuring financial responsibility.

Long-term Care

Previous experience with the long-term care of hazardous waste managment facilities is limited. One method of ensuring long-term site care is to require deposit of a cash bond or maintenance of a surety bond by the hazardous waste management facility operator. The bond must be of sufficient size to assure proper site closing and site monitoring, surveillance, and maintenance for a specified number of years. The appropriate bonding level should consider site characteristics (size, geology, hydrology, etc.), the particular hazardous waste destined for storage, disposal, the degree of waste treatment prior to disposal, and the likelihood of off-site damages (i.e., proximity to population centers, etc.) should be considered as well, although it has not previously been a factor, when choosing an appropriate bonding level. A surety bond would probably be less burdensome to the site operator than a cash bond of an equivalent amount. The premium paid for a surety bond presumably being less than the cost of a loan needed for deposit of a cash bond.

In the case of a cash bond, adequate provision for perpetual site care is assured if the annual real rate of return (i.e., the return on the principal over and above the rate of inflation) offsets the cost of site upkeep. A portion of the bond could be used to correct major site deficiencies or to offset damages caused by leachate run-off or migration. Sufficient funds would have to remain in escrow to provide for annual site upkeep subsequent to such expenditures. If a change in facility operators occurs (in advance of site closure), then the former site operator should be allowed to withdraw the bond's principal and the new operator required to deposit an equivalent amount.

An alternative to the required bond deposit is assessment of a perpetual care fee on each user of the waste facility. The user surcharge would be fixed on a volumetric basis. In general, facility site operators have not varied this fee with the type of incoming waste. The aggregate fees are deposited in an account, and when a level sufficient to maintain long-term care of the site has been reached (including accrued interest), the fee may be discontinued. (Of course, the fee may be calculated such that the desired fund level will not be reached until the site is full.) The major drawback to this method of financing long-term site care is that the operator can cease facility operations without having accumulated a fund large enough to assure adequate facility closure and perpetual care.

Either a cash or surety bond can be combined with a perpetual care fee to provide for perpetual site care. A cash bond deposited with a State could be withdrawn when an equivalent amount accumulated through aggregate perpetual care fees has been deposited by the site operator. Alternatively, a surety bond, equal to the difference between the apparent required sinking fund and the expected size of the sinking funds for that year (i.e., cumulative perpetual care fees plus accrued interest), could be required of the site operator. The apparent required sinking fund would be a site specific reserve sufficient to provide for routine maintenance, surveillance, and monitoring costs, as well as contingency funds in the event of major facility repair. In essence, this method of assuring long-term care would require the site operator to purchase declining term insurance to protect a State against early close-out of site operations.

A combined surety bond/perpetual care fee was suggested as an adequate means of financial security for one of serveral low-level radioactive waste sites in the United States. The apparent required sinking fund was to be calculated on an annual basis, i.e., varying with the amount of waste deposited at the disposal site. An appropriate size for the contingency fund was calculated on the basis of the "expected value" of major site repair costs (i.e., the sum of projected repair costs multiplied by their respective probabilities of occurrence). Alternatively, a contingency reserve sufficient to cover the estimated cost of major site repair, given the need for such action, could be required as part of the apparent required sinking fund.

Rather than accumulate a perpetual care fund for each hazardous waste management facility, a mutual trust fund is another option that could be developed for all sites within a given jurisdiction (e.g., within a State). This proposal could be funded by any of the foregoing mechanisms. The trust fund would provide a larger reserve to cover unexpected site repairs or damage claims. Also, due to the pooling of the risk of major site repair, the contingency reserve required of each site operator would be less than that needed if a separate sinking fund was maintained for each site. Private operators might not be as careful in site construction and maintenance if they are not directly liable for these costs, however, the enforcement agency would have to provide the incentive for continued site care.

Another option for long-term site care is a convenant which is placed on the land to prohibit the transfer of site maintenance responsibility with the deed unless the new owner accepted the responsibility and was capable of guaranteeing continued site maintenance. The question then arises of what constitues capability to guarantee site maintenance. The owner would probably have to offer some sort of financial security in order to guarantee site maintenance. A long-term care fund, similar to the alternatives just mentioned, might well have to be established. Thus, this method of ensuring long-term care is not really a discrete proposal, but rather a different context for posing the problem of adequate financial security for long-term care.

Liability

Some States which have hazardous waste management legislation require that disposal sites be deeded to the State and that performance bonds be posted to obtain a license to operate (e.g., Oregon, Washington). These requirements should improve long-term care of disposal sites and reduce the liability problem for the private sector. Previous owners, however, could still be held liable for damages which arose from their actions. Oregon, or any State, if acting as a proprietor could be open to suit or there may be State statutes permitting tort claims against the State.

Just as there are questions about private and public sector roles in long-term care and liablity, there are questions regarding liability for consequences concerning incidents entirely involving the private sector that occur after a change in ownership of the waste or that occur as a result of operations by a previous owner of the facility. The confusion over responsibility partly stems from the fact that the liability laws and the judicial processes vary from State to State and from municipality to municipality. As a consequence, it is possible to hear opinions that liability for damages from a hazardous waste can be entirely transferred from a generator to a disposer of the waste or that most States adhere to the rule that the generator always bears at least some of the liability.

In an effort to better understand some of the information regarding long-term liability, this part of the paper will focus on first, a discussion of the assessment of liability for occurrences related to hazardous wastes. Next there will be a discussion of nuclear liability insurance followed by the hazardous waste service industry experience with liability insurance. The final part is a discussion of the implementation of the insurance technique as a tool for insuring financial responsibility and long-term care of hazardous waste management facilities.

There are two areas of law that apply to hazardous waste in connection with damages - tort liability and criminal law. Tort liability is resolved in a civil action brought by a private plaintiff representing his own interest. In criminal action, a public official will bring suit on behalf of broad social interests. The "Rivers and Harbors Act of 1899" has sometimes been used by Federal officials as the legal basis in a criminal liability case against polluters. Hazardous waste management is covered by specific statute in only a few States and covered by the 1976 Resource Conservation and Recovery Act.

Since civil actions are the most common to hazardous waste damage cases, the four theories of tort liability including negligence, strict liability, nuisance, and trespass will be discussed. Although the distinctions between the four theories are sometimes not clear at the applied level the following discussion summarizes their main features.

Negligence bases liability on the failure to use the proper degree of care in conducting an activity. It usually involves an operational defect or omission of a reasonable precautionary measure. The concept of reasonableness is based to some extent on generally employed standard practices but varies with the facts of the particular situation.

At the other end of the spectrum, the theory of strict liability imposes liability without regard to the degree of care or precautions taken to prevent damage. Losses are automatically shifted to the party who initiated the damage-causing activity. The application of this theory is generally applied to those activities that pose a considerable threat to others even when conducted with every possible precaution.

The concept of nuisance falls between the theories of negligence and strict liability with regard to the requirements for liability. Applications generally involve unreasonable interferences with the use and enjoyment of land resulting from the actions of other parties. Emphasis is on the invasion of the injured party's rights rather than on the reasonableness of the initiator's conduct with the courts using discretion on balancing the interests involved. Although negligence is not always a requirement for proof of nuisance, proof of negligence is often accepted in support of an allegation that a nuisance exists. Nuisance can look very much like the strict liability concept when liability is based on the results of an activity without regard to the care or precautions employed.

Trespass usually involves an unauthorized entry onto the land of another or an invasion of property rights. The entry or invasion need not be by a person, but may be accomplished by something within the control of that person, which brings escaping hazardous wastes within the scope of trespass.

The success of a plaintiff's legal action depends on his successful presentation of proof of damages. The elements of proof required vary among the liability theories but in general include: 1) necessity of showing injury; 2) establishment of causation; 3) establishment of fault. These three elements of proof deserve more detailed explication. The injury can take various forms: 1) actual physical injury to person or property, which is the most significant form; 2) infringement of legally protected rights; 3) anticipated injury. The view that infringement of a legal right constitutes injury in itself usually arises in a trespass case which primarily involves unauthorized entry onto the land of another. Here suit is brought not for an actual injury, but rather for vindication of a right. Anticipated injury by trespass or nuisance involves suits brought in prohibitory injunctions. Injunctions traditionally are granted to a complaining party only if it can prove the likelihood of direct injury to his rights.

Physical injury from the polluting effect of hazardous wastes can take a variety of forms including loss of or damage to human life, livestock, crops, water supplies, aquatic life, etc. In cases where compensatory damages are sought through litigation, the plaintiff normally must quantify his injury in monetary terms which may be possible in some situations, but not very feasible in others. Traditionally if an injury cannot be measured, it goes uncompensated. If the plaintiff is unable to prove damages, he still may be awarded an injunction especially if something unique is injured or there is a denunciation in property value. The judge or jury may adjust damages to reflect their interpretation of an injury.

The plaintiff must also prove the source of the injury. In some cases involving a hazardous waste incident, the cause and effect relationship will be obvious. In a groundwater pollution incident, as the distance between a disposal facility and the injury increases and as the spread of leachate is affected by natural processes, the positive identification of a source becomes more difficult. Incomplete knowledge about the movement of a groundwater pollutant generally makes a causal relationship difficult to prove especially if the alleged incident occurred over a long period of time. However, a good case might be possible if direct evidence in a case of injury from groundwater pollution can be obtained. For example, if a dye or other tracer is deposited at the site of the pollution incident and it then appears at the place of injury. The courts in some cases may accept indirect proof based on circumstantial evidence. It is difficult to generalize with regard to the evidence necessary for proof, but there are several key factors. Included are the proximity of the incident to the injury site, the time relationship between the incident and occurrence of injury, the existence of a physical connection and the elimination of other possible sources for the injury.

In addition to proof of injury and of a causal relationship, the plaintiff in some cases may also have to prove that the injury resulted from improper conduct on the part of the defendant through fault or culpability. Negligence is of primary interest here since the underlying basis of this theory is the failure to conform to a certain standard of conduct which is based on the conduct of the hypothetical "reasonable man". Compliance with industry-used practices is not necessarily a successful defense against negligence actions. Proof of negligence by a defendant poses a formidable obstacle where the activities in question occurred on the defendant's property and involved operations exclusively within the defendant's knowledge. Some courts have accepted general proof of negligence in place of proof of specific details. On the other hand, allegations of negligence have been turned down in courts because of an absence of a reasonable basis for the anticipation of harm in connection with conducting lawful activities.

Other cases decided under the strict liability theory have imposed liability for injury from escaping pollutants without regard to fault. Liability here is viewed as an integral part of conducting hazardous activities, and this approach stresses accountability through compensation for injuries. The strict liability theory only requires the plaintiff to show injury and a causal relationship with the defendant's operations. The strict liability concept in various forms has been accepted in 30 States with the number growing at a rate of about one per year. Guidelines for defining hazardous activities include six factors: 1) degree of risk to the person or property of others; 2) seriousness of potential harm; 3) risk elimination by exercise of reasonable care; 4) common usage of activity; 5) appropriateness of activity relative to place where carried on; 6) value of the activity to the community. These guidelines were applied to a Maryland case where an owner of a large gasoline tank in close proximity to a water well was held liable when gas leakage contaminated the well.

Environmental law and case law is very meager on the subject of responsibility of a polluter or a waste generator and someone acting on his behalf to manage or control the pollution. In addition to assigning direct liability to the person causing the damage, there is a secondary type of liability for aiding or instigating an environmental occurrence. In this unsettled area of law, it is generally necessary to rely on the established law of liability of contractors. This is of great importance in hazardous waste management because of the importance of off-site treatment and disposal of hazardous wastes.

A typical definition of a hazardous waste management firm acting as an independent contractor is one who exercises an independent employment and contracts to do specified work according to his own methods, without being subject to the supervision and control of his employer (waste generator) except for the results desired. This definition is important when establishing whether or not a relationship between hazardous waste generator and a management firm is that of an independent contractor or employer - employee. The kind of relationship will answer in many cases the question of the liability of the employer for personal injury or property damage to others from wrongful acts of the contractor or his employees. The general rule in the United States is that the employer is not liable for the wrongful acts of one who is found to be an independent contractor. There is no absolute test for determining whether a person is an independent contractor or an employee; each situation must be determined on its own facts. The degree of control exercised by the employers is a common factor, however.

An exception to the non-liability of an employer occurs when he (or his agent) negligently hires an incompetent contractor who the employer knew or should have known, had he used due care, was not qualified to perform the work. Another exception occurs when an employer is aware of a violation of a law by his independent contractor and does not protest or attempt to rectify the violation. In this situation the employer cannot escape liability.

A valuable source of information for its relevance to the implementation of liability and insurance requirements is a report entitled Nuclear Insurance - An Estimate of the Cost of the Nuclear Hazard. It is valuable because of its description of the insurance mechanism used for covering liability due to nuclear hazard. The Price-Anderson Indemnity Act of 1957 (an amendment to the Atomic Energy Act of 1954) initiated and fostered the nuclear insurance and indemnification program in the United States. The Act was extended in 1976 to an effective date of 1985.

The main features of the Act regarding insurance requirements are: 1) the Nuclear Regulatory Commission (NRC, formerly AEC) requires financial protection for licensees; 2) the amount of financial protection must be the amount of liability insurance available from private sources; 3) the Federal Government provides an indemnity above the financial protection required of the licensee (the maximum indemnity for each nuclear incident for all persons indemnified is $560 million); 4) the NRC is authorized to collect a fee from all persons with whom an indemnification agreement is executed (the fee is based on generating capacity); 5) the NRC has the responsibiliity for implementing and administering the Price-Anderson Act.

The scope of coverage of government indemnification includes practically all nuclear incidents involving transportation, storage, or reactor operation whether nuclear fuel or nuclear waste. Coverage extends to any person legally liable for an incident. The maximum indemnification of $560 million was legislatively set in the 1957 Act as a realistic and affordable ceiling after testimony from nuclear experts, insurance underwriters, and others was evaluted. The fee charged for coverage, however, is not specified on the basis of risk estimation.

The "nuclear energy hazard" being insured is defined as "the radioactive, toxic, explosive, or other hazardous properties of nuclear materials, when such materials are at the designated facility or are being transported to or from the facility." Unlike traditional liability, bodily injury and property damage liability are combined for nuclear hazard. Also, the policies are continuous rather than for a specified period of years.

The nuclear liability insurance offered by two worldwide liability polls is currently $125 million for each nuclear site insured. The nuclear liability insurance premiums were established for the two pools by rating and underwriting bureaus. Since there originally was not actuarial experience, the premium rate formula was based on judgment. The underwriters established a base rate for the first $1 million of insurance with the percent of the base rate per $1 million of insurance declining for additional increments. The factors considered in establishing a base rate are: 1) reactor type; 2) intended use (power, test, research); 3) designed power load; 4) location in relation to population and property exposure; 5) degree of containment. The premium cost for a nuclear power plant in 1971, which had the insurance limit per location of $82 million, ranged from $170,000 to $325,000.

A unique feature of the nuclear insurance policy is a credit rating plan which exists because of the judgmental factors used in setting premiums. A part of the premiums (67% to 75%) goes into a reserve fund for possible refund. The credit is determined on the basis of loss experience over the preceding 10 year period.

From the viewpoint of the consumer who ultimately must bear the cost of the insurance, the added electricity cost due to nuclear insurance is 0.5% of their electric bill.

The determination of a fair rate of liability insurance is a significant problem to the insurer (and to the insured) when a decision is made to extend coverage to a new area such as hazardous waste management. A basic function of an insurance company is to respond to new needs in spreading risk for a business firm which is in a new and risky business and is concerned with unknown costs of insurance. In evaluating a hazardous waste management facility risk situation, an insurance company is concerned with three elements: frequency, severity, predictability. To an insurance company, most risk situations are completely insurable from the private sector (exclusions would be nuclear occurrences and climatic castastrophe) especially if the occurrences are predictable. The high severity of an occurrence is not a critical insurance problem as long as the frequency is low. The high frequency, high severity risk occurrence is a troublesome insurance problem. Risk assignment or actuarial experience concerning the interrelated elements of a hazardous waste framework are generally lacking regarding occurrences because of the infancy of hazardous waste management.

Two specific problem areas appear of concern to insurance companies regarding risk coverage. The first problem, which may be peculiar to hazardous waste, is the delayed effect of some incidents. This actually adds a fourth element to a hazardous waste risk situation. Not only is there limited knowledge about the frequency, severity and predictability of a hazardous waste occurrence but experience on the suddenness of an occurrence versus delayed effects is almost nonexistent. Ordinary liability policies will cover accidental and sudden risk situations but to cover the long-term consequences of hazardous waste incidents, special policies may be required.

Communications with the insurance company which until several years ago offered fleet and landfill coverage to National Solid Waste Management Association (NSWMA) members, indicated that the company's underwriters were greatly concerned about the potential for a major groundwater or surface water pollution case. Most of the firms covered by the group insurance policy were strictly solid waste landfill firms. Although the liability coverage was dropped for NSWMA members because of a poor experience (loss) on the fleet operations, an underlying factor was that the insurance company was aware of and somewhat apprehensive about the delayed aspect of a groundwater or surface water pollution occurrence.

Another significant problem area is the social aspect of an insurance company providing liability insurance to protect the activity responsible for an environmental damage occurrence. According to a spokesman for the insurance industry, public interest groups and their "hang the polluter" attitude have generated opposition against relieving a polluter (private company) from a burden associated with an occurrence. This attitude has impeded the field of pollution liability insurance and made it difficult for insurance companies to enter new fields, e.g., hazardous waste facility liability. Pressure from environmentalists has made it very difficult for oil tanker companies to obtain oil spill insurance. Some companies, as a result, have been forced to obtain liability insurance coverage from European companies.

There are two kinds of liability insurance. One is the insured peril coverage for direct loss or damage to person(s) or property such as from a fire or explosion. The peril inclusion in a liability policy includes things not unique to hazardous wastes and should not present any problem for hazardus waste service firms. The other area of liability insurance is civil action protection against a loss causing event sustained by a plaintiff - commonly called "an occurrence" by an insurance company. As far as the concept of liability is concerned regarding insurance, the insurance company is not concerned about whether or not the occurrence is due to trespass, negligence, nuisance, or strict liability.

A progressive hazardous waste service firm obtains liability insurance from a competitive desire to offer the best and most secure service. Ideally, a hazardous waste generator would select a service firm who is technically qualified. If interested in doing business, the service firm in turn would analyze the waste stream to determine if it is capable of treating, storing or disposing of the waste. Any subsequent agreement to do business usually means the signing of a contract. Upon pick-up and receipt of the waste under a contract, the title changes hands and the service firm assumes liability for the hazardous waste. Generators normally would insist on this provision in their contracts. Actually a service firm, according to contract, would intend to assume liability for problems that are his "sole" responsibility. What this actually means in terms of a lawsuit and shared responsibility has yet to be tested in the courts. Punitive damages are excluded from coverage by the insurance company and must be borne by the activity.

Information is particularly limited regarding the scope of insurance coverage. It appears that most insurance coverage by either the generator or the service firm is the insured peril coverage and not coverage for a civil action to protect against lawsuits based on serious hazardous waste occurrence. The average liability coverage under the NSWMA group policy was $100,000 per occurrence for bodily and personal injury and $300,000 per occurrence for property damage. The insurer would offer whatever a company wanted to buy with some policies having coverage as high as $5,000,000/$10,000,000. One hazardous waste service firm (not under the NSWMA policy) has coverage of $500,000 bodily, $500,000 personal and $3,000,000 for property for each occurrence. The firm's annual insurance cost is estimated at about $10,000 or less than a penny per gallon. However, this policy is for insured peril coverage and does not address the accidental and long-term occurrences. Other than nuclear insurance, the closest experience to hazardous waste is for damage from water and air pollution whereby it costs $50,000 per year for $1,000,000 of liability insurance to cover exclusions from a general liability policy.

When areas of new coverage are offered, insurance underwriters rely heavily on positive technical aspects of an operation such as chemical processing or detoxification which reduces the potential hazard. They also require compliance with applicable standards. Because of a lack of actuarial experience, rates are set artificially high with the service firm reliant upon insurance company competition and credit rebates to reduce the cost of insurance. A high risk situation may require an insurance company to reinsure the activity with a specialty insurance company. This allows the insurance company to share or to spread its risk and gain added experience and a second judgment. Most importantly it means insurance coverage is provided.

Summary/Conclusions

Long-term care and financial responsibility regarding hazardous waste facilities under the new Act appropriately call for regulation at the State level of government. States are able to implement regulations for facilities located in the same geographic area and account for problems unique to an area. They will be able to incorporate local peculiarities into the long-term care and insurance standards. Federal standards, i.e., minimum acceptable provisions for long-term care or Federal approval of each State's regulations, would be necessary in order to avoid discrepancies between States.

Although standards are not required until 18 months after Bill enactment, a combined surety bond/perpetual care fee appears to be an equitable and effective method of ensuring long-term site care. A mutual trust fund, pooling the risk of environmental damage and major site repair, could encourage investment in the hazardous waste management industry. A trust fund, however, could not be established unless there was strict enforcement of hazardous waste management regulations. Formulation of specific long-term facility care regulations would be a State responsibility. "Acceptable" regulations will have to be generally defined by EPA.

A discussion of liability indicates three things. Firstly, problems such as quantifying damages and proving causation related to hazardous waste incidents will always exist. Secondly, although environmental law, including hazardous waste law, is incomplete and often contradictory, it is likely that as it evolves the use of the strict liability theory will increase. Thirdly, these things will in turn increase the necessity for hazardous waste generators to hire competent hazardous waste management firms. Despite these desirable changes in hazardous waste management and law, incidents will occur for which generators and service firms will need some form of financial protection. Insurance is one such form of protection.

Recommendations for liability insurance are somewhat more difficult to make. Less is known about insurance as it relates to hazardous occurrences. What can be said is that the financial responsibility requirement requires that an operator have insurance against a hazardous waste pollution incident versus the standard liability protection. Many questions, however, need answers before standards can be set for financial responsibility. Should the amount of financial protection required for an incident be set at the amount of liability insurance available from private sources? Can it be assumed that the private insurance industry would be able to provide "adequate" liability coverage and that government indemnification will not be required? Is it reasonable to require a hazardous waste management firm to obtain coverage over all aspects of operating a hazardous waste facility including transportation accidents, contamination incidents and other risk activities associated with long-term consequences even after closure of a facility and/or a change in ownership? To an insurer, one thing is clear, the operator of a facility, as a condition for obtaining insurance, would be required to meet all standards associated with the operation of a hazardous waste management facility as a condition for obtaining insurance.

Hazardous waste disposal sites, for example, will ultimately reach full capacity and must be closed; but the potential for occurrences still remains. Regardless of the kind of firm originally owning such a facility or the current ownership whether public or private, liability for damages is an important fact or burden that someone may have to bear. Certainly the possibility exists that the owner and operator of a closed hazardous waste facility still under his ownership could be held liable for long-term damages. The problem is complex when ownership has changed. In order to provide protection in the event of future occurrences after closure, the liability insurance requirement must include coverage for long-term damage regardless of whether ownership is retained or not.

LONG-TERM SITE MAINTENANCE PROBLEMS
AND THE POTENTIAL FOR LIABILITY

By

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BACKGROUND

Historically man has discarded his solid waste in dumps and used burning to reduce its volume. However, open dumps and open burning cause air pollution and involve numerous hazards and problems. Although open dumps are all too common, the trend is clearly toward sanitary landfills. A sanitary landfill is, of course, an engineering method of disposing solid waste to land by spreading the waste in thin layers and covering the waste with earth each day in a manner which prevents environmental pollution. Most of the major problems associated with open dumps were thus supposedly overcome with the advent of the sanitary landfill. The refuse in a sanitary landfill is also compacted to the smallest possible volume, thereby increasing the useful life of the landfill. While the philosophy of the sanitary landfill is admirable, we now realize that we have helped to create new problems. Open dumps and open burning, unsightly and unhealthy as they are, do dispose of organic matter quickly and therefore are not conducive to the generation of gases and some of the intermediate and final products of decomposition. As we tend to embrace sanitary landfill as the only environmentally suitable method for the disposal of solid waste to land we also now recognize new long-term problems which must be assessed.

The purpose of this paper is to review the technical aspec f sanitary landfill post-operation problems, their causes, and th r solution.

First, the problems. The principal so-called post-construction liability and "perpetual care" problems include the impact of gas or leachate on the environment, settlement performance of landfill, erosion of landfill cover soil, various aesthetic issues, and the impact of the landfill on property values.

GAS

Landfills produce gas, varying only in total quantity and the time frame in which it is produced. Carbon dioxide, one of the principal gases of decomposition of refuse, has liability association, principally related to its solubility in water, creating a weak acid, corrosive environment, and increasing water hardness. Relatively little concern is directed to preventive, or remedial, action insofar as carbon dioxide is concerned, and as such it will not be addressed further in this paper.

Methane, the other principal gas from refuse decomposition, is highly combustible in certain concentrations in air, a characteristic that gives methane a dual personality. On the positive side, methane can be a definite asset, representing, in certain cases, an economically recoverable energy resource. On the negative side are hazards and liabilities associated with uncontrolled release of the gas from the fill confines, with an accompanying possibility of fire, or when accumulated in confined areas, explosion.

The production of methane gas as a function of time is of interest for at least two reasons: (1) to evaluate the expected "active gas life" of a landfill, and (2) to consider the feasibility of recovery of methane for energy. Consider that methane gas is generated only from the organic matter which may be characterized as in Table 1.

TABLE 1
METHANE GENERATION FROM ORGANIC MATTER

Organic Matter	Active Life		Composition (%)
	Half Life (years)	90% of Life (years)	
Readily Biodegradable	0.5 - 1.5	½ - 3	9
Food Wastes			
Moderately Biodegradable	5 - 25	15 - 80	91
Paper Products			
Garden Waste			
Textile Products			
Wood			
Non-biodegradable	50 - ∞	--	0
Rubber			
Plastic			

It should be noted that more than 90 percent of methane gas produced is generated from the moderately biodegradable fraction of which paper products predominate. To merely close a site does not stop gas production which may continue for 20 to 100 years.

The potential for gas hazard is probably present to varying degrees at the majority of landfills. The liability aspects of landfill-produced methane are generally recognized throughout the industry. Concern for methane stems from its combustibility when present in concentrations between 5 and 15 percent by volume in air. While fire alone is concern enough, combustion initiated within a confined space can result in an explosion. If migrating methane accumulates in a poorly-ventilated area (i.e., building subfloor, basement, closet, utility vault, storm drain) and achieves combustible concentrations, a hazard to public safety and/or property exists. Since methane is usually present in concentrations above the combustion range within landfills, it always must pass through the combustion range as it is diluted with air. Fortunately, under the majority of circumstances, a combustion energizer such as an open flame is not present during passage through the critical range and combustion does not occur. The numerous instances on record of fires and explosions resulting from landfill-originating methane, however, serve to warn that all too often gas migration proves hazardous.

The movement of gas to the limits of a refuse fill and into the surrounding soils occurs by two basic processes: convection, or movement in response to pressure-temperature gradients; and diffusion, or movement from areas of high gas concentration to regions of lower concentration.

Gas flow is greater through materials with large pore spaces and high permeability (i.e., sands, gravels) and lower in materials of lower permeability (i.e., clays). Gas migration from landfills is therefore dependent in part on the geological environment of the site. In general, a landfill constructed in a sand-gravel environment experiences greater vertical and lateral movement of gases than one in a clay environment.

Being lighter than air, methane tends to rise and will exit preferentially through the landfill cover if it is of sufficient permeability. A cover of clay with small diameter pores tends to retain moisture in its pores and is thus relatively impermeable, and tends to restrict gas loss. Any type of soil may be made less permeable by saturation with rain or irrigation water, or by paving or frost. In such instances gas flow through the cover will be impeded, and lateral migration will be encouraged. Also, rain water may infiltrate the refuse and increase the moisture content, which in turn increases the rate of decomposition, and thus the gas production. This condition, occurring in combination with the decreased permeability of surface soils, can result in significant seasonal variation in the extent of gas migration. Where a groundwater table exists beneath a disposal site, it provides an absolute limit to the depth of gas migration.

The gas produced within a landfill must escape; the geologic-hydrologic environment and construction of a particular site combine to determine the direction the gas will flow, either through the cover, laterally, or in both directions. Uncontrolled relief of the gas may mean its release occurs in an undesirable area, leading to environmental and hazard problems. Controlled relief means release is in a manner compatible with environmental security and safety.

Placement of a thick, moist, vegetative final cover may act as a gas-tight lid that forces gases to migrate laterally from the landfill. If the site is converted into a paved parking lot, this may prevent gases from venting into the atmosphere.

In 1968, seepage of methane from a landfill caused an explosion in a National Guard armory in Winston-Salem, North Carolina that took the lives of three men and seriously injured two others. Two workmen in Milwaukee were killed when methane seeping into a deep storm sewer trench ignited. In 1975, small buildings at two separate fills in Michigan suffered structural damage due to methane explosions, while in Vancouver, Canada a newly-poured foundation slab was structurally damaged by an explosion in the underslab air space initiated by a cigarette. The list of similar incidents is certainly much larger and continues to increase annually. Law suits are evolving around methane hazard and its effect on adjacent property value, public safety and health, and on vegetation stress.

LEACHATE

Leachate is liquid which has percolated through solid waste and emerges from a landfill carrying with it soluble and suspended substances. However, leachate production may be years in its initial showing and is not always produced from landfills. It requires substantial water infiltration (say 2 inches of water per foot of refuse thickness) to produce leachate at all. Leachate production will probably occur when annual rainfall exceeds 30 inches, and will probably be of no concern when less than 20 inches of rainfall occurs per annum.

The sources of water which ultimately produce leachate include rainfall which either infiltrates the refuse soil cover or flows off the surface of the disposal site. Some of the portion which infiltrates the surface will percolate into the solid waste below as net infiltration. Other sources of water infiltration include runoff from surrounding land, and water entering through the bottom or sides of the fill. The moisture created by waste decomposition is so little as to be of no impact. Obviously, liquid wastes placed in the landfill during landfilling may contribute to leachate production.

The first water entering the solid waste is absorbed much as a sponge absorbs water. Eventually, however, the solid waste reaches a level of moisture content known as field capacity. At this moisture content further addition of water causes leachate to leave the solid waste. Leachate is formed before the refuse is fully saturated because solid waste is not homogeneous, channels exist, and some of the waste does not absorb water readily. These factors may cause water to concentrate in some areas and create leachate even though all portions of the fill are not at field capacity.

Typically, leachate production should not be noticed until after the refuse has received at least two inches of net infiltration per foot of refuse thickness. Even then production should be limited, as the refuse still has the ability to absorb additional water before it reaches its maximum degree of saturation. If a landfill is well managed (good cover application, good drainage, uses impermeable soil cover, is dense and well compacted, etc.), then leachate production may not occur until well after the site is closed. This statement is applicable even in areas of high annual precipitation, and obviously true, almost without exception, where annual rainfall is less than 20 inches per year.

Although the landfills of the past were principally uncontrolled dumps and filling took place with little if any technical supervision, the cases of reported leachate damage are remarkably few. We are aware, however, of a few serious cases of environmental pollution as reported in the literature, and in addition must recognize that what was below ground and never measured may never be known. Today, and in the future, we will be required to determine the migration or control of leachate through monitoring systems. We expect that the sound engineering principals incorporated into current and future landfill design and operations will support upgraded performance standards. In some instances this will mean the leachate is encouraged to move outward from the refuse and seek attenuation in the surrounding soil and water environment. If the monitoring data supports the design predictions, then all is well and good.

A real dilemma may be in the offing as regulatory bodies and dischargers of chemical, toxic, and hazardous wastes apply pressures on landfill operators to accept these more difficult, non-municipal wastes. The operator finds a unique opportunity to increase revenues at the encouragement of regulator and disposer alike, who judge, rightly or wrongly, the landfill to be the best repository for these wastes. Now, however, think what will happen when monitoring data reveals an adverse parameter performance, and then another and yet another. What then will be the posture of the regulatory body? The discharger? And not the least, the public? What can the operator do?

Suppose, however, that the site receiving these wastes is a full containment site (no leachate migration), and that there is a continual building of leachate (net infiltration). Sooner or later the landfill will be fully saturated and the contained liquid must be properly handled. Again, the leachate will exhibit those characteristics which reflect the materials deposited therein. The cost of handling and treating may in fact far exceed the revenues received when the operator was thanking the regulatory body and discharger for the short-term revenue windfall.

The most important effect of uncontrolled leachate migration is water quality degradation, but there are other deleterious consequences. The effect on fish and/or plants in areas contaminated by leachate are often serious. Visual effects and malodor are two environmental impacts resulting from leachate.

SETTLEMENT

A sanitary landfill will settle as a result of waste decomposition, filtering of fines, superimposed loads, and its own weight. Bridging that occurs during construction produces voids. As the waste decomposes, fine particles from the cover material and overlying solid waste often sift into these voids. The weight of the overhead waste and cover material helps consolidate the fill, and this development is furthered when more cover material is added or a structure or roadway is constructed on the fill.

The most significant cause of settlement is waste decomposition, which is greatly influenced by the amount of water in the fill. A landfill will settle more slowly if only limited water is available to decompose the waste chemically and biologically. In Seattle, where rainfall exceeds 30 inches per year, a 20-foot fill settled four feet in the first year after it was completed. In Los Angeles, where less than 15 inches of rain falls per year, three years after a landfill had been completed a 75-foot-high area had settled only 2.3 feet, and another section that had been 46 feet high had settled a mere 1.3 feet. A demonstration grant we are currently completing in Sonoma County, California showed up to 20 percent settlement at the completion of stabilization by leachate recirculation. This settlement occurred even though the refuse was placed at a relatively high density of 1000 pounds per cubic yard.

Settlement also depends on the types of wastes disposed of, the volume of cover material used with respect to the volume of wastes disposed of, and the compaction achieved during construction. A fill composed only of construction and demolition debris will not settle as much as one that is constructed of residential solid wastes. A landfill constructed of highly compacted waste will generally settle less rapidly than one that is poorly compacted. If two landfills contain the same types of wastes and are constructed to the same height, but one has a waste-to-cover volume ratio of 1:1 and the other a ratio of 4:1, the one with the lower ratio will settle less.

Differential settling may form depressions that permit water to pond and infiltrate the fill. In Houston, Texas it is reported that a one to two-acre section of a completed landfill dropped one to three feet overnight. Settling may cause structures on the landfill to sag and possibly collapse; underground utility lines that serve buildings or traverse the site may shear. Settlements will continue for many years after the site is closed, and may be incident dependent, e.g., a sudden flood.

EROSION

Erosion results when sheet runoff of a covered landfill is non-uniform, and when the underlying cover soil is erodable (non-cohesive soil, devoid of vegetation, loose, etc). Differential settlement due to the decomposition of refuse material at different rates can lead to the redirection of surface drainageways which in turn collect water and lead to erosion of the cover material. The improper design or placement of drainage ditches, culverts, driveways, or streets may also lead to premature erosion of cover material and exposure of refuse. Wind erosion may also adversely affect the durability of landfill cover and must therefore be considered among the long-term maintenance problems. Gas migration may adversely stress erosion resistant vegetation, thereby indirectly fostering erosion.

PROPERTY VALUES

A landfill can impact significantly on land values in tangible as well as intangible ways. The value of a completed landfill may be on the order of 50 to 80 percent of the value of similar zoned adjacent property. The reason for the reduction is obvious: increased improvement and maintenance costs.

The impact on adjacent properties may be far more intangible. The mere potential of: (1) future malodors appearing, (2) future gas hazard, and, (3) unsightliness caused by vegetative stress, erosion and grade changes induced by settlement, are enough to have a negative effect upon property values.

VISUAL AESTHETICS

Aesthetics, in particular the visual aspects of a completed landfill, cannot be ignored as a potential long-term problem or even as the cause for a legal complaint.

NEED FOR QUALITY CONTROL

The foregoing discussion identifies the most prevalent problems which can surface subsequent to closure of a landfill. This is not meant to indicate that sanitary landfills are not a practical or economic means for the disposal of wastes. On the contrary, sanitary landfilling is the principal means for the disposal of the nation's waste. The point to be made is that a sanitary landfill requires careful planning and engineering to control potential problems.

Now let us examine what can be done in the way of preventive or remedial actions which should be taken to preclude post construction maintenance, decline in property values, or property damage and litigation. In each case it will be seen that preventive action taken during landfill design and construction is less costly than remedial steps taken after a landfill has been closed.

METHANE GAS CONTROL

There are three basic approaches to the control of methane gas: (1) control of the production, (2) prevention of migration by means of impervious barriers to flow; and, (3) venting.

Controlling rate of production, although technically feasible, is not practical at present. The future holds promise in (1) rapid stabilization of refuse through leachate recirculation which will result in a relatively early cessation of gas production, and (2) exhaust venting internally of the refuse limits thus drawing oxygen through the methanogenic bacteria environment. Since the oxygen is toxic to these microorganisms, this procedure will limit methane production.

Impermeable membranes consisting of natural clay; plastic, rubber, or similar film sheet; and asphalt can be utilized to control gas flow. Soil barriers are most effective when maintained at a high saturation level. Soils utilized for cover sealing, however, may develop cracks as a result of drying or large differential settlement occurring across the surface of the fill. For this reason, the thinner flexible polymeric membranes or reinforced rubber are often preferred for migration control. Barriers typically are best implaced during landfill construction, as subsequent installations are often costly, less extensive than required, and occasionally impossible to accomplish. During construction, barriers can be placed to cover the base and lateral surfaces of the fill space. Installation after fill completion might be limited to trenching in the area requiring protection and insertion of a membrane into the trench, followed by backfilling.

Venting systems may be either passive (relying on naturally occurring pressure or diffusion gradients) or induced exhaust (blowers are utilized to create a pressure gradient), the selection being dependent on site conditions. The passive systems rely on imposition of material of high permeability, such as gravel, in the path of the gas flow, the effect being to present a path for gas flow more conducive to flow than the surrounding medium, and thereby redirecting flow to a point of controlled release. These systems usually consist of a gravel blanket or continuous trench backfilled with gravel. Passive systems are most effective in controlling convective gas flow, less so in instances of diffusive flow. Since most of the flow is diffusion related the designer must judge the effectiveness of his selection based on the character of the flow regime.

Induced flow systems, particularly those employing suitably designed vertical wells, have proven very effective in the control of lateral migration, whether convection or diffusion induced. Typically these systems incorporate a series of vertical wells emplaced in large diameter bore holes not unlike those being considered in gas recovery (for fuel) systems. Wells are spaced at intervals along the margin of the landfill requiring protection, either located interior to the limit of fill, or externally in the surrounding native soils, depending on system requirements. The wells are connected by manifolding to a central exhaust blower which draws gas from the well field. The gas flow in the volume of refuse or soil influenced by each well is therefore toward the well, effectively controlling migration. Systems combining both recovery and migration control should be considered whenever practical.

Gases collected by exhaust systems are generally disposed of by direct stacking, incineration, or by passage through various sorption media. Gases from passive vent systems usually are allowed to direct discharge; in certain cases, the gases are combusted as in "tiki torches." In all instances, uncombusted gas must be exhausted at a location where it is not subject to careless ignition, generally in a protected enclosure, or above normal reach. Direct discharge may release noxious odors and the designer should always be prepared for a backup burner system to control odors, if objectionable.

The success of any control system is measured by a monitoring system throughout the gas production life of the landfill.

LEACHATE CONTROL

The objective of any leachate control system is to prevent the flux of landfill-produced contaminants to the groundwater and/or surface water regimes. Many soils have an ability to attenuate waste residues and thus reduce the contaminant flux to the hydrologic system. Where possible this natural ability of the soil to treat leachate should be employed. Where compatible with the environment and relevant regulations, it is by far the simplest and most economical method of leachate control. Many fine-grained moderately permeable silt and clay rich soils offer excellent potential for natural control of landfill-produced contaminants.

The slope of the water table indicates the general direction of leachate movement. The actual path may be influenced by other factors such as difference in specific gravity of leachate from water, variations and/or stratification of earth materials, the topography and elevation of the top of the zone of saturation, and by external factors such as streams that intercept the water table, and/or pumping wells. The third dimension, the vertical component of flow, must always be considered. Close to streams that receive groundwater discharge there may be an upward movement of groundwater. In such areas, the natural flow system controls the movement of leachate - extensive groundwater pollution is prevented but undesirable quantities of contaminants may reach the stream.

In situations where natural control systems are deemed to be insufficient, because of inadequate or poorly understood soil conditions, or for other reasons, facilities for leachate containment, collection and treatment may be developed, and in practice are imperative. Leachate control can be accomplished by controlling the generation rate and chemical composition, for example by design of the fill so as to minimize infiltration, by recirculation, by control of pH, and by full or partial containment through the use of liners.

The quantity of leachate produced, and thus the amount requiring treatment after collection, can be greatly reduced by careful site design and good management. By using a thick final cover of well compacted clayey soil graded to relatively steep slopes and well vegetated with erosion-resistant plants, it may be possible to reduce and perhaps preclude the production of leachate. The ultimate control would be to eliminate infiltration into the landfill by placement of an impermeable liner between the refuse and cover soil.

Waste may be deposited upon essentially impermeable in-situ soil or bedrock where careful bottom grading directs leachate along the bottom of the fill to suitable collection facilities. Handling and treatment of the leachate beyond the collection point requires a site specific design solution.

In recent years public concern over the pollution potential of landfill produced leachate has grown tremendously. As a result of this concern, and because of the difficulty in procuring the most desirable sites for landfill, there has been an increasing interest in the use of impermeable membranes or liners that will intercept leachate at the base of buried refuse and thus prevent it from entering the soil beneath the landfill site. Leachate thus intercepted must be collected and removed for treatment before release into the environment. A liner can be employed so as to utilize land for solid waste disposal that otherwise may be unsuitable from a hydrogeologic viewpoint. A liner of suitable material, carefully installed beneath the entire fill area, is a positive method of leachate control.

SETTLEMENT CONTROL

Subsidence in landfills has been tentatively determined to be a function of the initial compaction of refuse materials, compaction of refuse materials due to surcharge loads, volume reduction caused by biological decomposition of the organic constituents of the refuse, volume reduction caused by saturation, the nature of refuse materials such as compressibility, and volume reduction resulting from removal of leachable materials. Minimization of heterogeneity may be accomplished by mixing the refuse with inert material, addition of water to an optimum moisture content to facilitate compaction, and maximized compaction. Shredding and baling also contribute to volume reduction and therefore minimize settlement.

Leachate recirculation can greatly shorten refuse stabilization time, thereby inducing maximum settlement in minimum time. This approach lends itself to early use of the site for development purposes.

EROSION CONTROL

Erosion control measures include planting vegetation; use of mulches such as straw, hay, wood chips; soil stabilization, structural coverage, as well as energy dissipators and rip-rap protection for flowing water.

Planting vegetation is an important and effective method of preventing and limiting erosion, but vegetation alone will not provide adequate protection on soils that are unstable because of their structure, nutrient availability, internal water movement, or excessively steep slopes.

Mulch plays much the same role as vegetation - intercepting rain and preventing soil displacement by impact and retarding runoff. It also enhances viability of seedings by conserving soil moisture.

Soil stabilization includes compaction to increase relative density and the addition of gravel and clay to reduce erodability. Chemicals may also be added to the topsoil to reduce erosion.

Drainage channels or watercourses with steep gradients should be lined with suitable structural coverage - sod, concrete, asphalt, rip-rap, or gunnite.

VISUAL AESTHETICS

Landscaping, contouring, and general maintenance procedures are the principal means for controlling the appearance of a landfill. In addition to being aesthetically attractive, trees can also help prevent wind erosion.

PROPERTY VALUES

One problem that cannot be fully controlled at this time is the intangible problem of the impact of landfills on property values. The answer to this problem, however, is in the implementation of appropriate quality control techniques as discussed in the previous paragraphs. With proper quality control, landfills can become technically sound products and minimum degradation in property values should result.

CONCLUSION

The major point to be made in all of the foregoing is that a sanitary landfill requires careful planning, engineering, and design, plus sound operation to insure that long-term maintenance problems will not prove a source of liability. If properly designed and operated, a sanitary landfill can actually increase the value of surrounding land. When completed, properly designed and engineered landfill sites can be converted to community assets as parks, golf courses, green spaces, ski hills, and other attractive uses. What a community might otherwise consider an undesirable neighborhood liability can evolve into an attractive park or, in the case of a commercial/industrial development, a highly desirable taxable asset.

ECONOMICS OF LANDFILL LOCATION

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TRADITIONALLY, THE LOCATION OF LAND DISPOSAL SITES HAS BEEN PREDICATED ON TWO IRRATIONAL FACTORS; "OUT OF SIGHT, OUT OF MIND" AND "CHEAP LAND HOLDS DOWN DISPOSAL COSTS." WHILE THESE ATTITUDES HAVE STRONG PUBLIC APPEAL, THE LONG-RANGE COST MAY BE MORE THAN TAXPAYERS CAN OR SHOULD SUPPORT. ASSUMING ALL SITES UNDER CONSIDERATION ARE ENVIRONMENTALLY ACCEPTABLE, RATIONAL DECISIONS AS TO THE LOCATION OF NEW DISPOSAL SITES SHOULD BE BASED ON AN ECONOMIC APPRAISAL OF THE LONG-RUN COSTS.

IN RECENT YEARS, MANY COMMUNITIES OPTED FOR NEW SITES 15 TO 30 MILES FROM THE CITY. ALTHOUGH CITIZEN OPPOSITION AND THE PRICE OF LAND WERE LOW, THE DECISION REQUIRED THE CONSTRUCTION OF TRANSFER FACILITIES THUS INCREASING CAPITAL AND OPERATING COSTS. OTHER COMMUNITIES WITH CLOSE IN SITES ACQUIRED SHREDDING FACILITIES WITH THE IDEA OF INCREASING THE VOLUME OF SOLID WASTE PLACED IN A SITE. WHILE THIS DECISION MAY HAVE LENGTHENED THE LIFE OF THE SITE TO SOME EXTENT IT ALSO INCREASED TOTAL SYSTEM CAPITAL AND OPERATING COSTS SUBSTANTIALLY.

Recently, the Office of Solid Waste Management Programs (OSWMP) in EPA conducted a study of landfill, shredder, and transfer station costs.[1] Results indicated the price of land is such a small portion of total disposal costs, that paying a very high price for land adjacent to the community maybe a sound economic decision. This is especially true if the land can be acquired in lieu of transfer or shredder facilities.

Use of shredding or transfer facilities is an intermediate rehandling step between collection and disposal. The recent OSWMP examination of the costs of these processes indicated that:

- Shredding operations cost about $7.46 per ton of solid waste processed
- transfer operations cost $5.21 per ton, exclusive of collection, and disposal costs in 1975.
- The cost of land was less than 4 percent of solid waste disposal costs based on the 17 sites surveyed.
- In most instances paying a high price for land close to the center of waste generation or adding liners and leachate control will add less to the cost of waste management than would installation and operation of shredding or transfer facilities.

SW DISPOSAL COSTS ARE THE LOWEST COST ITEM IN MUNICIPAL SOLID WASTE MANAGEMENT

THE FOLLOWING TABLE OF 1975 SOLID WASTE COSTS SHOULD HELP SUBSTANTIATE THE FACT THAT LAND DISPOSAL IS THE LEAST COSTLY OPERATION IN SOLID WASTE MANAGEMENT IN MOST COMMUNITIES.

ITEM	COMMUNITIES REPORTING	AVERAGE COST PER TON
COLLECTION	102	$21.00[2]
SHREDDING (10-MILE HAUL)	7	7.46
SHREDDING ONLY	10	5.83
TRANSFER (17-MILE HAUL)	11	5.21
LANDFILLING MIXED SOLID WASTE	14	3.33
LANDFILLING SHREDDED SOLID WASTE	3	1.84

THE 17 LAND DISPOSAL SITES SHOWN ABOVE PLACED AN AVERAGE OF 380 TONS PER DAY. COSTS RANGED FROM $1.30 PER TON FOR ONE SHREDDED SITE TO $6.72 PER TON FOR A LOW TONNAGE SITE WITH HIGH ENVIRONMENTAL STANDARDS. THESE FIGURES INCLUDE LAND AND DEVELOPMENT COSTS BUT NOT INTEREST.

CAPITAL AND OPERATING COSTS FOR 17 PERMITTED LAND DISPOSAL SITES IN 1975

CAPITAL COSTS PER TON PLACED		OPERATING COSTS PER TON PLACED	
LAND	$ .13	LABOR AND FRINGES	$1.20
DEVELOPMENT	.13	STATIONARY EQUIPMENT	.04
STATIONARY EQUIPMENT	.01	VEHICLE O & M	.84
VEHICLES	.39	ADMIN. & OTHER	.31
TOTAL	$ .66	TOTAL	$2.39
			.66
			$3.05

LAND COSTS FOR THE ABOVE SITES AVERAGED 13 CENTS PER TON OF SOLID WASTE PLACED AND RANGED FROM .02 TO 39 CENTS PER TON. TYPICAL LAND COSTS REPORTED FOR NEWLY ACQUIRED LAND AVERAGED ABOUT $2,000 PER ACRE (RANGING FROM $163 TO $10,600). NATURALLY, THE DEPTH OF THE FILL, AMOUNT OF COVER, NON USEABLE LAND, AND SOIL COMPOSITION HAD AN EFFECT ON TONS PLACED PER ACRE. THE 17 SITES AVERAGED 16,400 TONS OF SOLID WASTE PER ACRE RANGING FROM 4,000 TONS IN FLORIDA TO 34,000 TONS IN CALIFORNIA.

DEVELOPMENT COSTS ARE ANOTHER IMPORTANT CONSIDERATION IN LOCATING A SANITARY LANDFILL. IN THE OSWMP STUDY CITED ABOVE, DEVELOPMENT COSTS FOR DESIGN ENGINEERING, PERMITS, ROADS, FENCES, LEACHATE COLLECTION, DRAINAGE, VENTING, AND OTHER ASSOCIATED COSTS AVERAGED .13 CENTS PER TON; THE SAME AS LAND COSTS. THE DEVELOPMENT COSTS RANGED FROM 0 TO 88 CENTS PER TON. BASED ON DATA COLLECTED, LOW PRICED LAND WAS NOT

ALWAYS THE MOST EXPENSIVE ITEM IN THE LOCATION OF A SITE. OFTEN A ROAD COSTING $80,000 TO $150,000 WAS NEEDED. SEVERAL CITIES REPORTED EXTENSIVE COSTS IN GETTING UTILITIES TO THE SITE OR HAD A CONSIDERABLE AMOUNT OF DRAINAGE TO DO BEFORE THE SITE COULD BE OPENED.

VALUE OF LAND IN RELATION TO TRANSFER COSTS. IN RECENT YEARS, MANY COMMUNITIES HAVE LOCATED SITES AT CONSIDERABLE DISTANCES FROM THE SOURCE OF WASTE GENERATION. THIS HAS MADE IT NECESSARY TO INSTALL ONE OR MORE TRANSFER STATIONS AND A FLEET OF TRACTOR TRAILER TRUCKS FOR MOVING SOLID WASTE TO THE SITE. MOST TRANSFER STATIONS HAVE BEEN JUSTIFIED ON THE BASIS THAT LOST TIME FOR COLLECTION VEHICLES IN NON ROUTE ACTIVITIES MORE THAN COMPENSATE FOR COSTS OF OPERATING A TRANSFER STATION. WHILE MOST TRANSFER STATIONS ARE JUSTIFIED, HAULING SOLID WASTE A LONG DISTANCE BY ANY MEANS IS A COSTLY OPERATION.

AVERAGE HAULING COSTS PER TON WERE ESTIMATED AT $2.70 BASED ON 10 SITES. THIS INCLUDES DRIVERS AVERAGE WAGES OF $5.00 PER HOUR AND 20 PERCENT FRINGE BENEFITS. ABOUT 52 CENTS OF THE PER TON COST WAS FOR VEHICLE DEPRECIATION. MOST TRANSFER FACILITIES USED TRACTOR TRAILER VEHICLES WITH A 30,000 POUND NET WEIGHT CLASSIFICATION. ON A MILE BASIS, COSTS WERE

ABOUT $1.36 FOR A 15 TON LOAD OR ABOUT 9 CENTS PER TON MILE. THIS MUST BE DOUBLED TO COMPENSATE FOR THE ROUND TRIP. THUS, EACH MILE CLOSER TO THE TRANSFER STATION THAT A DISPOSAL SITE IS LOCATED REDUCES TRANSPORTATION COSTS BY 18 CENTS PER TON. IF WE ASSUME A SITE HOLDS, 16,000 TONS PER ACRE, EACH MILE CLOSER TO THE TRANSFER STATION A DISPOSAL SITE IS LOCATED WILL REDUCE HAULING COSTS BY $2,280 PER ACRE OF LAND USED. THIS SAVING IN TRANSPORTATION COSTS COULD BE APPLIED TO THE PURCHASE OF MORE EXPENSIVE LAND CLOSER TO THE TRANSER STATION.

ANOTHER WAY TO LOOK AT HOW COSTLY AN INTERMEDIATE PROCESSING STEP LIKE A TRANSFER AND HAULING OPERATION CAN BE IS TO ASSUME VERY EXPENSIVE LAND COULD BE PURCHASED WITHIN THE CITY LIMITS IN LIEU OF A TRANSFER STATION AND LOW COST LAND 15 MILES AWAY. COST SAVINGS OF $5.21 PER TON FOR OPERATING AND CAPITAL COSTS OF THE TRANSFER FACILITY MULTIPLIED BY 16,000 TONS PER ACRE WOULD MAKE THE LAND WORTH $83,000 PER ACRE AS A DISPOSAL SITE. SIMILARLY ONE COULD JUSTIFY TAKING NEARBY LAND WHICH IS LOW PRICED OR SUBMARGINAL, AND MAKING IT ENVIRONMENTALLY SUITABLE FOR LANDFILLING BY INSTALLING LINERS AND LEACHATE CONTROL IN EXCHANGE FOR A LONG HAUL OR THE NEED FOR A TRANSFER FACILITY.

Other factors such as political and environmental considerations can negate the argument for disposal sites adjacent to the community. But, planners and decision makers should at least make an attempt to evaluate, on a long run cost basis, alternatives to transfer and long distance hauling of solid waste before reaching a conclusion on the location of disposal sites.

Value of land in relation to shredding

Shredding or the grinding of waste into uniform particle size is another alternative step for reducing landfill (land) costs. Advocates of shredding generally list high compaction, little or no cover material and vector control as primary justifications for shredding. Based on the 1975 OSWMP study of 7 shredder operations, with a 21 mile round trip haul to a disposal site, total costs were $7.46 per ton. Of this amount, $5.76 was for operating costs and $1.70 for capital cost excluding interest. The hauling costs of $1.47 per ton on a 21 mile trip basis, included drivers wages and fringes and were included in the operating cost.

There has been considerable amount of literature published in recent years on the use of shredding and high density compaction to extend the life of a disposal site. Most information indicates shredding can extend the life of

A DISPOSAL SITE BY 25 TO 33 PERCENT WHEN DAILY COVER IS USED AND UP TO 60 PERCENT IF DAILY COVER IS NOT REQUIRED. HEAVY DUTY COMPACTORS CAN INCREASE SITE LIFE BY 10-15 PERCENT. WHILE THESE CLAIMS MAY BE TRUE, IF THE LAND COST IS ONLY $ .13 PER TON PLACED, HOW MUCH ADDITIONAL CAPITAL AND OPERATING COSTS CAN OR SHOULD A COMMUNITY SPEND FOR BETTER UTILIZATION OF THEIR DISPOSAL SITE THRU SHREDDING AND HIGH DENSITY COMPACTION? ASSUMING A COMMUNITY CAN EXTEND THEIR SITE CAPACITY BY ONE THIRD THROUGH SHREDDING, THE VALUE OF THE LAND SAVED IS WORTH ONLY 6-7 CENTS A TON. ON LAND WORTH $10,000 PER ACRE THIS WOULD RESULT IN A LAND SAVING OF ONLY 30 CENTS PER TON WHILE COSTING ABOUT $5.83 PER TON FOR OWNERSHIP AND OPERATION OF THE SHREDDING FACILITY EXCLUSIVE OF THE HAUL COST.

DISPOSAL OF SHREDDED MATERIAL WAS LESS COSTLY THAN DISPOSAL OF CONVENTIONAL SOLID WASTE. THREE SITES PLACING ONLY SHREDDED MATERIAL REPORTED OPERATING COSTS OF $1.32 PER TON, AND CAPITAL COSTS OF $ .52 FOR A TOTAL OF $1.84 PER TON. THIS WAS 55 PERCENT LESS COSTLY THAN THE $3.33 FOR PLACING CONVENTIONAL WASTE. (THESE DATA INCLUDE LAND, AND EQUIPMENT DEPRECIATION BUT NOT INTEREST). HOWEVER, SEVEN OF

THE SHREDDER FACILITIES PLACED THE SHREDDED MATERIAL INTO A TYPICAL DISPOSAL SITE ALONG WITH DEBRIS FROM ALL OTHER SOURCES. THUS THE ADVANTAGES OF RELAXED STANDARDS FOR COVER MATERIAL AND VECTOR CONTROL WERE LOST. MOREOVER IN SOME CASES, THE ECONOMIC ADVANTAGE OF LOWER COSTS FOR A SHREDDED SITE WERE OFFSET BY THE NEED FOR OPERATING A SECOND SITE FOR NON-SHREDDED WASTES SUCH AS CONSTRUCTION DEBRIS, INDUSTRIAL MATERIAL, STUMPS, YARD MATERIAL AND BULKY ITEMS. THE OPERATION OF A SECOND SITE REDUCED ANY ECONOMY OF SCALE IN THE UTILIZATION OF EQUIPMENT AND LABOR ASSOCIATED WITH ONE LARGE DISPOSAL SITE.

ALTHOUGH SHREDDING IS A NECESSARY PART OF RESOURCE RECOVERY, SHREDDING PRIOR TO LAND DISPOSAL IS NOT NECESSARY AND CAN BE A VERY COSTLY OPERATION. USING A TOTAL CAPITAL AND OPERATING COST FOR SHREDDING OF $5.83 PER TON LESS $1.49 LOWER LAND DISPOSAL COSTS, THE NET COST OF SHREDDING IS $4.34 PER TON. ASSUMING THE TYPICAL LAND DISPOSAL SITE WILL HOLD 16,000 TONS PER ACRE AND THE WASTE WAS NOT SHREDDED, COST SAVINGS TO THE COMMUNITY WOULD EXCEED $69,000 PER ACRE BURIED. THIS COST SAVINGS COULD BE USED FOR THE PURCHASE OF NEW OR ADDITIONAL LAND OR LINERS FOR SUBMARGINAL LAND.

IN RECENT YEARS MANY COMMUNITIES HAVE BEEN UNDER PUBLIC PRESSURE TO IMPROVE THEIR SOLID WASTE MANAGEMENT PRACTICES. IN MANY INSTANCES THEY REACTED BY CONSTRUCTING SHREDDER FACILITIES AND TRANSFER STATIONS, AND LOCATING LAND DISPOSAL SITES LONG DISTANCES FROM THE SOURCE OF WASTE GENERATION WITHOUT CONSIDERING THE LONG RUN ECONOMIC COSTS. IN MANY INSTANCES (1) PAYING A HIGH PRICE FOR LAND CLOSE TO OR WITHIN THE CITY; (2) INVESTING CAPITAL IN LINERS AND LEACHATE CONTROL ON SUBMARGINAL LAND OR (3) ANNEXING LAND TO THE CURRENT DISPOSAL SITE THRU EMINENT DOMAIN WOULD HAVE BEEN SUBSTANTIALLY THE LEAST COSTLY ALTERNATIVE ASSUMING ENVIRONMENTAL ASPECTS ARE EQUAL.

TOLEDO, OHIO WAS CONFRONTED WITH THE PROBLEM OF LOCATING A NEW DISPOSAL SITE. AFTER CONSIDERATION OF MANY SITES AND ALTERNATIVES, TOLEDO ARRIVED AT WHAT WE BELIEVE WAS THE CORRECT DECISION. THEIR NEW 160 ACRE SITE IS LOCATED WITHIN THE CITY LIMITS. IT IS SERVED BY TWO MAJOR HIGHWAYS AND 17 ACRES ARE SET ASIDE FOR A SHREDDING FACILITY IF AND WHEN A MARKET FOR THE WASTE BECOMES REALITY. IN PURCHASING THE LAND, IT WAS NECESSARY TO ACQUIRE 28 RESIDENCES ON 55 PARCELS OF LAND. MUCH OF IT THRU EMINENT DOMAIN. AVERAGE LAND COST WAS $10,600 PER ACRE. BASED ON AN ESTIMATED PLACEMENT OF 28,000 TONS PER ACRE IN A 35 FOOT DEPTH, LAND COSTS WILL BE APPROXIMATELY 38 CENTS PER TON.

THIS IS A VERY LOW SOLID WASTE DISPOSAL COST WHEN CONSIDERED AGAINST OTHER ALTERNATIVE COSTS IN SOLID WASTE MANAGEMENT.

IN SUMMARY, DECISION MAKERS SHOULD EVALUATE THE LONG RUN CAPITAL AND OPERATING COSTS FOR ALL PHASES OF THEIR SOLID WASTE MANAGEMENT SYSTEM IN LIGHT OF THE FACT THAT LAND AND LAND DISPOSAL OF SOLID WASTE MAY BE ONE OF THE LOWEST PRICED VARIABLES IN THEIR OVERALL SOLID WASTE SYSTEM.

1/ COST ESTIMATING HANDBOOK FOR TRANSFER, SHREDDING AND SANITARY LANDFILLING OF SOLID WASTE. 85 P. BOOZ ALLEN AND HAMILTON. AUGUST 1976. PRINTED COPY $5.00 PB-256-444-1WP. NATIONAL TECHNICAL INFORMATION SERVICE, U.S. DEPARTMENT OF COMMERCE, 5285 PORT ROYAL ROAD, SPRINGFIELD, VIRGINIA 22161

2/ EVALUATING THE ORGANIZATION OF SERVICE DELIVERY IN SOLID WASTE COLLECTION AND DISPOSAL. SAVAS, E.S.; COLUMBIA UNIVERSITY, OCTOBER 1975.

GROUNDWATER PROTECTION ISSUES

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The subject of groundwater protection has become a very important issue in solid waste management. Various methods of protection have been described and evaluated.

The various strategies might be summarized as follows:

I. Separation

A. Distance:

This implies physical distance such that the native soil will have a chance to attenuate the potential pollutants. The efficiency of such separation is obviously dependent on many factors among which is the type of soil itself.

B. Barriers:

The implication here is that the barrier be installed on-site before the waste is discharged. The barrier may consist of a number of materials that have been very well described by Haxo[2], among which are:

1. Selected soils
2. Plastic membranes
3. Asphalic derivations
4. Portland cement derivations

II. Monitoring

A. Wells

The use of wells in strategic locations within and around the periphery of the landfill is a well established practice.

The detection capability of such a system is very helpful in giving warnings or alaying fear (whichever is the case) with respect to the apparent migration of leachate from the refuse mass.

B. Under drains

With the advent of the wider use of the barriers mentioned earlier an accompanying system of collection drains is often considered. The justification for such a system is to:

1. Assist in the detection of a break or leak in the barrier.
2. To provide a means of collection and extraction of any potential pollutants before they can migrate away from the site.

It is the ability to not only detect the presence of a possible source of trouble but to do something in a positive way to prevent any subsequent damage or danger that is the most important feature of an acceptable design.

The attenuation of various metal ions by the soil has been investigated and discussed by Fuller[1]. In addition to the heavy metals and other ions mentioned in his investigation there is the question of the attenuation of some of the chlorinated hydro carbons and various pesticides and herbicides which may be placed in a hazardous waste fill. It would be a reasonable assumption to say that the various factors which were stated by Fuller would probably apply to these more complex materials as well. However, considering the risks involved, we should understand their behavior more thoroughly and additional research should be conducted on the attenuation and migration of these materials.

Much has been reported in the literature on the biological activity within the solid wastes placed in a landfill. Some of this information has been based on research on refuse placed in a lysimeter where conditions can be monitored and controlled. Other work has been carried out in landfill cells in a more natural setting with conditions being monitored but with less ability to maintain them in a designated condition. We also have information on sewage sludge digestion both anaerobic and aerobic which may or may not be applicable to solid waste decomposition.

A basic question needs to be considered with respect to the biological degradation of solid wastes. Under normal conditions this process is a natural one which serves to reduce the volume of the waste and to return it to a stable form which possesses less threat to the environment. In the process gases and various liquids containing organic acids and other solubolizing components are formed. These may give rise to problems of themselves. However, the question I raise is that of the presence of toxic materials being disposed of along with the normal mixed municipal refuse. What happens if the toxic materials interfere with the development of the bio-mass which is usually counted upon to produce the aerobic and anaerobic decomposition of the material to stabilize it? If biological action is not materially interfered with it has been shown by several investigators that the toxic substances are made much more mobile by the products of decomposition and will migrate much more forcely. It has been recommended therefore that toxic substances not be mixed with biodegradable organic materials in the same location within the sanitary landfill.

III. Construction

In the development of hazardous waste fills, or sanitary landfills in general for that matter, in some locations liners have been required. As experience is gained by those who are using various lining methods their successes and problems should be brought out for the benefit of all. Haxo[2] has described the research directed toward evaluating the performance of several liner types. There is a need for developing a standardized methodology for testing liners in such a way as to more accurately predict their performance under expected landfill conditions. An established set of standards would also allow the prospective user to specify and subsequently receive a predictable product.

Due to the limited time wherein data gathering and experience with various liners has been possible we are unable as yet to predict accurately the life of such liners. However, based on the knowledge that plastics have a long life in landfills there is every confidence that several liner materials will provide the protection necessary. As practioners we should ask for as candid a report on the application of these methods to be made public in as short a time as possible.

We have long been accustomed to being governed by various regulations set forth by established regulatory agencies at all levels. The requirements as set forth in these regulations are usually set at such a level as to provide the necessary protection or performance in the best judgment of the group formulating the regulation. This minimum requirement is often translated into the maximum provided without regard to the possibility that corrective measures that may be required later may be much more inconvenient and expensive than some foresighted additional provisions beyond those required being provided at an earlier time.

Such a precautionary situation may be illustrated in conjunction with the problem of gas (CH_4) migration from a landfill. It is most certainly cheaper to install gas barriers and the necessary venting prior to completing the landfill construction than to have to return to the site in an emergency situation to correct a problem which has subsequently developed.

We should continue to request and support research on the conditions which influence and determine the production and migration of gas so that the need for protective measures can be more accurately anticipated and the necessary precautionary measures taken before damage or injury occurs.

Fuller[1] has made mention of the use of some natural materials such as nut shells for the initial fixation of certain heavy metals. There are other natural materials such as tree bark or wood chips which are resistant to degradation and contain lignon that should have an attraction for heavy metals which might be useful for such a purpose. It should be noted that these materials have a specific retention capacity and when that is exhausted they will no longer retain more metals. The quantity of these natural materials necessary, therefore, must be determined based on the anticipated amount of heavy metals to be attenuated from the leachate expected to be generated from the material in the landfill. Any method which is successful in reducing the amount of leachate will assist in prolonging the time of effective attenuation.

In conclusion it is my observation that the field of solid waste management is moving rapidly towards a much more sophisticated level where a great deal of technical information is required. The only way that this type of information can become widely enough available to all who need it is for those who are in a position to gain it through practice or research to pass it along freely through organizations such as the NSWMA.

REFERENCES

1. Fuller, W. H., "The Importance of Soil Attenuation for Leachate Control," Proceedings 5th National Congress NSWMA, Dallas, December, 1976.

2. Haxo, H. E., Jr., "Liners-Viable Options and Their Applications," ibid.

EFFECTIVE STATE PROGRAMS

THE IMPORTANCE OF AN EFFECTIVE STATE SOLID WASTE MANAGEMENT PROGRAM

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The need for capable systems of management for solid wastes is finally being realized by the people of our country. The "findings" of the U.S. Congress and the developments in every state are proofs that these activities are properly located in state government. These recognized needs, findings, and developments acknowledge the importance of an effective state solid waste management program.

The elements in consideration here are: 1) Is it important (of much significance or consequence) that we have an effective (adequate to accomplish the purpose) program for the management of the detritus from our effluent society ? and 2) Is the state somehow the best suited or most appropriate level of government to conduct such an important function? Let's begin with why it's important to have an effective solid waste management program tho, it hardly seems necessary for the group assembled at the Fifth National Congress on Waste Managment.

Proper management of solid wastes is a requirement for our national well being. There is sufficient evidence at hand to recognize that improper practices in the solid waste field endanger human health. We know of the environmental degradation that results from solid waste incorrectly managed. And, further, we now appreciate the waste of resources and energy which we have allowed with our "throw away" life style.

We have, as a nation, somewhat belatedly come to recognize the vast quantity of material that is discarded. Whether you use five pounds per person per day, a thousand tons per person a year, include or exclude certain sources, the sheer mass is staggering. Just to accomodate this pile we are using space or acreage that in most instances could be better used in other ways. The successes in air and water pollution control are adding to the solid waste problem. Things that used to go up the stack or down the drain are commonly special problem additions to the land disposal burden.

Incineration of the combustible part of the waste stream has been a serious air pollutor which requires large capital outlays to correct. The production of leachate from dumped or buried trash is a well recognized threat to ground and surface waters. Methane migration from landfills is a continuing and perhaps, increasing problem. Since open burning has been stopped to protect air quality more organic material is decomposing in landfills increasing the possibility of the hazards of uncontrolled gas migration.

Where the methane can be captured it can be a useful resource. This idea of recovering resources is only scratching at the surface of its potential, however. The big picture is one of tremendous waste - of resources and energy. A country made great, in large part, by seemingly boundless resources and cheap energy can no longer afford the throw away style of life. We are running out of domestic sources, importing more and adversely effecting the nation's balance of payments. The costs, the savings to be realized, the tons of materials, dollar values, etc. etc. are too familiar to this audience to need repeating here.

Enough has been said, where it probably needed no reminder, about the importance of an effective solid waste management program. Health, environment and economy require it. The element perhaps less accepted and certainly not as abundantly reviewed in literature, press and professional conference is the appropriateness of the concentration of program effort at state level.

Last year, at the Fourth Congress, Moses McCall in his report on "The Role of the State in Solid Waste Management" said "the state level this is 'where it's at' program wise". He further observed that state governments have the obligation of assuring that local governments provide for efficient, environmentally sound solid waste services for their inhabitants, either by the public or the private sector.

There are a tremendous number of local governments. In New York State, for example, there are approximately 1600 units of local government. Most local governments represent small populations, limited territories, narrow economic bases and frequently, part time government. They most commonly have neither resources or capacities to carry out an effective solid waste management program within their own jurisdiction.

At the opposite end of the government scale is the Federal establishment. The Federal government has provided a very limited solid waste management program, especially as compared to their entry into air and water pollution control activities. This is quite appropriate in recognition of the relative uniqueness of the states. Their variation in size, physical land characteristics, geology, economic development, and population distribution; all of which influence solid waste management, point to the level below the Federal as most appropriate. This also agrees with the concept that governemnt should be as close to the governed as the desired effect will allow.

Further support for keeping the management program below the Federal level derives from the nature of the solid waste problem in as much as it doesn't commonly accumulate to become ar interstate and international problem as is often the case with air and water pollution. In apparent recognition of these several arguments the Congress in its "findings" in the Resource Conservation and Recovery Act of 1976 said ".... the collection of and disposal of solid wastes should continue to be primarily the function of State, regional and local agencies,....".

There is a strong theme throughout PL94-580 in support of State solid waste management programs. The appearance of such terms as "providing technical and financial assistance to State and local government", "Authorization of State Programs", and "Authorization of Federal Financial Assistance" are indicators. The amounts of the authorized funds for support of State programs and planning is adequate proof that the Congress intends to create effective solid waste management programs at the state level.

To be effective the programs must provide results. They must safeguard the health and welfare of the people, protect the environment and conserve and recover resources and energy. It requires complete programs to accomplish such difficult goals. The complete program regulates, assists and leads. State programs must include these functions to achieve results.

The USEPA "Solid Waste Management Strategy" recognizes the importance of effective State solid waste management programs. In Mr. Train's letter of October 31, 1974 introducing the strategy and included in the document he says, " A further element which we believe is integral to a viable waste management and resource conservation program is a strong and effective State and local program". And further, he states, "Greater attention by EPA will be required to assist States and local governments.....". The Strategy itself, makes the statement,."This strategy relies heavily on the States". The strategy document and Mr. Train's letter say that EPA is attempting to "strengthen the State role" and "will assist States in developing their programs".

Testimony is support of the need for effective solid waste management and recognition of the appropriate role of the State is provided by the following summary comments.

Ten years ago only two states had administrative programs in solid waste; now all do. That all the States have reconized and accepted this responsible role is significant. These state programs could not have come to pass in our democratic system without support of the people, including local government entities which by their support have placed themselves under the jurisdiction of the state program. The United States Environmental Protection Agency in its "Solid Waste Management Strategy" and that Agency's Administrator, Mr. Russell Train, recognize the importance of the State programs and declare the intention to assist and to strengthen the role of the State. And, finally, in both importance and time, the United States Congress, has passed a progressive act PL94-580, which directs the intention of the Federal Government to support and assistance of State programs for solid waste management.

The urgency for adequate means and mechanisms to be brought to bear on the solid waste management problem is not debatable. We all recognize the significance to human health, environmental protection and resource conservation. We know that Federal, State and local governments each have important functions in the solid waste management task. Each has a piece of the action. The starring role, however, as we have now seen, is actually and appropriately being played by the State.

In summary, the importance of an effective state solid waste management program is substantial, is recognized and is being supported by words, deeds and dollars.

GOVERNMENT RESOURCE RECOVERY PLANS

RHODE ISLAND SOLID WASTE MANAGEMENT CORPORATION

TOWN HALL PRESENTATION QUESTIONNAIRE RESPONSE

Considerations for implementing resource recovery in Rhode Island

I. Material supply

A. Tonnage-We are presently considering a 1200 ton per day design figure.

B. Collection-Each jurisdiction in the state is responsible for the collection of its own raw solid waste. The Solid Waste Management Corporation has no authority to involve itself in the collection of waste.

C. Delivery of solid waste to the facility- The Corporation will seek binding contracts with municipalities to guarantee tonnage to a resource recovery facility.

D. Waste Characteristics-The waste to be delivered to the facility will not have any special characteristics that should be noted.

II. Facility Funding

A. Financing Options - -The Corporation can employ a variety of funding options including revenue bonds, private capital, and other approaches. We cannot, however, employ general obligation bonds.

B. Indebtness Limitations-No such limitations are imposed in our legislation.

III. Economics of Existing Disposal Methods

A. Operating costs-The Corporation does not at present operate any facility.

B. Affect of Existing Disposal Economics-Rhode Island probably enjoys the cheapest landfill operating costs in this part of the country. This is attributable to the competitive nature of the private landfill business in the state. We feel, however, that the remaining life of the existing privately owned landfills is a key factor. The Corporation was created by the state and given its mandate to establish a statewide resource recovery system because it is foreseen that landfilling cannot be considered a long term solution. There is only one operating municipal incinerator in the state, and the costs of operating this facility are thought to be in excess of $10 per ton.

C. Remaining Years of Use of Existing Facility-Our estimate of the remaining life of the landfills presently approved by the Health Department, is 5 to 7 years. This could be optimistic, however, as environmental standards become more stringent and more rigidly enforced.

D. Environmental and Other pressures affecting existing disposal methods - The state health department has recently enacted a new licensing program which will place more stringent controls over the operation of disposal facilities. It should also be noted that several municipalities have enacted local ordinances prohibiting importation of out-of-town waste, thus limiting the regional use of state approved landfills in several instances.

IV. Resource Recovery Systems Choices

A. At present we have not eliminated any significant technology for consideration in our R.F.P.

V. Energy and materials markets

A. Markets identified based on preliminary evaluation of our market study results indicate that there is a strong market possibility for steam, pyrolysis gas and oil, and electricity. The potential market for refuse derived fuel in simple or processed form is still being explored.

B. Potential Markets for Materials-In the same manner we feel that there is a good potential market for light and heavy ferrous metals, and aluminum and other non-ferrous metals. No determination has as yet been made regarding glass, paper fibers or other materials.

VI. Other institutional, legal concerns

A. Institutional-Legal Concerns-

Under Section 13 of the legislation establishing the Solid Waste Management Corporation, any municipality in the state that seeks to dispose of its municipal waste beyond its own borders must use a facility or arrangement designated by the Corporation. The Corporation has already started exerting this control over the disposal of waste, and is presently negotiating contracts with 6 municipalities whose wastes are being sent to a privately owned landfill under the auspices of the Corporation. Through this program we are now collecting a surcharge from these municipalities.

B. Contract Period-The Corporation can legally enter into long term contractual commitments.

C. The state role-The R.I. Solid Waste Management Corporation is a quasi-public state agency and as such does act for the State. The Corporation's plans, as is the case with any state agency, must be reviewed in terms of compliance with an overall State Guide Plan.

:kam

Middlesex County, New Jersey

RESOURCE RECOVERY FACT SHEET

BACKGROUND

MIDDLESEX COUNTY'S ACTIVE INVOLVEMENT IN SOLID WASTE MANAGEMENT BEGAN IN 1972 WHEN THE COUNTY PLANNING BOARD OBTAINED A GRANT FROM THE U.S. ENVIRONMENTAL PROTECTION AGENCY TO PREPARE A COMPREHENSIVE SOLID WASTE MANAGEMENT PLAN AND PROGRAM FOR THE COUNTY.

REFUSE QUANTITIES:

IN 1975

- OVER 1 MILLION TONS OF SOLID WASTE WERE GENERATED IN MIDDLESEX COUNTY.
- 1.7 MILLION TONS WERE DISPOSED OF IN MIDDLESEX COUNTY; 40% IMPORTED FROM OUTSIDE OF THE COUNTY, INCLUDING 300,000 TONS OF REFUSE FROM NEW YORK CITY.
- 60% OF THE COUNTY'S REFUSE IS FROM INDUSTRIAL SOURCES; 40% IS FROM MUNICIPAL (HOUSEHOLDERS, ETC.) SOURCES.
- MIDDLESEX COUNTY IS THE 2ND LARGEST REFUSE SHED IN NEW JERSEY, AFTER THE HACKENSACK MEADOWLANDS.

BY 1985

- POPULATION GROWTH, INCREASED EMPLOYMENT, INCREASED REFUSE IMPORTS WILL RAISE THIS DISPOSAL FIGURE TO OVER 2.5 MILLION TONS/ YEAR, OR OVER 8,000 TONS/DAY.

COSTS:

IN 1975

- THE COUNTY'S MUNICIPALITIES AND INDUSTRIES SPENT APPROXIMATELY $20-25 MILLION ON REFUSE COLLECTION AND DISPOSAL.
- 80%+ FOR COLLECTION AND HAULING; LESS THAN 20% FOR DISPOSAL.

BY 1985

- THESE COSTS MAY DOUBLE TO $50 MILLION ANNUALLY.

REMAINING DISPOSAL CAPACITY AND COSTS

* AT PRESENT MIDDLESEX COUNTY CONTAINS 8 REGIONAL-SCALE LANDFILLS AND 10 SMALL MUNICIPAL-TYPE DISPOSAL SITES.
* FIVE OF THESE SITES (FOUR PRIVATE) RECEIVE 80% OF THE TOTAL REFUSE DISPOSED OF IN THE COUNTY.

* BY 1980, THREE OF THESE, INCLUDING THE COUNTY'S LARGEST LANDFILL, WILL EXHAUST THEIR PRESENT CAPACITY.

* BEFORE 1985 ONLY ONE OF THE COUNTY'S EXISTING REGIONAL LANDFILLS WILL REMAIN; ALTHOUGH THE REMAINING CAPACITY OF THIS SITE IS EXTENSIVE, THIS SINGLE SITE WILL NOT BE ABLE TO ACCOMODATE THE REFUSE REQUIRING DISPOSAL IN 1985.

* AS A RESULT, FOUR NEW LANDFILLS CONTAINING OVER 600 ACRES OF LAND WILL BE NEEDED IN THE COUNTY BY 1985. BY THE YEAR 2000, 13 NEW LANDFILLS CONTAINING A TOTAL AREA OF ALMOST 2,000 ACRES WILL BE NEEDED TO MEET THE COUNTY'S REFUSE DISPOSAL NEEDS.

* ALTHOUGH IMPROVED OPERATING PRACTICES AND INCREASED DESIGN HEIGHTS (TO 60 FEET) MAY REDUCE THE NUMBER OF DISPOSAL SITES AND TOTAL ACREAGE REQUIREMENTS SOMEWHAT, THE SITES THAT WILL OPERATE WILL BE MUCH LARGER IN AREA AND OPERATING LEVELS THAN ANY PRESENTLY IN OPERATION IN THE STATE.

* LAND FOR THESE NEW SITES WILL HAVE TO BE FOUND NOT FROM MEADOWLANDS AND OTHER ''UNUSABLE'' AREAS, BUT FROM PRIME INDUSTRIAL AND COMMERCIAL LAND NEAR REGIONAL HIGHWAYS.

* THESE SITES WILL ALSO BE LOCATED IN LESS DEVELOPED SUBURBAN AREAS REMOTE FROM CENTERS OF REFUSE PRODUCTION. AS A RESULT, HAULING COSTS WILL GO UP AND SO WILL THE COST OF ACQUIRING, DEVELOPING AND OPERATING TRULY SANITARY LANDFILLS. THE POTENTIAL IMPACT OF NEW REGIONAL LANDFILLS ON COMMUNITY DEVELOPMENT, ENVIRONMENTAL QUALITY AND LOCAL TRANSPORTATION PATTERNS COULD ALSO BE SUBSTANTIAL.

THE PROSPECT OF THIS TYPE OF ''MAXIMUM LANDFILL STRATEGY'' IS NOT APPEALING TO OUR BOARD OF FREEHOLDERS AND OTHER PUBLIC OFFICIALS IN MIDDLESEX COUNTY.

<u>RESOURCE RECOVERY</u>

FORTUNATELY, THE PLAN ALSO CONCLUDES THAT ANOTHER MORE WORKABLE ALTERNATIVE EXISTS - RESOURCE RECOVERY.

* THE SOLID WASTE DISPOSED OF IN MIDDLESEX COUNTY THIS YEAR CONTAINS THE ENERGY EQUIVALENT OF OVER 2 MILLION BARRELS OF FUEL OIL.

* IT ALSO CONTAINS ENOUGH FERROUS METALS TO SUPPLY A SMALL STEEL MILL FOR A YEAR.

* IT CONTAINS LARGE QUANTITIES OF NON-FERROUS METALS, SUCH AS ALUMINUM AND BRASS, AND NEARLY 30,000 TONS OF GLASS.

* AT PRESENT FUEL PRICES THE ECONOMIC VALUE OF THE COUNTY'S MUNICIPAL REFUSE ALONE IS OVER $8 MILLION PER YEAR. IF WE ADD CREDITS FOR THE ''NON-DISPOSAL'' OF THIS REFUSE, ITS VALUE INCREASES TO OVER $9 MILLION PER YEAR.

* THESE ENERGY RESOURCES AND RAW MATERIALS ARE VALUABLE AND SHOULD NOT BE LOST.

THE PLAN

* IN RESPONSE, THE PLAN RECOMMENDS THE DEVELOPMENT OF A MIXED SYSTEM OF RESOURCE RECOVERY FACILITIES AND SANITARY LANDFILLS TO RECOVER THE MAXIMUM FEASIBLE QUANTITY OF ENERGY AND MATERIAL RESOURCES CONTAINED IN THE COUNTY'S SOLID WASTE AND PROVIDE SAFE, SANITARY AND ECONOMICAL DISPOSAL OF THOSE MATERIALS THAT CANNOT BE RECOVERED.

* SPECIFICALLY, THE PLAN RECOMMENDS THE DEVELOPMENT OF 2-3 LARGE-SCALE RESOURCE RECOVERY FACILITIES IN THE URBAN PORTIONS OF OUR COUNTY BY 1980-85 AND THAT THIS SYSTEM BE EXPANDED TO THE RAPIDLY GROWING SUBURBAN AREAS AS SOON AS POSSIBLE THEREAFTER.

* EACH OF THESE INITIAL FACILITIES WOULD PROCESS 1,000 - 1,500 TONS/DAY OF SOLID WASTE AND MAY COST APPROXIMATELY $30 MILLION EACH.

* BY 1981 AS MUCH AS 60% OF THE SOLID WASTE DISPOSED OF IN THE COUNTY COULD BE PROCESSED FOR RESOURCE RECOVERY.

* INCREASED ENERGY PRICES AS WELL AS THE INCREASED COST OF NEW LANDFILLS WILL MAKE RESOURCE RECOVERY COMPETITIVE WITH THESE CONVENTIONAL DISPOSAL METHODS BY 1980.

* THE PLAN RECOMMENDS THAT THE FACILITIES BE CONSTRUCTED AND OPERATED BY PRIVATE INDUSTRY AND THAT A COUNTY IMPROVEMENT AUTHORITY BE CREATED TO FINANCE THEM.

THE PLAN WAS COMPLETED IN DECEMBER 1974 AND ACCEPTED BY OUR BOARD OF FREEHOLDERS IN MARCH 1975. SINCE THAT TIME A NUMBER OF IMPORTANT STEPS HAVE BEEN TAKEN TOWARD THE IMPLEMENTATION OF THIS PLAN:

1) THE DEPARTMENT OF SOLID WASTE MANAGEMENT PROGRAMS WAS ESTABLISHED IN APRIL 1975. THE DEPARTMENT IS DIVIDED INTO THREE PROGRAM AREAS: RESOURCE RECOVERY, HAZARDOUS WASTE MANAGEMENT AND TECHNICAL ASSISTANCE.

2) A PERMANENT POLICY ADVISORY COMMITTEE ON SOLID WASTE MANAGEMENT WAS ESTABLISHED IN MAY 1975. THIS GROUP CONSISTS OF LOCAL ELECTED OFFICIALS, REPRESENTATIVES OF THE PRIVATE SOLID WASTE INDUSTRY, THE REGION'S INDUSTRIAL WASTE PRODUCERS, ENVIRONMENTAL GROUPS, AND REPRESENTATIVES OF THREE ADJACENT COUNTIES. THIS GROUP ADVISES THE FREEHOLDER BOARD AND OUR DEPARTMENT ON ALL ASPECTS OF SOLID WASTE MANAGEMENT PLANNING AND PROGRAMMING IN THE COUNTY.

3) THE COUNTY APPLIED FOR AND WON IN JULY 1975 AN ENERGY RECOVERY IMPLEMENTATION GRANT FROM THE U.S. EPA TO BEGIN TO IMPLEMENT THE RESOURCE RECOVERY PORTION OF THE PLAN. THE FOLLOWING PROGRAM ELEMENTS WERE INCLUDED:

- A DETAILED ANALYSIS OF THE MARKETS FOR RECOVERED ENERGY AND MATERIAL PRODUCTS.
- A DETAILED ECONOMIC, ENGINEERING AND ENVIRONMENTAL ASSESSMENT OF EMERGING RESOURCE RECOVERY TECHNOLOGIES.
- AN ANALYSIS OF ALTERNATIVE FINANCIAL AND MANAGEMENT APPROACHES INCLUDING THE QUESTION OF PUBLIC OR PRIVATE OWNERSHIP.

- AND A DETAILED SITE SURVEY

4) A PROGRAM MANAGER FOR RESOURCE RECOVERY, DR. EDWARD JABLONOWSKI, WAS EMPLOYED IN JULY 1975. IN AUGUST OF THAT YEAR A CONSULTANT, ROY F. WESTON, INC., WAS SELECTED BY THE PAC AND CONFIRMED BY THE FREEHOLDER BOARD TO ASSIST IN THE PROGRAM TASKS.

5) A DETAILED REQUEST FOR SYSTEMS DEVELOPMENT PROPOSALS WILL BE ISSUED IN LATE 1976 AND THE INITIAL SYSTEM(S) SELECTED IN MID-1977.

6) THE FIRST RESOURCE RECOVERY FACILITY IN THE COUNTY MAY BE UNDER CONSTRUCTION IN THE NORTHERN AREA OF THE COUNTY BY 1978 AND IN FULL OPERATION BY 1980-81.

7) THE POSSIBILITY OF COMBINING THE RECOVERY OF ENERGY RESOURCES FROM MUNICIPAL REFUSE AND THE DISPOSAL OF SEWERAGE SLUDGE FROM THE MIDDLESEX COUNTY SEWERAGE AUTHORITY AT A FACILITY IN THE CENTRAL AREA OF THE COUNTY IS CURRENTLY BEING STUDIED, UNDER CONTRACT, BY PROFESSOR HELMUT SCHULZ OF COLUMBIA UNIVERSITY.

RICHMOND METROPOLITAN AREA RESOURCE/RECOVERY PLAN

by
C.F. Wilkinson, P.E.
Director of Public Works
City of Richmond

and

M.E. Fiore, P.E.
Virginia Branch Manager
Roy F. Weston

BACKGROUND

The City of Richmond, as well as many other localities throughout the country, is attempting to solve two problems, disposal of solid waste and conserving natural resources, with one decision. Richmond hopes to do this by burning solid waste to generate steam and then recovering ferrous and non-ferrous metals from the incinerator's residue.

The Richmond Metropolitan area (Figure 1) has a population of over 500,000 people living in the City of Richmond and the separate counties of Henrico and Chesterfield. A diversified industrial and commercial base supports this population and has resulted in continued strong growth and development in the region.

As the State Capital, the City is the center of the State political scene. It is located almost midway between Washington, D.C. and the Norfolk-Tidewater areas - - two of the fastest growing areas in the country. The City has established itself as a strong and progressive industrial and financial center. While considered by many as the tobacco capital of the world, the City has a diversity of industrial and commercial activity which has contributed to Richmond's reputation as a recession-free City. In addition to stable industries, $200 million dollars of new construction is underway in the Richmond area, including a $50 million dollar Federal Reserve Bank. These factors added to the approximately 60,000 government employees who work in the Richmond area help to create a financially secure and stable area.

The pressures of growth have had their impact on solid waste management in the area. Although sanitary landfills have served the area well in the past, their capability for future disposal is limited. Currently, three landfills are operated by the City of Richmond, two by the County of Henrico and two by the County of Chesterfield. Sanitary landfilling has been and is the principal method of disposal in this area. Consultants estimate that present landfills will be depleted in ten to fifteen years (Figure 2)

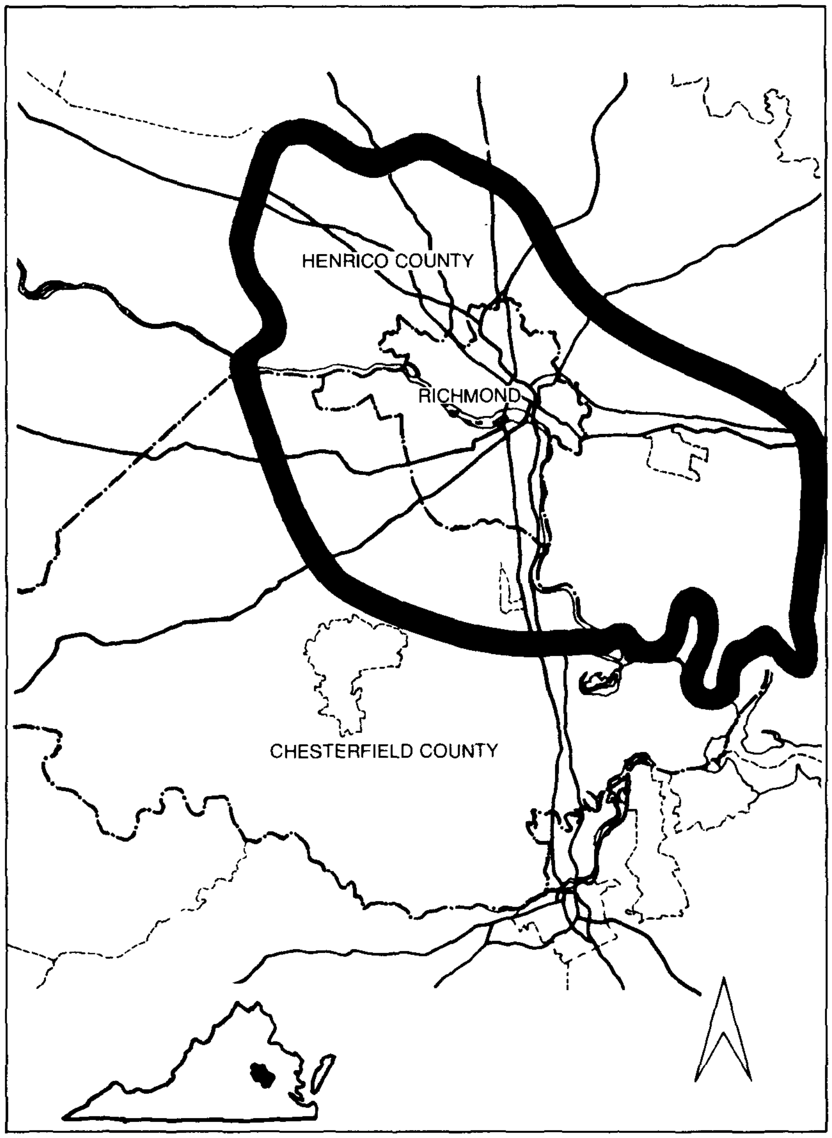

FIGURE 1 RICHMOND METROPOLITAN AREA

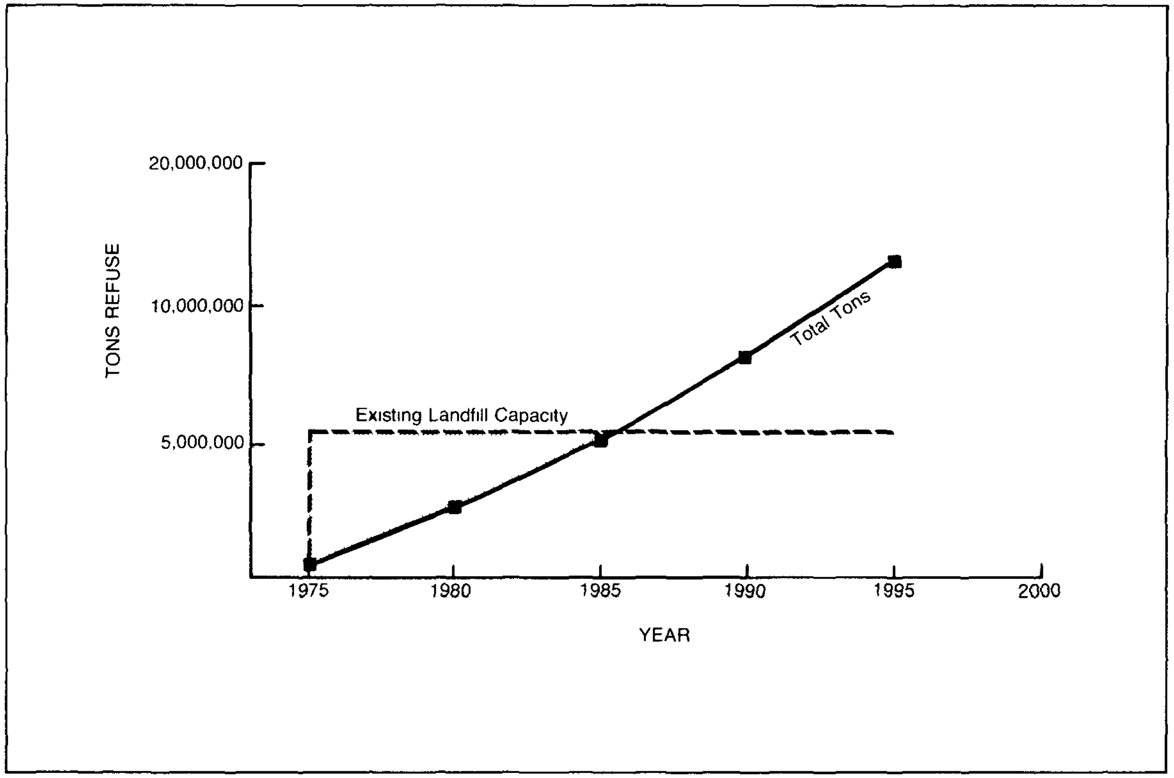

FIGURE 2 EXISTING LANDFILL CAPACITY

and that potential additional space will be depleted shortly thereafter because of the projected increase in volume of solid waste. Restrictions on available sites, limitations on potential sites, and increased environmental and operating costs are eroding the usefulness of sanitary landfilling as the sole method of disposal in the region. This is particularly true in the long run.

TASK GROUP FORMED

The Richmond Metropolitan Area can ill afford to face further years without a solution to the solid waste problem. To provide a permanent, long range plan, the Solid Waste Utilization and Task Group was formed in 1973, representing the City and two counties in the region plus the Commonwealth of Virginia; the Virginia Electric and Power Company; Reynolds Metals Company; and Wheat, First Securities, Inc. The group has embarked upon a program to find and implement solutions to the area's solid waste problems.

The formation of the Task Group alone indicates the significant local commitment that exists within the region. To reinforce that commitment, the Task Group obtained a pledge of funds from the local governments to initiate the Resource Recovery Program.

One of the first tasks of this group was to visit other cities (such as Nashville and St. Louis) with Resource Recovery Projects. After observing these operations, a subcommittee of the Task Group was assigned to prepare a request for proposals to be forwarded to consultants with experience in Resource Recovery. This work was accomplished, and the proposals were received in the fall of 1974 from eight consulting firms. After detailed analysis and discussion, Roy F. Weston, Environmental Consultants-Designers, was selected for the Phase I Study. Actual work began in June 1975.

FUNDING

The Solid Waste Program was divided into several phases with Phase I being totally funded by the local governmental agencies participating in the Program (see Figure 3). During its Phase I effort, the City, in behalf of the Task Group, applied for and received a federal grant to finance a continuation of the program, Phase II. The Task Group felt especially fortunate in receiving this grant because only seven other cities received grants from EPA to investigate implementation of an energy recovery systems.

Work of Phase I was initiated in June 1975 and was essentially completed in May 1976. Phase II of our program is now underway, and we anticipate completion by mid-1977. The total cost of Phase I and Phase II will be $118,000.

TASK	1975	1976	1977	1978
Start Phase I Study	●			
Begin Phase II Grant Application	●			
Meet with EPA Relative to Work Plan		●		
Complete Technical Alternatives		●		
Prepare Executive Summary		●		
Approve Initiation of Phase II Effort		●		
Complete Phase II Work Plan		●		
Submit Work Plan for EPA Approval		●		
Start Phase II Program		●		
Complete Phase II Program			●	
Begin Phase III Program			▬	▬

FIGURE 3 PROGRAM SCHEDULE

PHASE I--PROGRAM OUTLINE

The Phase I work plan included collection and validation of all existing field data, field evaluation of existing systems, in-depth interviews with local officials, and discussions with local operating agencies and State regulatory agencies to permit the project team to become familiar with the existing solid waste system in the area. Existing State and local regulations, ordinances, administrative structures, the legal framework, and unique social, economic, and political character of the area were reviewed. Available markets for by-products generated by a resource recovery program were assessed, concentrating on potential users of secondary materials, particularly paper, glass, ferrous and non-ferrous metals. A review of energy and fuel needs in the metropolitan area, including an inventory of existing facilities for power generation, fuel storage and distribution, and major users of both fuel and energy, was performed. Using this information, processing alternatives were identified and evaluated using the present system of sanitary landfilling and its potential for the future as the basis for economic comparison. The total evaluation included the cost and facility requirements of waste transportation and waste transfer as well as the processing and disposal for it.

PHASE I--SURVEY RESULTS (Table 1)

The materials and energy survey indicated that local and regional markets did exist for products produced from a potential Richmond area Resource Recovery system. Letters of interest were received from local materials markets indicating interest in ferrous and non-ferrous metals as well as in paper. (See Figure 4.) No local market for glass recovery was indicated, other regional markets outside the region are available and may be developed as part of a subsequent phase.

A detailed energy market survey was completed using questionnaires and interviews to establish intent and interest. Figure 5 shows the scope of the energy markets we sought.

The Energy Survey indicated strong interest by industrial and utility organizations in purchasing a competitively priced gaseous or liquid fuel; electricity and steam are also saleable commodities. A solid refuse fuel (RDF) proved to be the least desirable of all potential energy or fuel forms for our local markets. Required equipment modifications, storage and handling costs, and air pollution control concerns all may be reasons for this lack of concern.

TECHNOLOGY ASSESSMENTS

An assessment of the existing technology was prepared for the Task Group to identify technical options which offer potential for the region. Technical options capable of producing energy and materials that were saleable

POTENTIAL MARKET	PAPER	FERROUS METALS	NON-FERROUS METALS	
			Aluminum	Other
Federal Paper Board	X			
Reynolds Aluminum			X	X
Frank H Nott, Inc		X	X	X
Peck Iron and Metal		X		
Smith, Iron and Metal		X		
Annual Potential Tonnage (1975)	27,660	29,412	3,458	

TABLE 1 SIGNIFICANT POTENTIAL RESOURCE MARKETS
Richmond Metropolitan Area

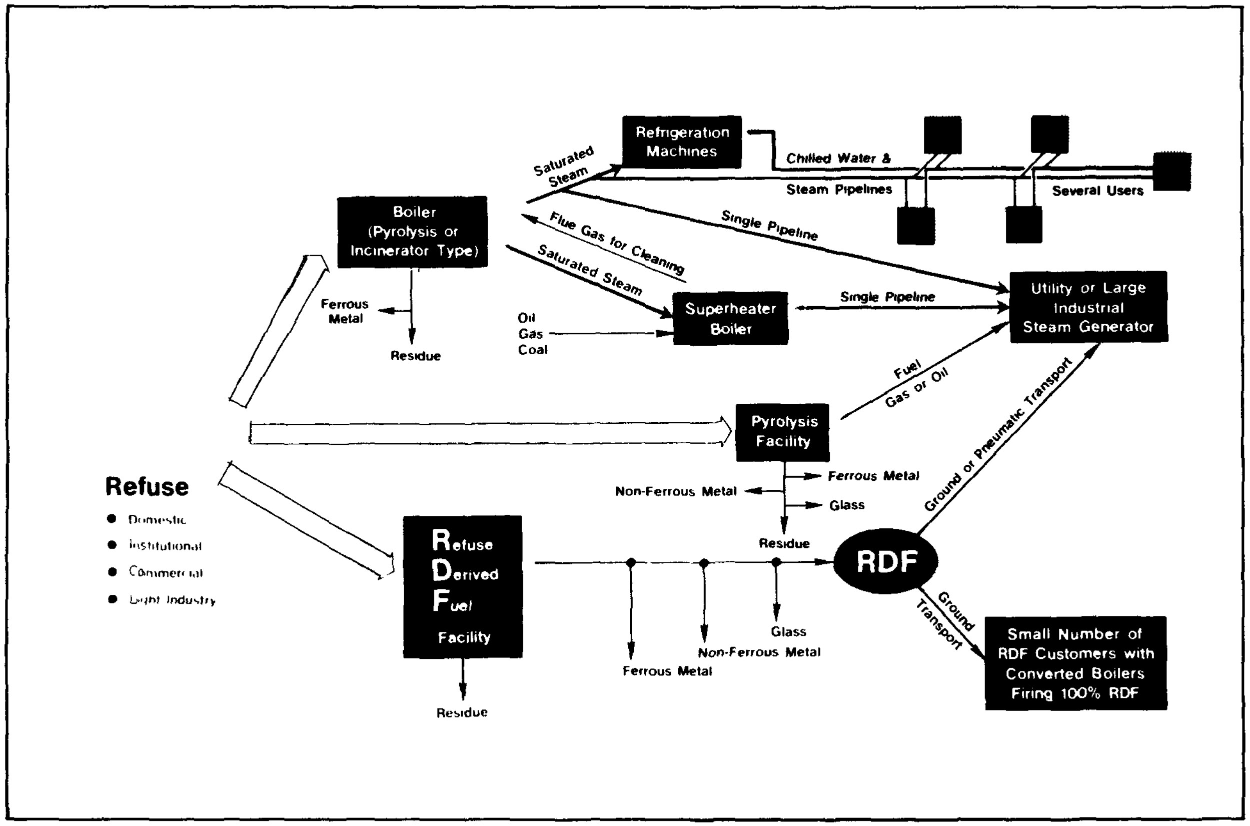

FIGURE 4 OPTIONS FOR ENERGY & ASSOCIATED MATERIALS RECOVERY FROM MIXED MUNICIPAL REFUSE

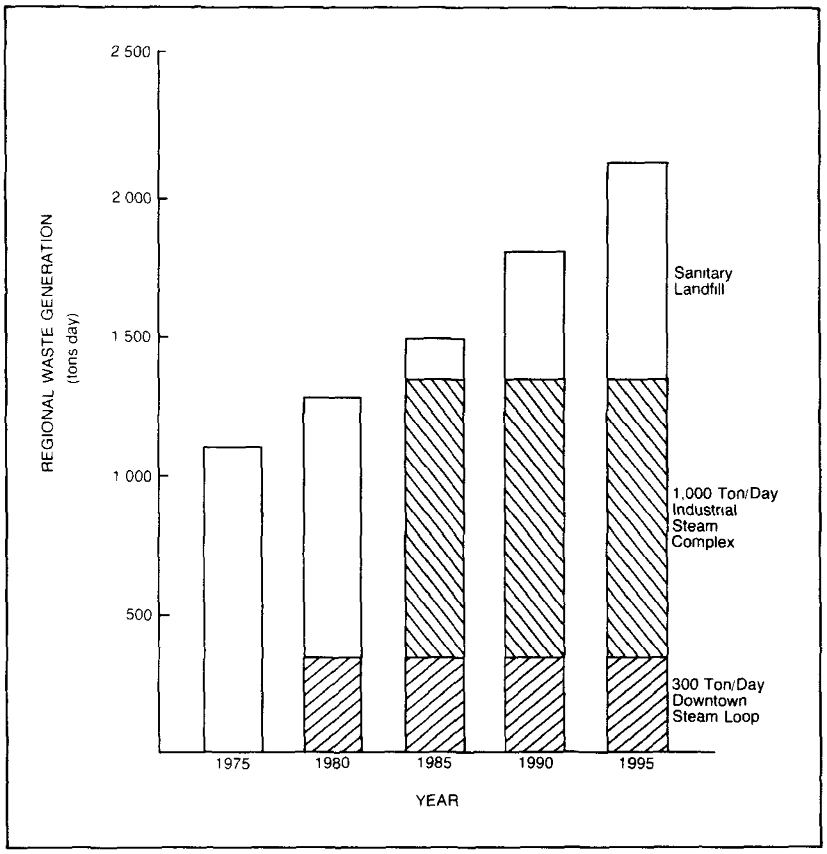

FIGURE 5 FUTURE WASTE MANAGEMENT SYSTEM WITH SANITARY LANDFILLING AND ENERGY RECOVERY

to the local markets were emphasized. A comparison of options was made, based upon market compatability, demonstrated reliability, full scale operation, capital and net operating costs, environmental concerns, and applicability to the local situation. Technologies evaluated included energy recovery incineration, pyrolysis, preparation and sale of an RDF, materials recovery, and alternative methods of land disposal, including shredding and baling of refuse.

Based upon reliability, technical soundness, and cost, we determined that steam produced by energy recovery incineration should be the leading candidate for implementation. Three markets for this steam exist in the metropolitan area and are currently being studied. These markets are the Richmond Downtown Steam Loop, an industrial complex south of the regional area, and the Chesterfield Power Station of the Virginia Electric and Power Company (VEPCO). The Downtown Steam Loop and the industrial complex offer the best potential for long term implementation, while the power station offers a market with declining needs because of VEPCO's conversion from fossil-fired to nuclear power plants.

It should be noted that comparing energy recovery alternatives with sanitary landfilling still shows significant economic advantages for landfilling. The problem with the availability and location of landfill sites, however, would indicate that the selection of a waste menagement system cannot be made solely on the basis of costs. For that reason, the regional study to implement a resource recovery system is still underway. Regardless of what system is used, however, sanitary landfilling will still be a functioning part of any solid waste management system. Figure 5 indicates the regional sanitary landfill needs if energy recovery can be implemented successfully.

ENERGY MARKET DEVELOPMENT

One of the two energy markets which appears most feasible is the Downtown Steam Loop. The Steam Loop in downtown Richmond, presently served by the Medical College of Virginia (MCV) power plant, has a seasonal steam demand that varies from approximately 20,000 pounds per hour (summer) to 130,000 pounds per hour (winter). This system provides steam to the existing loop that services MCV, the Capital District, and several other State, Federal and City buildings. (See Figure 6.)

Steam and energy demands coupled with operational and cost considerations resulted in a waste-management concept using refuse to supply a portion of the steam demand. A refuse facility with the capability of providing 60,000 lbs/hr of steam could be used as a base load steam plant. The existing MCV power plant would be maintained to supply steam during peak demand periods, thus conserving fuel and perhaps eliminating the need for the planned expansion of that facility. In addition, the refuse/steam

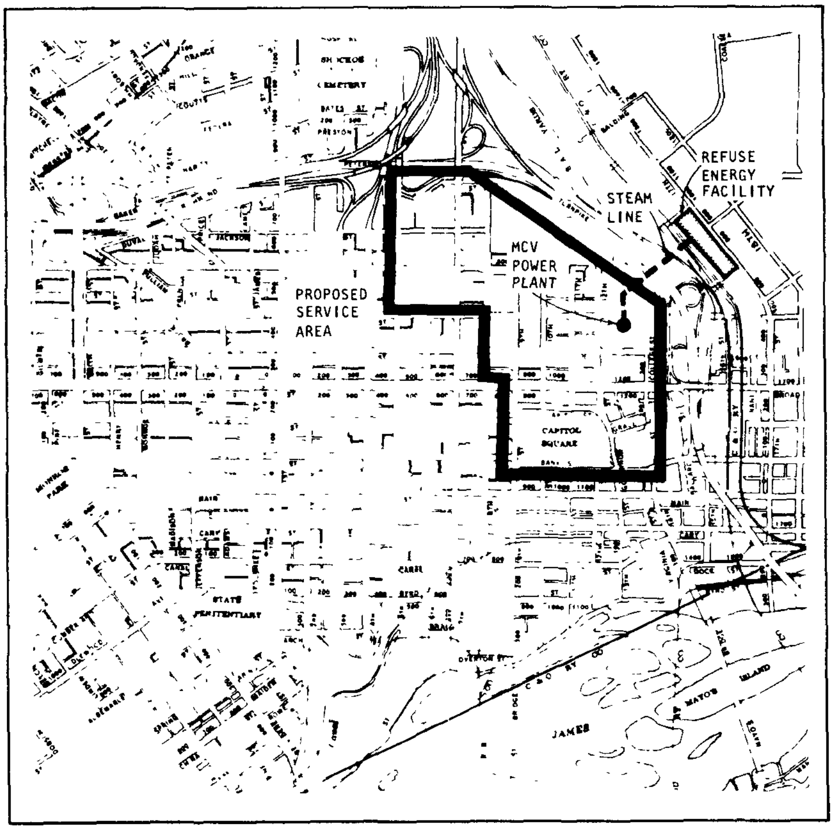

FIGURE 6 DOWNTOWN STEAM LOOP

plant could be readily expanded to serve future downtown area development. If future building utilities were designed to use the steam loop, greater economies in operation of the refuse system could be achieved.

The second feasible market for steam produced from refuse is the Bermuda Hundred Industrial Complex. The area is composed of a cluster of four steam-intensive industries located in the Bermuda Hundred area of Chesterfield County. It has a combined continuous steam demand of 200,000 to 300,000 pounds per hour. The industries have shown a preliminary interest in refuse steam. Steam of appropriate pressure and quality would be purchased from the system at a price negotiated after comparison with present energy cost. A conventional water-wall incinerator boiler system has been proposed to generate the 200,000 to 300,000 pounds per hour of steam required at the Bermuda Hundred Complex.

ENERGY SYSTEM OPTIONS

Two system options are being considered for implementation. First is the modular concept which uses preengineered, prefabricated systems which can be stacked to obtain the desired capacity. Significant cost advantages appear to be available if this concept is workable for a regional-scale facility (300 to 500 tons/day). The second system option is the more conventional water-wall incinerator design approach, using large incinerator/boiler units specifically sized, engineered, and built to specific design criteria. An evaluation of these concepts is being prepared as part of a subsequent study. The cost advantage of the modular concept can best be illustrated by reported net operating costs for a 300 ton/day facility which approaches $2.00/ton. A similarly sized conventional system could be expected to have a net operating cost of greater than $5.00 per ton. Although these costs do not include some specific site and equipment costs such as land, utility distribution, and feed water treatment, the costs are comparable and justify the need for further investigation.

TRANSPORTATION CONSIDERATIONS

The location of potential regional processing and disposal sites and the distance that wastes must be hauled for disposal are significant costs to a regional system. With Downtown Richmond considered as approximately the center of waste generation in the study area, the Downtown Steam Loop concept requires almost no adjustment to existing hauling routes. The Burmuda Hundred area, however, would require hauling waste distances of 20 to 25 miles in addition to a waste transfer station. For transportation costs alone, the Bermuda Hundred alternative then may cost the region $4 to $5 per ton more to operate annually.

PHASE I--CONCLUSIONS

In general, the Phase I study concluded:

1) Steam energy is the most marketable energy commodity in our area.

2) Materials recovery has local market interest and applicability to the technical alternatives evaluated.

3) The Downtown Steam Loop and the industrial complex are our primary energy market for implementation.

4) The Downtown Steam System offers economic advantages because no extraordinary hauling costs will be required.

5) The Downtown Steam System cannot supply a market for all regional refuse generated and that the industrial complex alternative must be developed in a total management system.

6) Recovery of ferrous and non-ferrous metals from incinerator residue is compatable with the alternatives evaluated for implementation and with the economic goals of the Richmond area.

PHASE II--PROGRAM

Based on these conclusions, the Task Group recommended authorization of the energy recovery alternatives. The local governments approved the Phase II program without any additional funding required. Accordingly, the City executed a contract with the consultant, Roy F. Weston, and work began on Phase II in September 1976. This study is expected to establish system capacity, system cost, revenue structure, energy distribution cost, indirect cost, institutional arrangements, cost sharing, and the administration and implementation schedule.

The emphasis of our Phase II effort is more institutional then technical. While answering some technical questions, the program will deal mainly with those questions asked most often by local decision-makers. These are questions generally asked: Who will own and operate the system? How will costs be allocated? How will we guarantee that our wastes are delivered to the facility? What are our options for procuring a system? What are our financial options? and How much will it cost?

To answer these questions, the Phase II program includes the following tasks:

Market Development

A more specific development of local energy and materials market including discussion of costs, revenues, and commitments. We anticipate that letters of commitment will be the output of this task from each market.

Waste Ownership

With private collectors doing a majority of the refuse collection in our neighboring counties, it is vital that we know how to assure that the refuse will be delivered to our regional resource recovery facility. A review of ordinances and our collection system will result in changes that may be necessary.

Institutional Arrangements

Who owns and operates our regional facility will be the outcome of this task.

System Procurement

A variety of procurement methods has become available in recent years for municipalities looking toward implementing a resource recovery system. We will investigate our jurisdictional and regional flexibility in procuring these systems and, if justified, consider changes to our procurement procedures.

System Development

Additional technical evaluation will be required to understand the options available to the region. Also, further evaluation of the modular and conventional approaches to energy recovery will be done. Field visits to operating systems will be made to further evaluate operating concepts before a decision is made.

RFP

A request for proposal will be prepared and sent to qualified bidders to supply an energy recovery system to serve the Richmond Metropolitan Area and the energy markets identified.

The Phase II program will be more concerned with those aspects of implementation that involve decision-makers. For that reason, a subcommittee approach is now being used. Each major task has a subcommittee made up of task Group Members with specific interest or background for that study task. The consultant will work directly with each subcommittee. This will facilitate the transfer of information and involve the Task Groups a little more deeply in the decision-making process.

The decision-making process will function continuously throughout the study program. As outputs are generated, they will be presented to the Task Group which will evaluate, comment and direct legislative and administrative thinking toward implementation needs. When these steps have been completed, the decision-making process can be finalized, and a plan of action can be established. Final coordination of political subdivisions will be required to obtain concurrence. The consultant will present this information as an executive summary, a report, which will be used to obtain jurisdictional approval to begin the Request for Proposal stage, establish the implementing agency/procedures, and initiate jurisdictional agreements.

As a final effort for this phase of the project, a brief request for proposal will be prepared by the consultant: this will outline the program and its objectives and invite qualified bidders to respond with their proposal for facilities, services, and costs.

When the request for the proposal is completed, estimated to be in June 1977, it is hoped that most questions relating to implementing a system will have been resolved. Then it will be possible to begin construction and thereby provide an essential Weston management solution for the Solid Waste Management needs of the Richmond Metropolitan Area.

Department of Public Works
Richmond, Virginia
September 24, 1976

QUESTIONNAIRE

CONSIDERATIONS FOR IMPLEMENTING RESOURCE RECOVERY

I. Materials Supply -
   A. Annual Tonnage - 400,000
   B. Who controls collection of wastes:
      1. City of Richmond
      2. County of Henrico
      3. County of Chesterfield
      4. Private collectors

   C. How to assure delivery of wastes -
      1. Legislation must be developed and/or contracts prepared.
      2. It is likely competitive dump charges would be considered.

   D. Wastes have no special characteristics.

II. Facility Funding -
   A. Capital Funding Options
      1. Revenue bonds
      2. In dustrial authority bonds
      3. Private capital
   B. Yes - We had a legal bonded indebtedness limit.

III.
   A. Present Operating and amortization costs -
      1. Landfilling - $4.00/ton dumping fee
      2. Incineration - none

   B. No, since landfill space is being rapidly depleted.
   C. Remaining landfill life -
      Chesterfield County:
         Chester - 5-7 Years
         Bon Air 1.25 Years
      County of Henrico:
         Springfield Road 12 years
         Nine Mile Road 1.5 Years

      City of Richmond
         East Richmond Road - 8 Years
         Fells Street - 1.5 Years
         Maury Street - 2 Years
   D. New landfill sites in Richmond are non-existent and zoning is very restrictive in the counties.

IV. Resource Recovery Systems Choices:

A. (1) Feasibility studies indicate our best choices to be steam generation in two locations with ferrous recovery from residue.

(2) None existing

B. Refuse derived solid fuel preparation was determined not feasible due to no existing markets in region.

V. Energy and Materials Markets:

A. Do you have readily - available markets for the following:

1. Steam - yes
2. Refuse - derived fuel - No.
3. Natural gas - Yes
4. Fuel Oils - Yes
5. Electricity - Yes
6. Other - No.

B. Do you have available markets for the following:

1. Light ferrous metals - Yes
2. Heavy ferrous metals - Yes
3. Aluminum - Yes
4. Other non-ferrous metals - Yes
5. Flint glass cullet - No.
6. Color sorted glass cullet - No
7. Color-mixed glass fines - No
8. Glass - aggregate - No
9. Recovered paper fibers - Yes
10. Inert Residue - No.
11. Other - no.

VI. Other Institutional legal concerns:

A. No decision has been made on the type institution to operate the facilities. The transporting of refuse across governmental boundaries and ownership must also be resolved.

B. Long term contracts would be contingent on the eventual form of institution.

C. The system must meet state rules and regulations for design and air and water pollution. A permit must be issued and inspections will be made by State.

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APPENDIX

NSWMA Institute of Waste Technology

The National Solid Wastes Management Association's Institute of Waste Technology (IWT) was established in June of 1974 to assist government and industry by offering technical and planning expertise in all aspects of waste management. Representatives of private waste service firms, resource recovery companies, landfill operators and engineers, public officials, and researchers serve on the Institute's major committees:

- Chemical Waste Committee
- Industry Resource Recovery Committee
- National Sanitary Landfill Committee

NSWMA Waste Equipment Manufacturers' Institute

The NSWMA Waste Equipment Manufacturers' Institute (WEMI) formed in 1972, is comprised of 73 leading U.S. manufacturers of wastes handling equipment. Five major equipment committees of WEMI are:

- Incineration and Thermal Energy Systems Committee
- Landfill Equipment Committee
- Mobile Equipment Committee
- Processing Equipment Committee
- Stationary Compaction Equipment Committee

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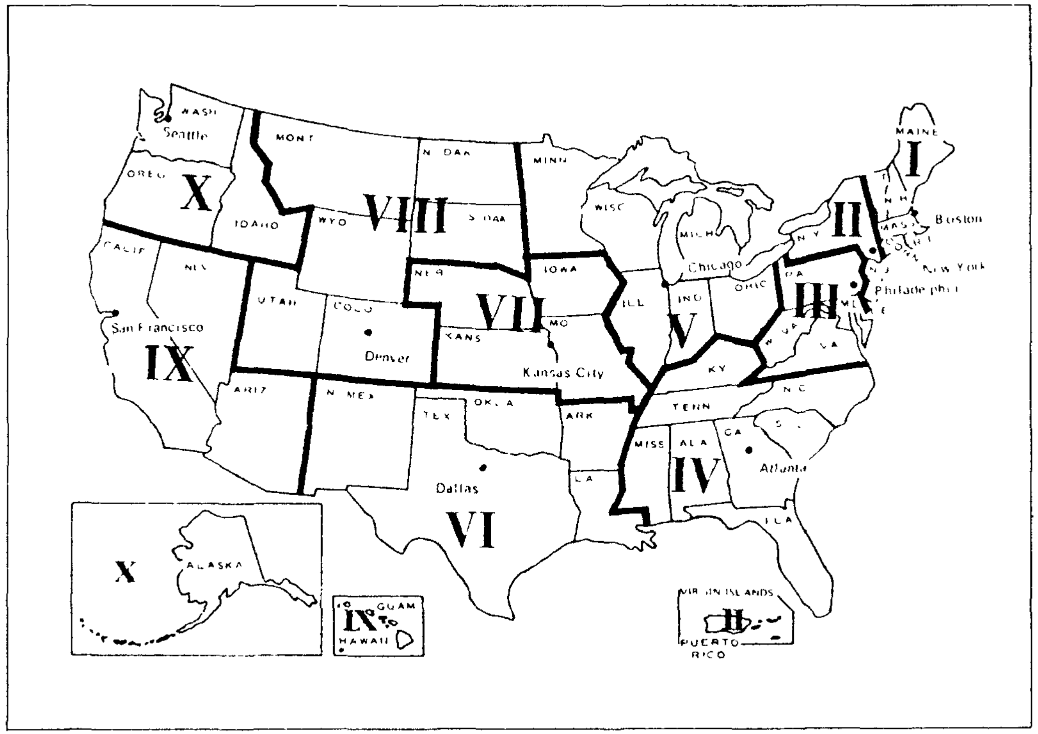

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