First United States Conference on Municipal Solid Waste Management

Solutions for the 90s

Proceedings
Volume II

June 13 - 16, 1990
(Wednesday p.m. - Saturday p.m.)

Ramada Renaissance Tech World
Washington, D.C.

**Sponsored by
The U.S. Environmental
Protection Agency**

Office of Solid Waste

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RECYCLING AND COMPOSTING

ADVANCES IN COLLECTING PLASTICS

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Presentated at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

Acknowledgment

Much of the material in this paper was presented at the American Institute of Chemical Engineers Conference in San Francisco in November 1990. Partial funding for the original presentation and paper was provided by the Center for Plastics Recycling Research at Rutgers University.

ADVANCES IN COLLECTING PLASTICS

INTRODUCTION

Plastic soda bottles and milk jugs are increasingly common components of municipal recycling programs, and recyclers are examining the feasibility of recycling different types of plastics such as colored HDPE bottles and other rigid plastic bottles. However, it is still unclear whether plastics, with their low weight to volume ratios, are cost effective to recycle. Thus, there has been much interest in methods to densify plastic materials onboard recycling vehicles. This paper discusses curbside collection costs, evaluates several on-truck systems for densifying plastics and concludes that perforator compactor systems warrant further study.

IMPACT OF PLASTICS ON RECYCLING SYSTEMS

The low density of plastics and the high number of serving units involved can raise the costs of collecting, sorting and processing plastics. And although plastic soda bottles and milk jugs command relatively high prices on a per ton basis, they contribute little to recycling program revenue due to their low density. Plastic soda bottles and milk jugs account for only 4 per cent of the weight while making up 36 per cent of the volume of material collected in Rhode Island.

Mixed rigid plastic bottles are present in most American municipal waste streams in amounts equal to or slightly greater than the amounts of plastic soda bottles and milk jugs. However, revenue will be lower for this less desirable feedstock than for soda and milk bottles. As discussed below, in certain cases, adding plastic containers can raise collection costs by a significant margin.

Revenue RI Recycling Facility

Four Months --

January 1990 through April 1990

Material	Revenue	% of Total	$/Ton
newspaper	$ 15,222.36	4.02	0.5-7
corrugated	0.00	0.00	0.00
clear glass	57,348.12	15.14	50-65
brown glass	16,237.00	4.29	30-50
green glass	16,483.00	4.35	20-40
pl milk j	26,056.40	6.88	120-180
pl soda b	51,538.00	13.61	160-240
mixed plstc	0.00	0.00	110-160
tin metal	6,039.00	1.59	0-10
aluminum	189,767.55	50.11	850-1000
other	0.00	0.00	NA
total	$378,691.43	100.00	

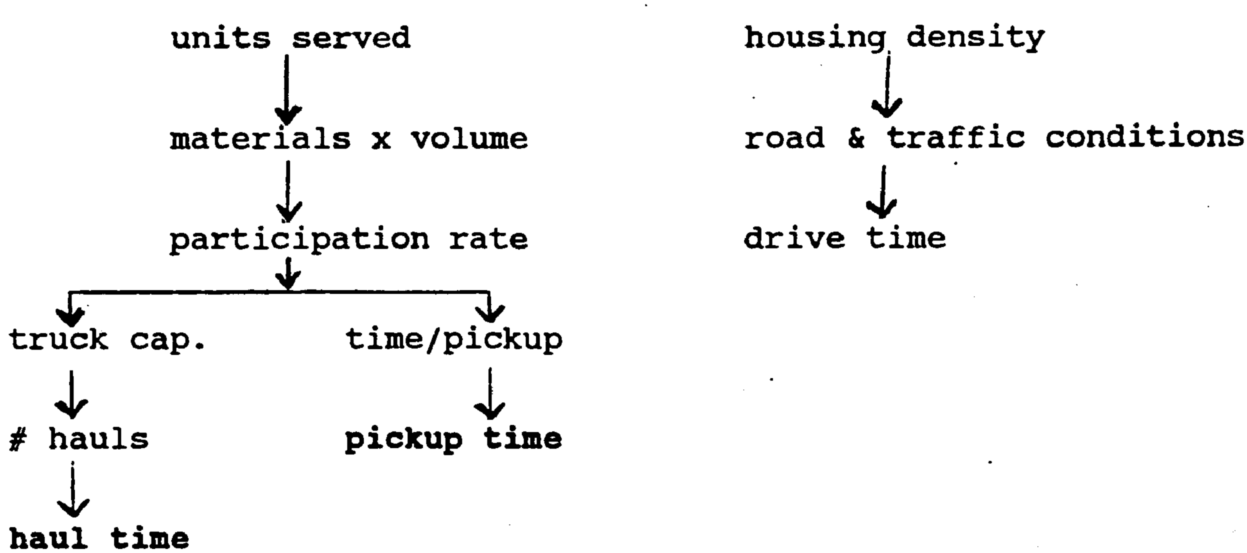
COLLECTION COSTS

The following discussion of collection costs is provided to provide a context for understanding the potential of on-truck densification for reducing costs.

The cost of putting a truck and driver on the road is the largest component of recycling collection costs. The truck fleet sizing model used in Rhode Island shows how various inputs influence the size of the fleet and therefore the cost of the program.

The model has three main parts: drive time, pickup time and haul time. Of these, only pickup time and haul time are affected by the amount and type of materials collected and therefore the amount of plastic materials present. Drive time is independent of these factors.

SIZING TRUCK FLEETS



The greater number of serving units and the increased volume of plastics lead to more full boxes, which in turn can lead to more setouts, requiring more pickups and possibly overtime. These factors also mean additional time to make more hauls, requiring more money to pay for overtime and increased operating and maintenance costs (tires, fuel, repairs, etc.). The greater volume can mean that larger, more costly trucks are required to accommodate plastics.

In most cases, the combined effect of all these factors produces only marginal increases in costs for overtime and larger trucks. However, in certain circumstances, such as when long hauls are involved, the increased volume and greater number of serving units means that an additional truck is required. In that case the cost of adding plastic is high -- about $65,000 per year (annual cost to own and operate a dedicated recycling vehicle).

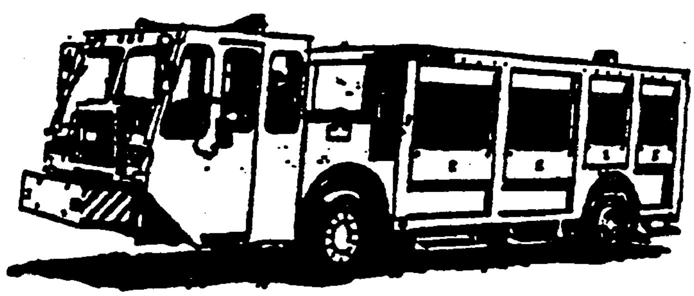
The cost of collecting recyclables is already high in comparison to the cost of solid waste collection due to the lack of compaction and the need to do at least one curbside sort to separate paper from bottles and cans. The average cost of collecting recyclables in Rhode Island is $70 to 85 per ton compared to $35 to 40 per ton for solid waste even for efficient recycling collection systems that use one operator, dedicated recycling trucks in order to keep costs down.

Collection Systems

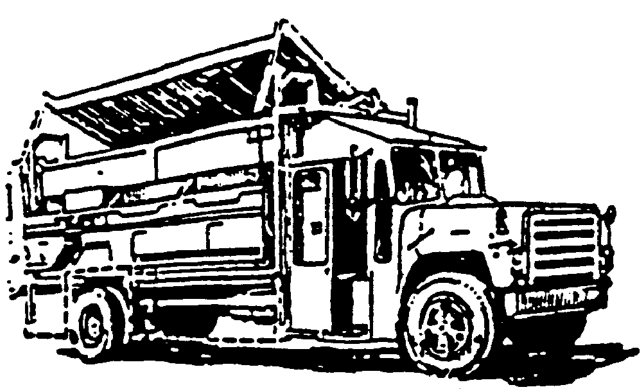
Before looking at how compaction and augmentation devices could work, a brief look at recyclables collection systems is in order. Recycling trucks generally hold from 15 to 30 cubic yards. Truck types include trailers and dedicated recycling trucks. Manually loaded recycling trucks come in either low or high profile versions, with low profile trucks being easier to load.

Semi-automatic trucks are easier to load than manual trucks but are available only in high profile versions. Trucks come equipped with from one to six compartments which may be fixed or moveable. Moveable compartments are preferred because they allow adjustments for differing mixes of materials.

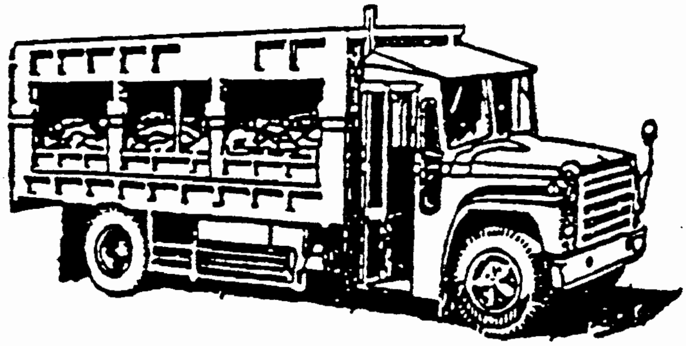
Low Profile Recycling Truck



Semi-automatic Top Loading Recycling Truck



Manual Truck



When a recycling facility is available, then the number of curbside sorts and the time taken for sorting can be kept to a minimum -- one for paper, another for bottles and cans. If no recycling facility is available, then further sorting by residents and/or operators is necessary to prepare materials for market.

Some programs report up to six curbside sorts. Based on information collected from programs around the country, it appears that each additional sort after the first one would take four additional seconds for the manual truck and three and a half additional seconds for the semi-automatic truck. (Don Fish, RIDEM, June 1989.)

In programs without a recycling facility, densification may be more feasible since additional sorting time will not be required in order to separate materials for densification.

DENSIFICATION METHODS

Manufacturers and recyclers are trying to fit more material in recycling trucks either by densifying material or augmenting the space available. Numerous projects to develop on-truck compactors or granulators, or to add space on recycling trucks have been conducted in the last two years. Of these, eleven were reviewed for this paper (see appendix). Most of the devices did not work. However, several warrant further study. A general discussion of each type of device and the advantages and disadvantages of each are provided,

Methods for making room for plastics include granulation, heavy compaction with or without perforation, light compaction, and augmentation of space on trucks either by adding bubblebacks or by adding wire baskets to the tops or sides of low profile vehicles.

Determining whether a device provides a benefit is a balancing act. Do the gains from increased capacity or reduced pickup and haul time outweigh the losses from the space taken up by the device (one to two cubic yards for compactors or densifiers); the time needed for extra sorting, and revenue lost due to increased glass breakage? (Glass breakage increases when plastics are sorted and placed in a separate compartment for densification, and the cushioning effect of the plastics is lost.)

The degree to which a densifier provides a benefit also varies according to certain program characteristics. The densifier will provide more benefit in programs that have smaller trucks, longer hauls, more material that can be densified, and/or where the residents or operators are already sorting materials.

In general on-board densification device have not worked because the size reduction achieved is not enough to offset the disadvantages: extra space consumed by the device itself, the time required for feeding and cycling, the time needed for extra sorting in programs that use recycling facilities, the extra cost of the devices (from $4000 to 20000), and the increase in broken glass due to loss of cushioning from the plastics when plastics are sorted into the compaction chamber.

Granulators

Granulation is unworkable despite high size reduction ratios (15:1) due to a host of specific problems in addition to those cited above: high cost ($20,000 each); high contamination levels; and frequent breakdowns. Moreover, granulators can be used with only one resin at a time. Therefore in order to granulate soda bottles, milk jugs and rigid plastic bottles, three granulators would be needed at a cost of $20,000 each for a total cost of $60,000 added to the initial cost of the vehicle (between $45 and 72K).

Light Compactors

Light compactors, such as a sheet metal wedge installed under the roof of a semi-automatic truck in Rhode Island, are inexpensive (less than $1000), and provided up to 20 percent size reduction in stationary trials. They can handle mixed recyclables so they require no extra sorting, and did not result in more broken glass since plastics were not separated out. However, the size reduction achieved in the stationary trials could not be replicated in field studies.

Heavy Compactors

Heavy Compactors have yielded up to threefold size reductions in field trials; up to fivefold reductions are theoretically possible. And compactors can be used to densify both plastics and aluminum. However, the disadvantages of heavy compaction are daunting: relatively high cost ($4000 to 10000); time lost to sort, feed and cycle (cycle time 8 -- 15 seconds); and more broken glass. Moreover, those compactors that do not perforate materials have a fatal flaw -- the plastic springs back to its original shape once the material is ejected from the compaction chamber.

Nonetheless, heavy on-board compactors that employ perforation deserve further study to determine whether higher levels of densification can be achieved; whether the time required to feed and cycle the devices can be reduced; and whether the time needed for sorting is offset by the gains in capacity. A compaction device that can be installed in a top loading semi-automatic truck is under development by the Labrie Corporation. Lummus Corporation is also conducting trials of a smaller, less expensive version of its side loading compactor-perforator in Louisiana.

Wire Baskets

In the meantime, some recyclers are making do with wire baskets attached to the sides and tops of low profile trucks or with bubbleback trucks. Wire baskets can increase capacity by up to 16 cubic yards at very low cost (about $1000).

The disadvantage of the baskets is the time required to sort material. One company is developing a wire basket system to use on high profile trucks as well as low profile vehicles. However, at least one hauler reports mixed results in using wire baskets.

Flattening by Residents

Rhode Island is also experimenting with having homeowners flatten material despite fears that participation and recovery rates will drop when residents are asked to perform extra work in order to recycle. A single observation of material collected in West Warwick during a previous trial of homeowner flattening showed that residents did flatten material and that approximately 30 percent of the soda bottles and 50 percent of the milk bottles were flattened on arrival at the interim recycling facility. Flattening rates were much lower for food and beverage cans.

CONCLUSION

If manufacturers can produce smaller, more powerful compactor-perforators, with either larger, lower, feed hoppers for side loading vehicles; or top loading models for semi-automatic trucks; and provide fullness indicators so that drivers would know how often to cycle the devices, we may see real advances in plastics collection technology.

APPENDIX

Perforator -- compactors

Labrie Equipment Company

302 Rue du Fleuve

Beaumont, Quebec

Canada G0R 1C0

Contact: Dominique Dubois 418-837-3606

Prodeva Inc.

100 Jerry Drive

Jackson Center OH 45334-0817

Contact: Fred Bunke 513-596-6713

Tri-State Trucking Equipment

Contact: Neil Buckman 215-657-1583

Lummus Development Corporation

PO Box 2326

Columbus, GA 31902

Contact: James Renfroe

COMPACTORS (without perforation at time of data collection in Fall 1989)

Impact Products
281 East Haven
New Lenox IL 60451
Contact: Tom Pawlak 815-485-1808

Rudco
Contact: Sal Marizio 609-692-1314

Nu-Way Occupational Rehabilitation Center (ORC)
Wisconsin
Contact: Ryan Squires, ORC
Bea Hoffman, Winona County MN

Jurek Manufacturing
2975 Soffel Avenue
Melrose Park IL 60160
Contact: Bill Rock 312-345-0200

Perkins Manufacturing Company (still under development, Fall 1989)
3220 West 31 Street
Chicago IL 60623
Contact: Richard Berman 312-927-0200

GRANULATORS

Shred-Tech Ltd.

PO Box 2526

Cambridge Ontario NIR 7G8

Contact: Vince Catania 519-621-3560

Foremost

Contact: Bill Turner 201-277-0700

SOURCES

Richard Berman, Perkins Manufacturing Company

Neil Buckman, Tri-State Trucking Equipment

Fred Bunke, Prodera Incorporated

Gretchen Brewer,

Vince Catania, Shred-Tech Limited

Dominique Dubois, LaBrie Equipment Company

Rea Hoffman, Winona Country, MN

Tom Kimmerly, General Engineers, Company, Inc.

Sal Marizio, Rudco

Patti Moore, Moore Recycling Associates

Tom Pawlak, Impact Products

James Renfroe, Lummus Development Corporation

Bill Rock, Jurek Manufacturing Company

Richard Sherer, General Engineers Company, Inc.

John Snellen, Waste Management Incorporated

Ryan Squires, Nu-Way Occupational Rehabilitation Center, Wisconsin

Bill Turner, Foremost

CO-MARKETING IN DUPAGE COUNTY, ILLINOIS

Miriam C. Foshay
Recycling Management, Inc.

Presented at the

First U.S. Congerence on Municipal Solid Waste Management

June 13-16, 1990

CO-MARKETING IN DUPAGE COUNTY, ILLINOIS

by
Miriam C. Foshay

Co-marketing to improve marketability is a method pioneered by Gary Olson and the New Hampshire Resource Recovery Association. But co-marketing has been identified with rural situations remote from markets. DuPage Cpounty's recycling centers are distinctly urban, part of the metropolitan area of the nation's third largest city. The Chicago area has markets for every material. Yet co-marketing is just as applicable here, although for slightly different reasons.

DuPage County currently has ten recycling centers. All but one of these is a small, severely underfunded operation manned largely by volunteers. All are short on storage space and many do not have a shelter or electric power. Brokers are available to help them market newspaper, glass, and aluminum. But plastic presents a special problem: because it has such a low density, it requires a tremendous amount of storage space, and it must be densified to make it marketable.

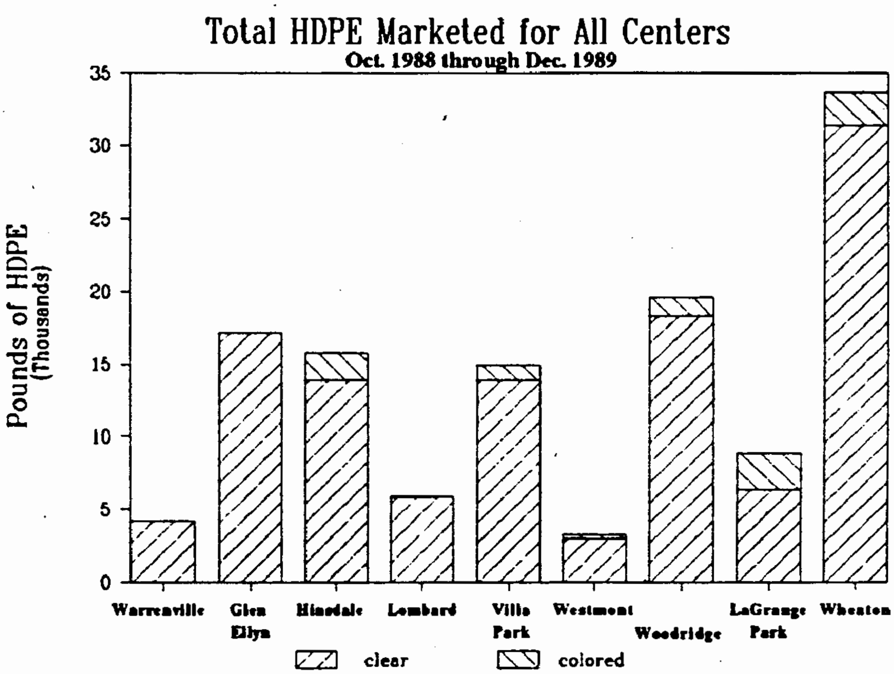
The largest of the recycling centers is Napervillle Area Recycling Center in the southwest corner of the county. NARC became involved in recycling high-density polyethylene (HDPE) in 1987 when the State of Illinois provided grant money to help purchase a baler. The baler was quickly outgrown, and in 1988 NARC proposed to the County that in exchange for a grant to purchase a plastics granulator, NARC would provide marketing services for HDPE for the county's recycling centers.

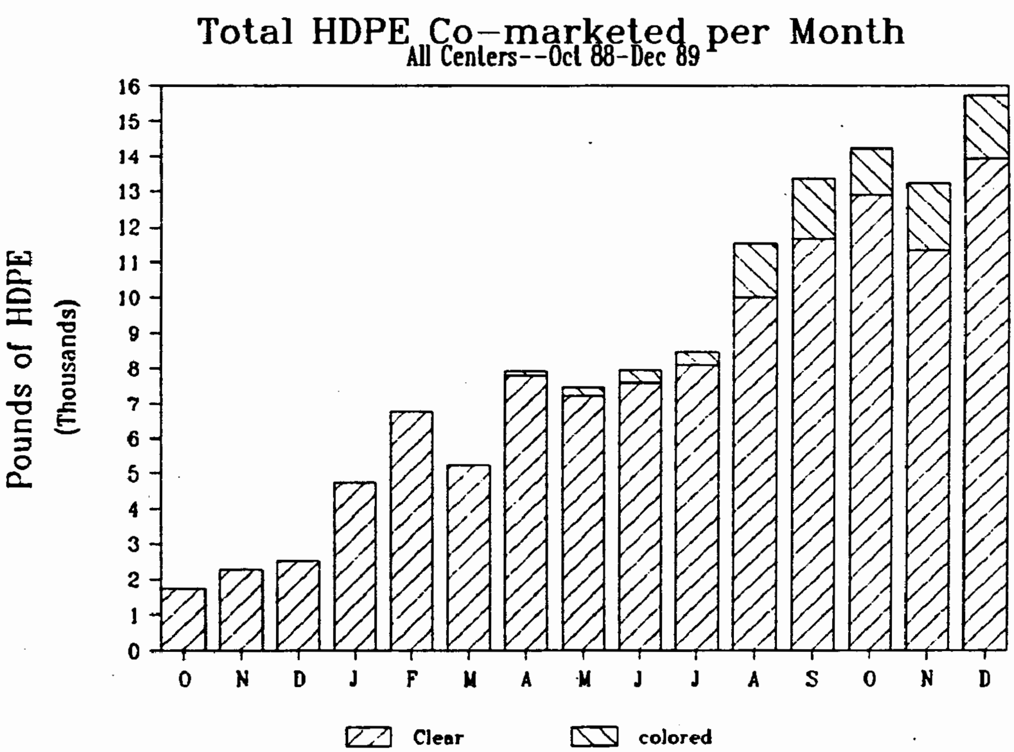
Since none of the other recycling centers had the volume or the space to justify the purchase of this piece of equipment, this arrangement seemed ideal. The services NARC provides include:

- Supplying woven polyester bags with a 2.2 cubic yard capacity for storing the plastic;
- Transporting the bags of plastic in a truck with a 22-foot box to the center in Naperville;
- Sorting the plastic by color and granulating it;
- Shipping the granulated plastic to Eaglebrook Plastics in Chicago.

NARC charges the recycling centers \$.04 per pound for supplying the bags and granulating the plastic. Transport costs \$12 per hour for labor and payroll taxes and \$1.25 per mile for use of the truck. NARC has agreed to charge only to cover its direct costs and none of the overhead. These charges are subtracted from the revenue paid to each recycling center from the sale of its HDPE.

As a result of this program, plastics recycling in DuPage County has increased tremendously. As of January, 1990, NARC was collecting 20 tons per month from participating centers. Recycling centers in surrounding counties have also joined, in spite of the fact that transportation costs can exceed the revenue from sale of plastic. The accompanying graphs show how volume has changed over time.





One interesting sidebar of the data we collected was a reading of the volume of colored HDPE that can be captured by a recycling program. Not all programs advertised that colored HDPE was accepted; most, however, accepted the colored HDPE that showed up at their doors. The following table shows the percentage of colored HDPE collected by each center during the period from May through December, 1989:

Center	*% of colored HDPE in a mixed-HDPE waste stream*
Hinsdale	23.5%
Villa Park	10.9%
Westmont	7.7%
Woodridge	8.0%
Wheaton	10.1%
Naperville	23.6%
La Grange Park	28.4%

Even in Naperville, where colored plastic has been collected for over a year, many recyclers don't realize that their detergent bottles can be recycled, too. One must assume that the lower figures reflect incomplete dissemination of knowledge that colored plastics can also be recycled. The higher figures, then, would approach the maximum level of colored HDPE recovery. It would appear from this table that colored HDPE constitutes one-quarter to perhaps as much as 30% of all household HDPE.

In addition to allowing small recycling centers to handle plastic economically, co-marketing has provided us with power in the marketplace. NARC found that their granulator had a difficult time handling colored plastics because the detergent residues would cause plastic flakes to adhere to the grinding chamber, clogging the screen and requiring extensive cleanup. This problem was solved by increasing the hole diameter of the screen from the standard 3/8" to 5/8", which also allowed faster processing of HDPE. Our buyer, however, refused to accept this coarser product, so we found another market. At 30 tons of plastic a month, we are a major supplier of post-consumer regrind, and it only took two shipments before our original market ate crow and agreed to accept our 5/8" material.

Co-marketing of materials is a technique with a number of advantages. It allows pooling of resources to allow maximum use of the resources available. It gives power in the marketplace, allowing more control over price and specifications. And it allows the recycling of materials which would otherwise be uneconomical to handle.

COMPOSTING OF MSW IN THE USA

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Cal Recovery Systems, Inc.

Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

INTRODUCTION

The convening of this Conference is ample evidence of the public's awareness of the magnitude of the solid waste managment problem and of the challenge to do something about it. Nevertheless, at the risk of stressing the obvious, we begin with a few words about the causes of the problem and the nature of the challenge so as to provide a setting for the subject of our paper.

Three factors share responsibility for much of the problem and the challenges. They are: 1) the continuing migration of the urban population to the suburbs; 2) the unceasing generation of large quantities of wastes; and 3) a serious shortage of professionals specifically capable of relying upon alternatives other than the land for the disposal of municipal solid waste (MSW). The shortage is critical for a rapidly increasing number of municipalities, inasmuch as for them, landfilling is no longer a viable alternative because of public pressure, cost, and intensification of resource conservation.

The nature and dimensions of the problem are such that each and every solution proposed for it and adopted by the community must not only be politically and environmentally acceptable, but also be economically feasible. A solution that sufficiently meets these requirements is to supplement sanitary landfilling with resource recovery (i.e., recycling). One of the more important forms of resource recovery is biological stabilization ("biostabilization"). Of the biostabilization methods, composting has much to offer, and moreover has been demonstrated as being economically feasible.

The main theme of our presentation is the past, present, and projected status of composting as a means of biologically stabilizing MSW in the U.S.A. We close with a discussion of the status of yard, leaf, and garden waste composting.

STATUS OF MSW COMPOSTING

Past

Chronologically, the status of composting MSW in the past can be divided into the two periods: "Early" and "Intermediate" (or "Dormant"). Broadly speaking, the early period began in the 1940s and continued until the onset of the intermediate period in the late 1960s. The intermediate period continued until the onset of the present or modern period in the mid-1970s. (The time frames are only approximate.)

Early Period

The compost record during this period would be best summarized by the adjective "mixed." Thus, through research and development, great strides were made in the advancement of understanding and knowledge of principles and parameters of the compost process. The progress and accomplishments were such as to raise composting from the status of an art to that of a science.

In sharp contrast, the record compiled by composting, when used as an option on a practical (municipal) scale in municipal solid waste management, was far from impressive. A very likely reason for the mediocrity of the early record was that at the time, composting was 3 to 4 decades "ahead of its time." Open dumping was only beginning to give way to the early and rather primitive versions of sanitary landfilling. Moreover, the prevailing illusion at the time was that not only was an abundance of land available for the disposal of wastes, but that the abundance would continue into the dim, distant future. These and other factors (e.g., public apathy towards resource recovery, little concern about the quality of the environment) combined to render disposal via the land economically much more attractive than composting. The situation was rendered almost hopelessly grim by an unwarranted and certainly not-fulfilled expectation of profits to be obtained from the sale of the compost product.

We conclude our discussion of the early status of composting with brief descriptions of a few of the compost operations that attracted attention at the time.

Sacramento, California

A refuse composting facility, operated as a demonstration facility and based on the use of a "Dano" reactor was designed and built in Sacramento in 1956. Having served its purpose, the facility was closed after having been in operation for about five years.

The Sacramento facility was operated in the following manner: Unsorted (mixed) waste brought to the facility in conventional waste collection vehicles was discharged onto a conveyor system. Noncompostable items, along with recyclable items (e.g., bottles, rags, cardboard), were removed manually. The non-compostable items were discarded. Ferrous material was removed with the use of a magnetic drum. Refuse remaining after the removal of objectionable items was primarily organic in nature. This organic residue was passed through a shredder, in which it was size reduced to a particle size that ranged from less than 1 inch to about 5 inches. The shredded material was discharged into a Dano reactor. Residence time in the reactor was on the order of 14 days. The final volume of the composted refuse varied from 60% to 70% of that of the incoming raw material. The Dano reactor used in the demonstration was much the same in design and operation as the modern Dano reactor. The Dano reactor was a closed, horizontally oriented cylinder that had a 100-ton capacity and was rotated at 0.8 rpm. The interior of the cylinder was equipped with vanes to impart a tumbling motion to the rotating wastes. Air was introduced into the cylinder to aerate the composting mass. Moisture content of the material was adjusted by means of water jets distributed along the side of the cylinder.

Chandler, Arizona

In the Chandler operation, a few oversize items and rags were grossly sorted from the incoming refuse. Ferrous metals were removed by means of an electromagnet (60% efficiency). The sorted refuse was shredded in a hammermill equipped with coarse grates. Moisture content was adjusted by adding either sewage sludge or water at the bottom of the primary elevator conveyor.

The shredded material was transferred to outdoor concrete slabs, where it was either piled into 4-ft high windrows that were about 6-ft wide at the base, or was placed in bins formed of hardware cloth. During the first 14 days ("active" stage), the material was aerated by way of "turning," and moisture was added when required. The active stage was followed by the "curing" stage (about 14 additional days). Apparently the quality of the compost was adversely affected by the inefficiency of the sorting process.

Phoenix, Arizona

The Phoenix refuse composting facility was owned and operated by the Arizona Biochemical Company. The company had a contract with the city to accept refuse for a tipping fee of $1.25 per ton for the first year and for $1.10 per ton thereafter. Operation of the facility was begun in 1962.

In the operation, refuse was manually sorted, followed by magnetic separation. The sorted residue was shredded and then introduced into a Dano drum. Two additional drums were expected to be put into operation about 5 to 6 months after start-up. Unfortunately, after seven months of operation the facility closed because of lack of financial support.

Johnson City, Tennessee

The construction and operation of the Johnson City compost facility was a part of a joint project conducted by the U.S. EPA and the TVA. The project was begun in 1967 and was terminated in 1971. The main objective of the project was to evaluate the feasibility of windrow composting for managing municipal solid waste. However, the scope of the study embraced a wide range of investigations, among which were: 1) the composting of mixtures of refuse and sewage sludge; 2) the evaluation of public health problems; 3) an assessment of economic benefits from using compost for agricultural, horticultural, or soil amendment purposes; and 4) the determination of permissible rates of compost loading on the soil.

The plant had a nominal capacity of 60 tons per day for an 8-hr shift. Incoming wastes were sorted manually and ferrous materials were removed by means of magnets. The sorted residue was either passed through a hammermill or through a rasping machine. Moisture was adjusted to a level of 50% to 60% by adding either water or sludge to the refuse. The size reduced material was stacked into 4- to 4.5-ft windrows that were about 9-ft wide at the base and as long as 230 feet. The material was aerated 8 or more times using a turning machine. The active composting period varied from 35 to 44 days. After composting, the material was cured, dried, shredded, and screened.

Other Facilities

Time and space permit only a brief mention of two other facilities, namely, the 35-ton per day plant at Norman, Oklahoma and the 70 ton per day plant (design capacity - 150 tons/day) at San Fernando, California. Both employed the "Naturizer" system.

The two principal features of the Naturizer system were the "pulverator" and two vertical 3-tiered digesters. The pulverator was a large diameter cylinder revolving slowly on a longitudinal axis with heavy bar hammers. It was followed by a horizontal hammermill with studded shells. Each digester consisted of 3 rectangular cells tiered one above the other. Slowly moving slat bottoms advanced refuse from the receiving end of the top cell to the discharge end. The discharged refuse was passed through the middle cell and then through the bottom cell. At this stage, the material was reground and then passed through a second tier of cells (the second digester).

Intermediate (Dormant) Period

The intermediate period is appropriately termed "dormant," since at the time, excepting by a dedicated few, composting was not regarded as being a viable option in municipal solid waste management. Despite this temporary loss of favor, the interest and research regarding composting as a treatment method persisted. This persistence paved the way for composting to become the candidate of choice when a viable alternative to landfilling and incineration had to be found for sewage sludge disposal in the late 1970s.

PRESENT AND FUTURE STATUS

Toward the end of the 1970s, the situation, hitherto so unfavorable to the compost option, began to change rapidly and drastically, to the extent that composting no longer was ahead of its time. On the contrary, its time had come. The change began with sewage sludge, then progressed to yard and garden debris, and now is making inroads on the entire organic fraction of the municipal solid waste stream. The magnitude of the transition from the low status of MSW composting in the late 1960s and early 1970s is emphasized by the fact that now composting is one of the more publicly accepted options for treating important components of the municipal waste stream, namely, yard wastes and sewage sludge.

Several factors have and are combining to bring about the remarkable rise in the status of composting to the level of being the popularly accepted option of choice for treating and disposing of organic municipal waste. Although the importance of the favorable economic situation resulting from the change in circumstances must not be overlooked, other factors come into play. Those factors include landfill shortages, high disposal fees, and legislation that prohibits the disposal of "unprocessed waste." Those factors, combined with the federal and state regulatory constraints imposed on the two principal competing options (sanitary landfill, incineration), and the higher costs of the two have substantially raised the status of MSW composting. In addition, financial assistance programs established in several states (e.g., Massachussetts, Minnesota, Iowa) are also having a positive impact on the growth of MSW composting.

Not to be underestimated is the legislative impetus. Recently, several states have enacted legislation in which priorities are established regarding alternatives for managing solid wastes. Typically, the laws assign top priorities to reduction of generation rates and volumes, expansion in recycling and composting, followed by incineration and landfilling. If put into effect, new regulations recently proposed by the

U.S. Environmental Protection Agency for landfills undoubtedly would raise the cost of landfilling. As it is, landfill costs are major incentives for the strenuous efforts now being directed to the reduction of the amount of wastes destined for land disposal. Composting has the advantage of fitting well with many of the approaches to waste reduction and recycling.

Potential Danger

A potential danger to the continued success of modern composting is in the uncritical attitude that could be an undesired offshoot of the present interest in MSW composting. The interest could be so intense as to engender an uncritical attitude; which in turn could lead to the selection of the composting option without having made a thorough analysis of alternative options and their costs. The uncritical attitude could take the form of failing to realize that composting MSW usually is an undertaking, the complexity of which is a function of the extent and type of separation required. Although manual separation can be and is successfully used for smaller operations, it is inadequate for coping with the massive quantities of refuse that must be sorted in the larger operations. Mechanical processing must be incorporated in designs for dealing with those quantitites. Consequently, with the exception of some particularly unusual set of circumstances, a combination of manual and mechanical sorting is the only practical means of accomplishing the degree of separation needed to render MSW a satisfactory feedstock for the compost process. The importance of doing so rests on the fact that the quality of the finished compost product depends heavily upon the effectiveness of the separation process [3,4]. The problem is that providing a satisfactory mechanical separation is a difficult task.

Modern Status -- Specifics

Operating Facilities

Judging from personal observations and information gained from discussions with their designers and operators, existing plants in the U.S. generally are characterized by a relatively low throughput and capital investment, and an over-simplification of design. Insufficient attention is given to the segregation of organic from inorganic matter in the refuse.

The status of MSW compost projects in the U.S. is summarized in Table 1. The location, capacity, year of establishement, and other pertinent information regarding MSW composting plants in operation in the U.S. in May, 1990 are listed in Table 2. The collective range of capacities was from about 15 to 350 tons/day. The table further indicates that with its capacity of 700 tons/day (design capacity - 1000 tons/day), the Wilmington (Delaware) plant was much larger than the other four plants in operation. The respective capacities of the latter four were only 15-20, 30, 50, and 65-70 tons/day. Moreover, the designs of the four were relatively simple and had been made operational within the preceding two years.

Wilmington Facility -- The Wilmington facility is designed to process about 1000 tons of municipal and commercial solid waste per day into refuse derived fuel and compost. It incorporates size reduction, air classification, magnetic separation, and screening to recover metals and glass. This sorting set-up results in the production of about 250 tons of highly organic residue each day. Sewage sludge (about 20% solids) is added to this residue, and the resulting mixture is introduced into one of four digesters, each of which has a holding capacity of 175 tons. Each digester is equipped such that its contents can be mixed and aerated while

Table 1. Summary of MSW Compost Projects

Status	Number
Operation	7
Pilot	7
Design	17
Permit	8
Feasibility	21
Total	60

Source: BioCycle and Cal Recovery Systems, Inc. [8]

Table 2. Operational Municipal Solid Waste Composting Facilities in the U.S. (1990)

Location	Capacity (tons/day)	Year Established	Type of System	Material Added	Markets
Lake of the Woods, Minnesota	5 to 10	1989	Windrow	--	None
Fillmore County, Minnesota	15 to 20	1987	Windrow	--	None
Portage, Wisconsin	30	1986	In-vessel/drum	Sewage sludge	None
St. Cloud, Minnesota	50	1988	In-vessel/drum	Sewage sludge	None
Sumter County, Florida	65 to 70	1988	Windrow	--	None
Wilmington, Delaware[a)]	~700	1984	In-vessel/silo	Sewage sludge	Yes
Skamania County, Washington	70	1988	Windrow		Yes

a) This facility was designed to process about 1,000 TPD of MSW to recover RDF, glass, and metals. An organic residue is mixed with sludge and composted in an in-vessel system.

in the digester. At the completion of a 5-day retention period in the digester, the material is removed and is stacked in a pile and is allowed to mature for 30 to 45 days. The matured material is screened. By virtue of a permit, the fines are used for horticulture. The rejects are mixed with top soil in a 1:1 ratio, and the mixture is used for erosion control at landfills.

Sumter County -- Since mid-1988, a windrow composting facility has been in operation in Sumter County, Florida. According to the operators of the facility, from 65 to 70 tons of residential waste and commercial waste are processed at the facility each day.

In the operation, incoming waste is introduced into a unit designed to open the bags and discharge the contents onto a conveyor belt. The belt passes the contents by a magnetic device such that ferrous metals are removed. Aluminum and some inerts are removed manually. The waste, now free of ferrous and aluminum metals and some inerts, is size reduced to an approximate 2 x 2 in. particle size. The size reduced material is stacked in 6 ft high by 10 ft wide windrows and is dosed with a proprietary bacterial inoculum. The operators claim that the compost is ready after six weeks. The operators hope to market the product as soon as the Florida Department of Environmental Regulation grants permission.

Market for the Compost Product

At present, information on product characteristics, expected quantities, and consistency of production is too uncertain and fragmentary to permit a firm definition of the present and hoped-for market for the MSW compost product. Apparently, no MSW composting facility is routinely marketing its product. The absence of marketing is to be expected, inasmuch as most MSW compost facilities are as yet in the testing and permitting stage.

The very little quantity of available MSW compost product makes it difficult or even impossible to collect needed information. Moreover, projections made on the basis of available information would be highly uncertain. It is unlikely that the characteristics of the product presently available would be the same as those of material routinely produced after full production is reached.

MSW as a Bulking Agent

Refuse has many shortcomings that would make it less effective than wood chips as a bulking agent in the composting of sewage sludge. However, the shortcomings can be lessened or even avoided by resorting to a combination of careful preprocessing, avoidance of excessive moisture, following suitable mixing, and aeration procedures.

Potential benefits from the use of MSW as a bulking agent could include significant cost savings, possible (but very unlikely) sale of the co-compost product, and the utility of the product in soil reclamation. The economic justification of the substitution of refuse for wood chips as a bulking agent in sewage sludge composting obviously would be determined by way of a careful analysis of the shortcomings of refuse versus the benefits of using it as a substitute for wood chips [5].

Future

The future of the implementation of MSW facilities seems bright. If it can be done successfully, the implementation would greatly lighten the management and disposal burden. Composting lends itself to integration into many material-recycling schemes -- including those that involve incineration. For example, the use of suitably processed MSW as a bulking agent for composting sewage sludge (i.e., co-composting) would ease the task of treating and disposing two major wastes.

Before the routine success of co-composting can be assured, certain requirements must be met. Among the more important are these: 1) assuredly reliable mechanical equipment; 2) advancement of the knowledge and understanding had by designers and system vendors; 3) means of removing or counteracting the toxic content of the sludge fraction; and 4) development of an outlet large enough to accommodate all or most of the resulting co-compost product.

STATUS OF YARD WASTE, LEAF, AND PARK DEBRIS COMPOSTING

Unless otherwise specified, the term "yard waste" refers to the three wastes collectively. The concept of reducing the size of the municipal waste stream destined for treatment and disposal by separately treating yard waste not only is becoming increasingly attractive, but also is being implemented throughout the country. Moreover, the usual method of treatment is composting.

Judging from information gained in various MSW characterization studies, 5% to 30% (by weight) of the municipal solid waste stream may be in the form of yard debris. Quantities of yard debris generated and its resulting proportion of the MSW stream not unexpectedly vary seasonly, as well as from region to region. Thus, generation is at its lowest during the winter season in those parts of the country that have such a season, and during the rainy season in the other parts. A precipitous influx of leaves into the waste stream occurs in autumn in the temperate zone --- as much as 95% of the MSW stream in some communities.

Because of the relative ease with which yard waste can be diverted from the landfill, hundreds of municipalities have established programs for utilizing the waste. Additionally, the diversion is encouraged by legislative measures. Some of the measures even prohibit the disposal of yard debris in landfills: In 1988, the State of New Jersey banned the disposal of leaves in landfills; other states include Minnesota, Wisconsin, and Illinois.

Collection of Yard Waste

Because yard waste is an excellent substrate for the compost process, the waste should not be permitted to be contaminated with other wastes, especially not with undesirable wastes. Prevention can be accomplished through appropriate collection strategies. For example, establish publicized drop-off sites and institute curbside collection.

The use of drop-off sites is, perhaps, the simplest and least expensive of the yard waste collection strategies. Large containers are placed in one or more strategic locations, and the public is encouraged to deposit its yard waste in the containers. Some public officials regard the dependence upon the public to both segregate the material and transport it to the drop-off site as being a weakness of the strategy. Thus far, public participation has been at a modest level.

Curbside collection has been more successful in terms of public participation. Curbside collection is carried on in many ways. One way is to impose a regulation that demands that the homeowner segregate and place the yard waste at a designated collection point. For example, have the yard waste piled curbside for either manual or mechanical collection. An alternative is to have the homeowner use a container (can, box, or bag) instead of simply piling the yard waste at the curb. The task of collecting the mass of leaves that accumulate in the autumn is accomplished in several communities through the use of vacuum trucks. However, the cost of collecting leaves via vacuum can be more than $80/ton of leaves collected.

Yard Waste Compost Technology

A few communities use an extremely low-technology approach that they unjustifiably label "composting." Their so-called "composting" makes minimal use, if any, of processing. The material is simply stacked in piles as high as 10 to 20 ft, which are not disturbed over periods of longer than 18 months. Because the wastes consist mostly of plant residues, and of shrub and tree trimmings ranging from twigs to large branches, the experience had by those communities has been far from satisfactory and has been marred by the development of fire hazards during the dry season.

The windrow system is the one of choice for communities interested in pursuing a satisfactory approach to composting yard waste. Aeration is accomplished either by mechanical turning, by forced aeration, or by a combination of the two. The general experience has been that forced aeration leads to an excessive drying and cooling of the composting mass, especially when the substrate consists largely of tree trimmings and dried vegetation (leaves, straw). The very porous nature of the waste mass permits a relatively unimpeded movement of air and diminishes the moisture holding capacity of the windrowed mass as a whole. The lowered "water holding capacity" is due to the rapid percolation of water to the bottom and out of the windrow.

As with mixed yard wastes, a minimal approach is used by some communities in the composting of leaves. Basically, the leaves are stacked in piles and are allowed to decompose without being given further attention. Decomposition may take as long as 18 or more months, and usually is accompanied by the development of unpleasant odors which are especially pronounced on the rare occasions on which the mass is turned. This approach is used in situations in which there is available land area.

A more positive approach is followed when available land is expensive. The approach is the windrow method described for mixed yard waste (i.e., aeration either by mechanical turning or by way of blowers). Moisture content and other parameters are maintained at levels that permit shortening the compost process to four or five weeks. The process may be further optimized through the addition of nitrogen.

Equipment

The unsatisfactory performance of many yard waste compost operations usually can be traced to the lack of a reliable shredder. A shredder has an adequate capacity if it can size reduce fairly large branches and brush, twigs, tree clippings, and other woody material to a particle size small enough to permit easy manipulation and promote biological breakdown. Moreover, the shredder must be sufficiently sturdy to deal with occasional contaminants such as rocks, bricks, and pieces of metal. An indicator of an inadequate shredder is an accumulation of branches and other woody debris. Eventually the accumulation reaches unmanageable proportions, becomes unsightly, and could well constitute a serious fire hazard. Other indicators are excessive downtime and high O&M costs.

Turning the piles in small operations can be adequately accomplished by means of a front-end loader or a bulldozer equipped with a standard blade. Exceptions might be the occasions when yard waste consists mostly or exclusively of grass clippings. Because of the matting tendency of grass clippings, a bulldozer or front-end loader might not be capable of dealing with the tendency of grass clippings to mat or form clumps. A machine specifically designed for the turning would be needed for large operations [6].

Moisture Problem

Neglect of moisture maintenance in the composting mass is an all too common occurrence in yard waste compost operations. Insufficient moisture can seriously inhibit the compost process and thereby lower the efficiency of the operation. A more serious consequence is the intensification of the fire hazard. The usual reason for the failing is the absence of an accessible water source. The absence generally is due to the high cost of providing the water source. Unfortunately, the high cost has no effect on lowering the minimum moisture content required for satisfactory composting. Some communities confronted with such a dilemma resort to an alternative, but doubtfully acceptable, approach. They simply allow the piles to remain undisturbed until the arrival of the rainy season, at which time they start or resume the compost program, as the case may be.

The Yard Waste Compost Product

Yard waste compost operations in which the feedstock is consistently free of objectionable contaminants, and the compost process is conducted satisfactorily, almost invariably produce a product that simultaneously is an excellent soil amendment and a partial source of fertilizer elements. Properly screened, the product could be safely used in the more demanding landscaping activities.

SUMMARY AND CONCLUSIONS

The many positive past and present developments in yard waste and MSW composting warrant the objective conclusion that the current status of composting as a waste management and disposal alternative is quite favorable in the United States.

The status of yard waste composting is steadily improving. Within the span of the past five years, the yard waste compost activity in the U.S. has expanded from a few scattered operations, to the hundreds of known operations distributed throughout the nation. Despite the unfortunate tendency of some communities and developers to oversimplify the operation to the extent that management disappears, the yard waste compost movement will continue to grow unabated, particularly in the role of diverting the waste from landfills.

MSW composting is experiencing a period of growth that, barring unforeseen reverses, will continue for some time to come. The rate of growth, although far slower than that of yard waste composting, nevertheless is respectable.

An unfortunate occurrence in MSW composting is the failure of most of the present and planned MSW composting programs to include source separation. The failure very likely will prove to be a substantial impediment to the attainment of design performance by the compost facility. Other major impediments to the success of the MSW compost movement include: 1) insufficient basic design data; 2) failure to establish standards for the finished product; 3) insufficiency of experience on the part of many designers, vendors, and clients; and 4) overly optimistic expectations regarding markets and uses for the material [4,6,7].

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THE COMPOSTING PLANTS IN MEXICO
A STATE OF THE ART

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Presented at the

First U.S. Conference on Municipal Solid Waste Management
June 13 - 16, 1990

ABSTRACT

THE RECYCLING AND UTILIZATION OF MUNICIPAL SOLID WASTE IS AN OLD PRACTICE IN MEXICO. SOME TIME AGO, THIS PRACTICE WAS CARRIED ONLY BY SCAVENGERS IN THE DISPOSAL SITES. IN 1972, HOWEVER, THE FIRST COMPOSTING PLANT IN MEXICO WAS BUILT IN THE CITY OF GUADALAJARA, WITH SWISS TECHNOLOGY.

PRESENTLY THERE ARE SIX COMPOSTING PLANTS, OF WHICH ONLY TWO ARE IN OPERATION. ONE MORE WILL BEGIN OPERATION BY 1990. THE TENDENCY TO PUT MORE OF THESE PLANTS IN OPERATION IS UNKNOWN, BECAUSE IT DEPENDS ON POLITICAL DECISSIONS, RATHER THAN TECHNICAL AND ECONOMICAL FACTORS. IN THIS RESPECT OUR ASOCIATION IS PROMOTING A REAL EVALUATION OF PROJECTS BEFORE GRANTING LOANS FOR THIS PURPOSE.

FOR THE PEOPLE WHO WORK IN THE FIELD OF CONTROL OF MUNICIPAL SOLID WASTE, THE COMPOSTING PLANTS INSTALLED, DO NOT REPRESENT A SOLUTION FOR RECYCLING IN MEXICO. WE ARE PRESENTLY WORKING IN THE DEVELOPMENT OF NATIONAL TECHNOLOGY AND ALSO TRYING TO STOP THE ACQUISITION OF CONVENTIONAL PLANTS WHICH MIGHT BE USEFUL IN DEVELOPED COUNTRIES BUT NOT IN OUR COUNTRIES.

AS A RESULT WE CAN RESUME THE FOLLOWING RESULTS:

1.- THE PLANTS REPRESENTS A LOSS OF HARD CURRENCY

2.- THE PLANTS PRESENTS NO SOLUTION TO THE PROBLEM

3.- THERE IS LACK OF EXPERIENCE OF PERSONNEL OPERATING THE PLANTS

4.- THE PLANTS REPRESENTS TECHCNICAL AND ECONOMICAL PROBLEMS

5.- THERE IS A LOW DEMAND FOR THE COMPOST

6.- TOO WIDE VARIATIONS IN THE PRICES OF THE RECOVERED MATERIALS COMPLICATE THE ADMINISTRATION OF THE PLANTS.

7.- LOW OR NO AVAILABILITY OF SPARE PARTS, MAKES MAINTENANCE EXPENSIVE AND SLOW.

8.- SCAVENGING IN THE COLLECTION VEHICLES, MAKES THE WASTES THAT ARRIVE TO THE PLANTS VERY POOR.

THIS PAPER PRESENTS THE PAST, PRESENT AND FUTURE OF THE COMPOSTING AND RECYCLING PLANTS IN MEXICO, AND ANALIZES THE MAIN TECHNICAL, POLITICAL, SOCIAL AND ECONOMICAL PROBLEMS THAT HAVE OCCURED, AS WELL AS PRESENT CONDITIONS.

I.- INTRODUCTION

HUMAN ACTIVITIES PRODUCE, AMONG OTHER THINGS, WASTES; MAINLY GASES, LIQUIDS AND SOLIDS. IN GENERAL MAN'S CHOSEN ENVIRONS HAVE A LIMITED CAPACITY TO ACCEPT, MODIFY AND INTEGRATE THESE WASTES INTO ITS ECOSYSTEM WITHOUT CAUSING MAJOR PROBLEMS. WHEN NATURE'S THRESHOLD LIMITS AND CAPACITY TO ADAPT ARE EXCEEDED, IRREVERSIBLE ECOLOGICAL PROBLEMS ARE TO BE EXPECTED, AND THE RESULTING ECOSYSTEMS MAY NOT BE AMIABLE TO MANKIND SURVIVAL.

OUR SOCIETY IS A WASTEFUL ONE. MANUFACTURERS AND THE MERCHANTS WRAP THEIR PRODUCTS WITH EXCESSIVE SUMPTUOUSNESS FOR THE SOLE PURPOSE OF CALLING THE ATTENTION OF THE BUYER; IN MANY INSTANCES THE WRAPPING MAY EXCEED THE VOLUME AND VALUE OF THE PRODUCT BEING SOLD. THE FINAL DESTINATION AND PURPOSE OF ALL THIS WRAPPING IS THE GARBAGE CAN, AND VERY LIKELY, OPEN DUMPS.

IN ORDER TO TRY TO SOLVE THE INCREASING PROBLEM OF SOLID WASTE, IN SOME PARTS OF MEXICO, MAINLY IN THE BIG CITIES, THE AUTORITIES LOOK, AMONG OTHER THINGS, FOR RECYCLING AND COMPOSTING PLANTS. IN 1972 THE FIRST COMPOSTING AND RECYCLING PLANT IN THE COUNTRY WAS BUILT IN THE CITY OF GUADALAJARA; AFTER THAT PLANT, FIVE MORE PLANTS WERE CONSTRUCTED AND ONE MORE IS UNDER STUDY.

NOW, AFTER 18 YEARS, ONLY TWO PLANTS ARE WORKING WITH A LOT OF PROBLEMS. THIS PAPER PRESENTS THE STATE OF THE ART OF THE COMPOSTING AND RECYCLING PLANTS IN MEXICO, MAKING AN EVALUATION OF THE TECHNICAL AND ECONOMICAL PROBLEMS THAT HAVE OCURRED IN THE PAST 18 YEARS, IN ORDER TO ARRIVE TO SOME CONCLUSIONS AND RECOMENDATIONS FOR DEVELOPING COUNTRIES.

I HOPE THIS PAPER WILL BE OF HELP TO THOSE PEOPLE IN POSITIONS WHERE DECISSIONS ARE TAKEN, SO THAT THEY BE VERY CAREFUL WITH THE IMPORTED TECNOLOGIES OFFERED BY DEVELOPED COUNTRIES.

II.- THE COMPOSTING PLANTS IN MEXICO

AS I MENTIONED, THERE ARE SIX COMPOSTING PLANTS IN MEXICO, IN FIGURE No.1, THEIR LOCATION IS SHOWN.

THE PLANTS IN GUADALAJARA, MONTERREY AND MEXICO CITY, HAVE THE BULHER MIAG PROCESS. THE MEXICO CITY PLANT, HOWEVER, THE FEEDLINE IS IN THE OPPOSITE DIRECTION AS IN THE OTHER TWO PLANTS. ACAPULCO AND OAXACA HAVE A COPY OF THE SAME PROCESS WITH LITTLE CHANGES BEFORE THE MILLS. THE LAST ONE IS LOCATED IN TOLUCA, AND HAD A TOLLEMACHI PROCESS.

PRESENTLY, ONLY THE GUADALAJARA AND MEXICO CITY PLANTS ARE STILL WORKING.

IN THE VERY NEAR FUTURE, POSSIBLY THIS YEAR, A NEW RECYCLING AND COMPOSTING PLANT WILL BE BUILT IN MERIDA, YUCATAN, WITH A CREDIT OF THE WORLD BANK, IN THIS PART OF MEXICO THERE IS NO COVER SOIL, BECAUSE THE YUCATAN PENINSULA IS CONSTITUTED BY CALCAROUS ROCK. AS USUAL THE EXPECTATIVES ARE FABULOUS, AS BEFORE THE OPERATION OF THE OTHER PLANTS BUILT, HOWEVER, I EXPECT THE SAME RESULTS AS IN THE OTHER PLANTS.

THE PLANT'S PROCESSES CONSIST BASICALLY IN THE FOLLOWING ACTIVITIES: FIRST THE COLECCTION VEHICLES DISCHARGE THE SOLID

LOCATION OF THE COMPOSTING PLANTS

FIG. No. 1

WASTES IN STORAGE PITS, LOCATED BETWEEN THE CONVEYORS THAT FEED THE BELTS WHERE THE SALVAGE MATERIALS ARE SELECTED BY SCAVENGERS MANUALY; AFTER THAT, AND BEFORE GOING THROUGH THE HAMMERMILL'S THERE IS A MAGNETIC SEPARATOR, AFTER THE MILL'S THE WASTES ARE DEPOSITED IN A VIBRATING SCREEN, IN ORDER TO SEPERATE THE WASTE NOT SUITABLE FOR COMPOSTING, WHICH CONSISTS MAINLY OF PARTICLES GREATER THAN FOUR INCHES.

THE WASTES ARE THAN PASSED THROUGH THE SCREEN AND THE DISTRIBUTION BRIDGE IN THE PRE-DIGESTION FIELD TO FORM WINDROWS. AFTER THREE MONTHS THE COMPOST IS FORMED BY AN AEROBIC PROCESS. AFTER THAT, AND DEPENDING ON THE MARKET, THERE IS ANOTHER MILL FOR FINE MILLING TO GET COMPOST WITH VERY GOOD PRESENTATION.

III.- SOLID WASTE CHARACTERISTIC IN MEXICO

IN MEXICO, THE SOLID WASTE GENERATED VARIES, BUT IT IS POSSIBLE TO PUT IT INTO THREE MAIN GROUPS: ONE, THE REGION IN THE BORDER WITH THE UNITED STATES OF AMERICA, WITH ALMOST ONE KILOGRAM PER CAPITA; THE CENTRAL PART OF THE COUNTRY WITH A GENERATION PER CAPITA OF AROUND 650 GRAMS AND THE SOUTHEAST WITH ABOUT 550 GRAMS PER CAPITA.

THE AVERAGE COMPOSITION IN THE SOLID WASTE GENERATED IN MEXICO FOR THE THREE GROUPS IS PRESENTED IN TABLE NO. 1, IN THIS TABLE IT IS POSSIBLE TO SEE THE GREAT DIFERENCE IN THE COMPOSITION OF THE SOLID WASTE GENERATED IN DEVELOPING COUNTRIES AND IN DEVELOPING COUNTRIES. MAINLY THE ORGANIC MATTER VARIES FROM 45 UP TO 60 PERCENT BY WEIGHT, AND IT IS ONLY POSIBLE TO GET 25 TO 30 PERCENT OF SALVAGE MATERIAL, THE

TABLE No. 1.- AVERAGE COMPOSITION OF THE MEXICAN REFUSE

RECUPERATED MATERIAL	PERCENTAJE BY WEIGHT	PERCENTAJE OF RECOVERING
CARDBOARD	4.10	70
PAPER	9.63	45
COLOR GLASS	3.40	75
WHITE GLASS	4.25	71
CANS	2.52	60
FERROUS MATERIAL	0.76	60
NON FERROUS MATERIAL	0.60	40
TETRAPACK	1.66	50
BONES	0.80	50
PLASTIC FILM	3.42	55
RIGID PLASTIC	2.28	55
DIAPERS	3.66	--
RAGS	1.94	60
ORGANIC MATTER	44.70	60
OTHER	16.28	--

REST IS MATERIAL WITH NO POSIBILITY OF RECUPERATION BECAUSE OF ITS CHARACTERISTICS OR THE DIFICULTY TO RECOVER THEM.

IV.- ANALYSIS AND EVALUATION OF THE RECYCLING AND COMPOSTING PLANTS IN MEXICO.

THE MAIN PROBLEMS DETECTED IN THE DIFERENT PLANTS IN MEXICO CAN BE RESUMED IN THE FOLLOWING:

4.1.- FEASIBILITY STUDIES

A.- POOR JUDGMENT IN DIFINING THE WASTE LOAD AND ITS CHARACTERISTICS, INCLUDING THEIR SEASONAL QUALITATIVE AND CUANTITATIVE CHANGES.

B.- THE INADEQUACY OF SAMPLING PROGRAMS USED HAVE RESULTED IN AN UNREAL FORECAST OF THE RECOVERY POTENTIAL OF THE SOLID WASTE.

C.- THE QUALITY, QUANTITY AND MARKETABILITY OF SALVAGE MATERIALS WERE PREDICTED OUT OF THE SAMPLING PROGRAMS WITH THE APPLICATION OF FICTITIOUS FACTORS OF EFFICIENCY.

D.- THE FLUCTUATION OF THE SECONDARY MATERIALS MARKET WAS UNDERESTIMATED.

E.- NO ATTEMP WAS MADE TO CREATE A MARKET FOR THE COMPOST. THE ASSUMPTION WAS THAT THIS WAS NOT AN ISSUE.

F.- THE REDUCED MARKET AND VALUE OF WET OR DIRTY RECOVERED MATERIALS WAS NO CONSIDERED IN THE REVENUE PROJECTIONS.

G.- THE GREAT IMPACT OF ON-ROUTE SCAVENGING -SPECIALLY VALUABLE PRODUCTS AS CARDBOARD, GLASS BOTTLES AND ALUMINIUM CANS- WASNOT CONSIDERED IN THE PROJECTIONS OF RECLAMATION AND SALES OF SALVAGED MATERIALS.

H.- AT THE FIRST PLANT, THE LACK OF EXPERIENCE WAS NOT CONTEMPLATED, THE PEOPLE GOT EXPERIENCIE BY THEIR OWN EFFORT AND VARIOUS COSTLY MISTAKES WERE MADE.

I.- THE OPENING OF IMPORTS FROM USA FOR USED COMPUTER PAPER, PAPER, CARDBOARD AND METALS, LOWER THE PRICES IN MEXICO FOR THIS TYPE OF SALVAGED MATERIALS.

J.- THE DECISSION TAKERS BELIVED ALL THE PLANT SALESMEN SAID. EXPERIENCE SAYS THAT ALMOST ALL WAS FALSE.

K.- NO COMERCIALIZATION PROGRAMS WERE MADE.

4.2.- COMPOST PLANT DESIGN

A.- THE STORAGE PITS WERE BUILT IN SUCH MANNER THAT IT IS ALMOST IMPOSSIBLE TO MANTAIN THEM IN A GOOD AND SANITARY CONDITION.

B.- IN THE MEXICO CITY COMPOSTING PLANT, THE ONLY WAY TO FEED THE CONVEYORS IS BY THE CLAM CRANE, IF THIS IS OUT OF WORK THE PLANT STOPS.

C.- AFTER THE FIRST PLANT IN GUADALAJARA, VERY LITTLE EXPERIENCIE WAS PUT IN THE CORRECTION OF THE DESIGN DEFECTS OF THE PLANTS.

D.- THE CLAM CRANE SYSTEM BEING USED TO FEED THE PLANTS HAS PROVEN INEFFECTIVE AND UNRELIABLE.

E.- THE PITS FOR THE CONVEYOR THAT FEEDS THE SELECTION AREA PRESENTS DEFICIENCIES FOR THE CHARACTERISTICS OF THE MEXICAN WASTE, AS THE WASTE TENDS TO FORM AN ARCH AND IT IS ALMOST IMPOSSIBLE TO FEED.

F.- THE AUTOMATED FEED CONTROL SYSTEM ON THE FEEDER CONVEYOR AND THE FEED CONTROL SYSTEM FOR THE SELECTION BELT DON'T GIVE POSITIVE RESULTS FOR THE MEXICAN REFUSE.

G.- THE BELT CONVEYOR IN THE SEPARATION AREA TENDS TO BUCKLE, AND IS TOO WIDE FOR THE MANUAL SELECTION OF MATERIALS.

H.- THE SPEED OF THE CONVEYOR IN THE SELECTION AREA, AS DELIVERED BY THE MANUFACTURER, WAS TOO FAST FOR THE SCAVENGERS TO PROPERLY SELECT RECYCLABLE MATERIALS.

I.- THE BELT IN THE SELECTION AREA DID NOT HAVE THE LENGTH TO GIVE THE NECESARY TIME TO GET THE SALVAGE MATERIALS.

J.- THE PLANT'S TWO VERTICAL HAMMERMILLS ARE A SOURCE OF CONSTANT MAINTENANCE PROBLEMS AND VERY EXPENSIVE REPAIR COSTS. THE HAMMERS WEAR OUT VERY QUICKLY DUE TO THE HIGH ABRASSIVENESS OF MEXICAN REFUSE, AND HAVE TO BE REPLACED OR REVITALIZED ALMOST EVERY SHIFT.

K.- MECHANICAL FAILURES OF THE DISTRIBUTION BRIDGE IN THE PRE-DIGESTION FIELD CAUSES THE CONDITIONED REFUSE TO RUN OUT OF CONTROL MAKING IT DIFFICULT TO MANAGE.

L.- THE FINE MILLING MILL IS TOO SMALL FOR THE PLANT'S PRODUCTION.

4.3.- OPERATION

A.- THE PLANT, NOT BEING DESIGNED FOR MEXICAN REFUSE, IS HARD TO MAINTAIN, GENERATING SEVERE OPERATION PROBLEMS, MAINLY IN CONVEYOR BELTS AND HAMMERMILLS.

B.- THE ABSENCE OF A PROGRAM OF INCENTIVES FOR THE PEOPLE IN THE SEPARATION BELT, CAUSES LOW EFFICIENCIES IN THE SEPARATION OF THE MATERIALS.

C.- THE HANDLING OF RECOVERED MATERIALS WAS NOT DONE EFFICIENTLY, LOWERING THE PRICE OF THE SALVAGED MATERIALS (DUE TO MIXING), AND INCREASING THE COSTS OF OPERATION.

D.- NOISE LEVELS ARE HIGH IN THE SEPARATION AREA, PARTIALY DUE TO THE KNOCKING OF THE MATERIAL WITH THE STEEL HOPPERS AND WHEN THEY FALL TO THE LOWER FLOOR. ALSO BECAUSE THE LACK OF ISOLATION ON THE HAMMERMILLS.

E.- THE LACK OF LABORATORY FACILITIES PRECLUDES THE ADEQUATE CONTROL OF THE COMPOSTING PROCESS. (EXCEPTION MEXICO CITY).

V.- CONCLUSIONS AND RECOMENDATIONS

5.1.- CONCLUSIONS

A.- THE COMPOSTING PLANTS IN MEXICO HAVE NOT HAD THE SUCCESS SALESMEN CLAIM.

B.- THE PART RELATED WITH THE SEPARATION OF RECOVERABLE MATERIAL OUT OF THE REFUSE SHOW THAT WE NEED MORE RESEARCH AND DEVELOPMENT TO IMPROVE A SEMI MECHANIZED SEPARATION MORE IN ACCORDANCE WITH THE CHARACTERISTICS OF MEXICAN WASTES.

C.- THE USE OF COMPOST AS A SOIL IMPROVEMENT AGENT IN SOME OF SOILS FOUND IN MEXICO HAS GIVEN GOOD RESULTS.

D.- THE OFFER OF COMPOST IS GREATER THAN THE DEMAND.

E.- THE SEPARATION OF MATERIAL ON ROUTE IN THE COLLECTION TRUCKS HAVE A SERIOUS IMPACT IN THE ECONOMY OF THE PLANTS.

F.- THE HAMMERMILLS HAVE SERIOUS MAITENANCE PROBLEMS DUE TO THE GREAT CONTENT OF ORGANIC MATTER.

G.- THE LACK OF MARKETS MECHANISMS OF COMPOST DERIVED IN A FAILURE OF SALES.

H.- THE ADMINISTRATION BY MUNICIPALITIES HAS NOT BEEN EFFICIENT.

5.2.- RECOMENDATIONS

A.- THE DECISSION TO INSTALL COMPOSTING PLANTS MUST BE ASSESED BY EXPERTS ON THE BASIS OF REALISTIC TECHNICAL AND ECONOMICAL FEASIBILITY STUDIES, AND NOT BECAUSE OF SALESMEN BLUFF AND POLITICAN'S DECISSIONS.

B.- A TRAINING PROGRAM MUST BE PROVIDED BY THE MANUFACTURER PRIOR TO STARTING PLANT OPERATION.

C.- THE SALVAGED MATERIAL MUST BE SEPARATED AND CLEANED TO GET BETTER PRICES IN SALES.

D.- THE COMPOST MUST BE PRODUCED ACCORDING TO DEMAND.

E.- A GOOD PROGRAM OF MAINTENANCE AND INCENTIVES FOR THE PERSONNEL IS A MUST. THE EXPERIENCE OF OTHER PLANTS EXISTING UNDER SIMILAR CONDITIONS MUST BE TAKEN INTO ACCOUNT.

F.- IF IT IS IMPOSSIBLE TO AVOID THE PRESELECCION ON THE COLLECTION TRUCKS DUE TO LABOR UNION PRESSURES OR OTHER FACTORS, THE ADMINISTRATION OF THE PLANT MUST BUY THE PRESELECTED MATERIALS.

G.- ONLY FOR REMARKS, THE COMPOST IS NOT A FERTILIZER, IT IS ONLY A SOIL IMPROVEMENT AGENT.

H.- THE COMPOSTING PLANTS ARE NO PANACEA, NO ONE IN MEXICO HAS HAD ECONOMICAL BENEFITS, AS NOT EVEN OPERATION COSTS HAVE BEEN RECOVERED.

I.- THE RECYCLING PROGRAMS IN MEXICO ARE INCREASING.

J.- THE ECOLOGICAL CULTURE IS GROWING INTO THE POPULATION, THIS DEMANDS THAT PUBLIC OPINION BE INFORMED OF REAL ALTERNATIVES TO SOLVE PROBLEMS, IN ORDER TO AVOID FUTURE FIASCOS.

K.- THE GROWTH OF ECOLOGICAL CULTURE MUST BE TAKEN ADVANTAGE OF, IN ORDER TO INCREASE THE PARTICIPATION OF PEOPLE IN RECYCLING PROGRAMS.

L.- THE PLANTS COULD BE MANAGED AS AN ENTERPRISE, IF THE DESIGN IS IN ACCORDANCE WITH THE KIND OF REFUSE GENERATED IN MEXICO AND WITH TECHNOLOGIES THAT ADAPT TO THE SOCIAL AND ECONOMICAL CONDITIONS OF THE COUNTRY.

A CRITICAL EXAMINATION OF THE RELATIONSHIP BETWEEN CONVENIENCE AND RECOVERY RATES IN RESIDENTIAL RECYCLING PROGRAMS

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

It is almost universally assumed that if participation in a recycling program is made more convenient, a higher rate of recovery will result. In fact, this "convenience assumption" is so compelling that people readily accept it without asking for supporting evidence. It is not surprising, therefore, that very little evidence of the validity of the convenience assumption has been developed. What is surprising, perhaps, is that when quantitative analysis of recovery rates is performed, some of the results cast doubt on the validity of the convenience assumption rather than confirming it.

BACKGROUND FOR THIS PAPER

During 1989 Camp Dresser & McKee was retained by Morris County, New Jersey to evaluate the recycling system in the county and recommend County initiatives to optimize the system. The authors of this paper had primary responsibility for the technical aspects of the Morris County study. One of the issues in the study was whether households served by a countywide collection system should be required to set out each targeted material in separate containers. Another issue was how often the materials should be picked up. This paper grew out of the Morris County study.

Sorted materials set out in multiple containers generally cost more to collect than commingled materials set out in a single container. However, sorted materials are worth much more than commingled materials. The value gained by having residents sort their recyclable materials may be substantially greater than the additional cost of collecting sorted materials. With respect to collection frequency, cost per ton generally decreases as collection becomes less frequent. This is because more material is picked up for the same distance travelled. Therefore, the most economical recycling program could be one in which completely separated materials are picked up infrequently.

A major question is whether people will participate in such a program. In an attempt to answer this question, the experience of the municipal recycling programs in Morris County was evaluated.

Morris County is an affluent suburban county in north-central New Jersey with a population of just over 400,000 persons. Essentially all residential solid waste generated in the county passes through two transfer stations with identical tipping fees of approximately $120 per ton. Therefore, the economic incentive to recycle is similar throughout the county.

A broad range of recycling programs is found among the 39 municipalities of Morris County. Collection frequency ranges from monthly to twice weekly. Some municipal programs that provide collection of recyclables require complete separation of materials at the curb, including clear, brown and green glass. Other municipal programs allow complete commingling of materials. Still other programs provide no pickup, relying on residents to bring recyclable materials to dropoff centers.

Residential recovery rates for aluminum beverage cans and glass food and beverage containers achieved by the municipal recycling programs in the county were examined. Commercial recycling was excluded from this analysis because (1) more than one approach to source separation is used by the private haulers serving the commercial sector in many municipalities, and (2) even if only one approach is used in the commercial sector, it may not be the same approach used in the residential sector. Aluminum cans and glass containers were chosen for analysis because they are collected in all municipalities in the county. Newspaper is also collected in every municipality, but was excluded from the analysis because it is kept separate from glass and aluminum in all programs.

RECOVERY RATES USING DIFFERENT APPROACHES TO SOURCE SEPARATION

Table 1 shows the combined recovery rates for glass containers and aluminum cans achieved by groups of Morris County municipalities in 1988 using different approaches to source separation. All averages shown in this table and in the other tables in this paper are weighted by population. Boonton Borough has been excluded because its reported per-capita residential recycling rate for glass and aluminum is almost twice as high as the second highest municipality in the county. This indicates that the recycling rate for Boonton Borough is so strongly influenced by factors other than its approach to source separation that its inclusion in the analysis would make the results less meaningful. Mount Arlington and Mine Hill have been excluded for the opposite reason: the recovery rates in these municipalities are so low that they cannot be considered reflective of the approach to source separation used.

Table 1 indicates that, on average, Morris County municipalities providing curbside collection achieved approximately the same residential recovery rate whether they required complete sorting, partial sorting, or no sorting by residents. The municipalities providing dropoff centers but no curbside collection achieved an average recovery rate approximately 20 percent lower than those providing curbside collection. As shown by the "highest recovery rate" column, individual municipalities achieved high recovery rates using all four approaches. The high standard deviations reflect the great variability within source separation categories.

It has been suggested that people higher on the socio-economic scale are more likely to participate in recycling programs, and may also be more willing to keep the various recyclable materials separate. Therefore, according to this argument, the success of municipal programs requiring complete sorting of materials may be a reflection of the affluence of the residents of the municipalities that have implemented those programs.

As shown by table 1, the municipalities in Morris County that required complete sorting of glass and aluminum by residents in 1988 have an average per-capita income approximately 10 percent higher than that of the municipalities that allowed their residents to commingle glass and aluminum. However, both groups of municipalities are highly affluent.

Residential recovery rates were also examined in Middlesex County, a mixed urban, suburban and rural county in central New Jersey with an average income per capita 20 percent lower than that in Morris County. Table 2 shows the residential recovery rates achieved by groups of Middlesex County municipalities in 1988 using three different approaches to source separation: curbside pickup of commingled materials, curbside pickup of sorted materials, and dropoff centers with no curbside pickup. Piscataway and South Brunswick were excluded from this analysis because

TABLE 1

COMBINED GLASS AND ALUMINUM RECOVERY RATES ACHIEVED IN MORRIS COUNTY IN 1988 USING DIFFERENT APPROACHES TO SOURCE SEPARATION (a)

Approach to source separation	Number of munici-palities	Population represented (1988 estimate)	Average income per capita (1985)	Average recovery rate (lb/cap/yr)	Highest recovery rate (lb/cap/yr)	Lowest recovery rate (lb/cap/yr)	Standard deviation
Curbside, commingled	6	122,103	$17,462	49.4	79.3	34.4	14.9
Curbside, semi-sorted (b)	4	37,595	$12,840	53.3	76.7	39.9	13.8
Curbside, sorted (c)	14	165,560	$19,220	50.1	86.4	29.4	17.2
Drop-off center only	12	79,698	$18,733	41.2	91.3	20.8	19.3

(a) From residential sources only. Boonton Borough, Mt. Arlington, and Mine Hill not included.

(b) Mixed glass separated from aluminum.

(c) Glass separated from aluminum and sorted by color.

Sources: For source separation methods and amounts recovered--Morris County Municipal Utilities Authority and municipal officials. For population estimates, New Jersey Department of Labor. For per-capita income, U.S. Bureau of the Census.

TABLE 2

COMBINED GLASS AND ALUMINUM RECOVERY RATES ACHIEVED IN MIDDLESEX COUNTY IN 1988 USING DIFFERENT APPROACHES TO SOURCE SEPARATION (a)

Approach to source separation	Number of munici-palities	Population represented (1988 estimate)	Average income per capita (1985)	Average recovery rate (lb/cap/yr)	Highest recovery rate (lb/cap/yr)	Lowest recovery rate (lb/cap/yr)	Standard deviation
Curbside, commingled	9	400,438	$13,059	33.7	54.5	12.5	14.3
Curbside, sorted (b)	7	111,010	$13,380	39.9	68.2	28.4	12.7
Drop-off center only	7	72,203	$15,019	32.2	76.3	5.9	21.9

(a) From non-commercial sources only. Piscataway and South Brunswick not included.

(b) In six programs, glass was separated from aluminum and sorted by color. In one program, glass was mixed but separated from aluminum.

Sources: For source separation methods and amounts recovered--Middlesex County Department of Solid Waste Management. For population estimates, New Jersey Department of Labor. For per-capita income, U.S. Bureau of the Census.

they each used two different approaches to source separation during significant parts of the year. In addition, aluminum recovery by Cranbury was excluded because it represents 19 percent of the aluminum recovered in the county even though Cranbury has less than 0.5 percent of the county population. This indicates that Cranbury's aluminum recycling is primarily the result of factors other than its approach to source separation.

As indicated by table 2, the Middlesex County municipalities that required their residents to sort glass and aluminum achieved a slightly higher average recovery rate than the municipalities that allowed residents to commingle these materials. As in Morris County, the municipal programs that did not provide curbside collection achieved the lowest average recovery rate. However, also as in Morris County, the highest of all the municipal recovery rates was reported by a municipality not providing curbside collection. The high standard deviations reflect the great variability within each source separation category.

In Middlesex County, the average income per capita is essentially the same for municipalities that required sorting in 1988 and for those that allowed commingling. Therefore, the higher average recovery rate achieved by the municipalities requiring sorting cannot be explained based on greater affluence in these communities.

Per-capita income is substantially lower in Middlesex County than in Morris County, and the average recovery rates are also substantially lower. However, it would be a mistake to conclude without further analysis that the difference in recovery rates can be explained by the difference in incomes. In Middlesex County, residential solid waste is disposed of in two in-county landfills where the tipping fees are approximately half the tipping fee at the Morris County transfer stations. Lacking a landfill of their own, Morris County residents are particularly mindful of the need to develop alternatives to landfilling.

To the south and east of Middlesex County lies Monmouth County, a suburban and rural area with an average per-capita income slightly higher than Middlesex but still significantly lower than Morris. An analysis of the recovery rates achieved in Monmouth County using different approaches to source separation was performed by Scott McGrath when he was with the Monmouth County Planning Board (Mr. McGrath is now with Gannett Fleming, Inc., King of Prussia, Pennsylvania). McGrath identified four degrees of separation required by municipalities providing curbside collection of glass containers, aluminum cans, and tin cans:

- Complete commingling, a one-container system.
- Commingling of glass with separation of aluminum and tin cans, a three-container system.
- Commingling of aluminum and tin cans with separation of glass by color, a four-container system.
- Complete separation of aluminum and tin cans and glass by color, a five-container system.

In analyzing data from the second, third and fourth quarters of 1988, McGrath found that the greater the number of containers required, the higher was the average per-capita recovery rate. When all four approaches to source separation were compared using analysis of variance, the differences among the average recovery rates were not found to be statistically significant. However, statistical analysis (a two-sample "Z" test) indicated that the average recovery rate achieved by the municipalities using the five-container system was significantly higher than the combined average recovery rate achieved by the municipalities using the other three approaches.

It should be noted that McGrath was able to exclude only a portion of the materials recovered from commercial sources from his analysis. Therefore, it is reasonable to assume that some of the material credited to each source separation system was actually recovered through different systems used by private haulers in the same municipalities.

The year 1988 was the first full year in which recycling programs were fully implemented in a large number of New Jersey municipalities. Therefore, data from 1989 and subsequent years will be very significant to the issues addressed in this paper. However, data from 1989 are still preliminary if they are available at all.

Table 3 shows the same information as table 1, but based on preliminary Morris County data for 1989. The preliminary data show the commingling municipalities with an average recovery rate approximately 11 percent higher than the municipalities requiring complete separation. The average per-capita incomes for these two groups of municipalities are quite similar. The very low numbers for commingling and complete sorting in the "lowest recovery rate" column indicate that the data may be incomplete. As in 1988, individual municipalities in each source separation category achieved high recovery rates.

RECOVERY RATES WITH DIFFERENT COLLECTION FREQUENCIES

The second major convenience factor examined in the Morris County study was frequency of pickup. Table 4 shows average recovery rates achieved by groups of Morris County municipalities using different collection frequencies. Zero collections per month indicates that a dropoff center is available but no curbside collection is provided.

The pattern of recovery rates is very similar to that in table 1. Municipalities providing curbside pickup achieved essentially the same average recovery rates whether pickup was weekly, monthly, or in between. Municipal programs with no curbside collection recovered approximately 20 percent less material. Again, the high standard deviations reflect the great variability within categories. Curiously, the municipalities providing only one pickup per month had the highest average per-capita income.

Table 5 shows the same information for Middlesex County. Here, the two municipalities providing weekly pickup achieved a substantially higher average recovery rate than the municipalities in the other three categories. These two municipalities also have a somewhat higher average

TABLE 3

COMBINED GLASS AND ALUMINUM RECOVERY RATES ACHIEVED IN MORRIS COUNTY IN 1989 USING DIFFERENT APPROACHES TO SOURCE SEPARATION (a)

Approach to source separation	Number of munici-palities	Population represented (1988 estimate)	Average income per capita (1985)	Average recovery rate (lb/cap/yr)	Highest recovery rate (lb/cap/yr)	Lowest recovery rate (lb/cap/yr)	Standard deviation
Curbside, commingled	10	159,858	$16,798	50.7	88.7	17.2	19.6
Curbside, semi-sorted (b)	2	15,074	$11,970	70.8	83.9	69.8	7.0
Curbside, sorted (c)	17	177,496	$17,764	45.5	93.6	8.9	20.4
Drop-off center only	7	52,528	$22,297	43.2	84.1	29.6	18.7

(a) From residential sources only. Boonton Borough, Mt. Arlington, and Mine Hill not included.

(b) Mixed glass separated from aluminum.

(c) Glass separated from aluminum and sorted by color.

Sources: For source separation methods and amounts recovered--Morris County Municipal Utilities Authority. For population estimates, New Jersey Department of Labor. For per-capita income, U.S. Bureau of the Census.

TABLE 4

COMBINED GLASS AND ALUMINUM RECOVERY RATES ACHIEVED IN MORRIS COUNTY IN 1988 USING DIFFERENT COLLECTION FREQUENCIES (a)

Collections per month	Number of munici-palities	Population represented (1988 estimate)	Average income per capita (1985)	Average recovery rate (lb/cap/yr)	Highest recovery rate (lb/cap/yr)	Lowest recovery rate (lb/cap/yr)	Standard deviation
0	12	79,698	$18,733	41.2	91.3	20.8	19.3
1	13	152,588	$19,256	49.8	76.4	29.4	15.3
2	4	53,606	$16,249	51.6	76.7	39.9	13.2
4	7	119,064	$15,697	50.0	86.4	32.2	18.6

(a) From residential sources only. Boonton Borough, Mt. Arlington, and Mine Hill not included.

Sources: For collection frequencies and amounts recovered--Morris County Municipal Utilities Authority and municipal officials. For population estimates, New Jersey Department of Labor. For per-capita income, U.S. Bureau of the Census.

TABLE 5

COMBINED GLASS AND ALUMINUM RECOVERY RATES ACHIEVED IN MIDDLESEX COUNTY IN 1988 USING DIFFERENT COLLECTION FREQUENCIES (a)

Collections per month	Number of munici-palities	Population represented (1988 estimate)	Average income per capita (1985)	Average recovery rate (lb/cap/yr)	Highest recovery rate (lb/cap/yr)	Lowest recovery rate (lb/cap/yr)	Standard deviation
0	6	70,930	$15,724	32.3	76.3	5.9	22.7
1	4	80,008	$12,353	39.5	52.2	25.1	11.2
2	11	370,113	$13,045	31.7	68.2	12.5	15.6
4	2	62,600	$14,540	49.3	54.5	42.5	6.0

(a) From non-commercial sources only. Piscataway and South Brunswick not included.

Sources: For collection frequencies and amounts recovered--Middlesex County Department of Solid Waste Management. For population estimates, New Jersey Department of Labor. For per-capita income, U.S. Bureau of the Census.

per-capita income than the municipalities providing one and two pickups per month.

Table 6, like table 3, is based on preliminary Morris County data from 1989. Frequency of pickup is still inversely proportional to average income, the opposite of the pattern in Middlesex County. The six municipalities providing at least weekly pickup achieved higher average recovery rates than the other groups of municipalities despite having lower average incomes. Nonetheless, the most affluent group achieved a comparable average recovery rate with only one pickup per month. This group also included the municipality with the highest recovery rate in the county.

The standard deviations in tables 3 and 6 are particularly high because of very low recovery rates for some municipalities. This is probably an indication of incomplete data.

CONCLUDING DISCUSSION

The Morris County and Middlesex County data evaluated in this paper do not indicate that allowing residents to commingle recyclable materials increases recovery rates. The data contain a suggestion that frequent pickup may tend to increase recovery rates, but are far from conclusive on this point. Individual municipalities in Morris County have achieved high recovery rates using a variety of approaches to source separation and the full range of collection frequencies.

If there is a message for recycling planners in the data from Morris and Middlesex counties, it is that they should give serious consideration to the less convenient but more economical forms their programs could take. Local, county, and regional officials should continue to design programs that reflect the specific circumstances of the municipalities they serve. They should not narrow their options by assuming that a recycling program must be convenient to succeed.

TABLE 6

COMBINED GLASS AND ALUMINUM RECOVERY RATES ACHIEVED IN MORRIS COUNTY IN 1989 USING DIFFERENT COLLECTION FREQUENCIES (a)

Collections per month	Number of munici-palities	Population represented (1988 estimate)	Average income per capita (1985)	Average recovery rate (lb/cap/yr)	Highest recovery rate (lb/cap/yr)	Lowest recovery rate (lb/cap/yr)	Standard deviation
0	5	37,558	$19,167	43.8	84.1	29.6	19.0
1	17	162,414	$19,523	49.0	93.6	11.0	20.5
2	8	110,997	$16,573	43.6	75.6	8.9	19.1
4	5	91,541	$15,096	54.2	88.7	35.0	22.1
8	1	2,446	$14,211	51.1	51.1	51.1	0.0

(a) From residential sources only. Boonton Borough, Mt. Arlington, and Mine Hill not included.

Sources: For collection frequencies and amounts recovered--Morris County Municipal Utilities Authority. For population estimates, New Jersey Department of Labor. For per-capita income, U.S. Bureau of the Census.

CUYAHOGA FALLS, OHIO'S INTEGRATION OF RECYCLING INTO SOLID WASTE COLLECTION

Patricia J. Smith
President, Waste Options

Presented at the the

First U.S. Conference on Municipal Solid Waste

June 13-16, 1990

CUYAHOGA FALLS OHIO'S INTEGRATION OF RECYCLING INTO SOLID WASTE COLLECTION

In Cuyahoga Falls, Ohio, like many other municipalities, we are changing our solid waste system to minimize the impact of skyrocketing disosal costs and to simultaneously protect the environment.

At the cornerstone of our new solid waste system is a voluntary, aggressive recycling comprehensive program that is integrated with the City's regular solid waste collection program.

Our successful recycling programs are not a panacea for the problems associated with solid waste disposal, but are ones that we can leave behind to make a better quality life for future generations.

Over 70% of Cuyahoga Falls residents now participate in recycling efforts and our City has diverted over 2,000 tons of recyclables from the waste stream in one year's time. The City has avoided paying over $70,000 in disposal costs!

In Cuyahoga Falls we don't want to be remembered as the throw-away generation that left our children a legacy of over indulgence and wasteful practices. But rather we have chosen to be remembered as the residents who sacrificed short-term convenience for long-term protection of the health and environment of the future.

OUTLINE

I. Overview of Solid Waste Dilemma

II. Discussion on landfill/waste-to-energy options

III. Reasons for integrating recycling into comprehensive solid waste management plans

IV. Overview of successful, aggressive public awareness/education campaign

a. media blitz; brochures, flyers, door-hangers

b. costumed characters; puppet shows

c. door-to-door efforts

d. school skits, assemblies, film strips, videos

e. recycling olympics

DESIGN OF MATERIALS RECOVERY FACILITIES (MRFs)

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Cal Recovery Systems, Inc.

Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

Abstract

The explosion in the demand for materials recovery facilities (MRFs) is straining the solid waste industry in terms of supplying reliable, efficient, and cost-effective recyclables processing systems. The design of MRFs is discussed, including the design criteria for the facilities, the available equipment, and system performance. The topic is approached in a broad context, addressing the processing of feedstocks in the form of singular recyclable components, of commingled recyclables, and of mixed municipal solid wastes.

Introduction

The design of a materials recovery facility (MRF) follows a series of basic considerations, which generally include the following:

1. Identifying the characteristics of the wastes to be processed.

2. Maximizing recovered product quality.

3. Maximizing diversion of wastes from landfill.

4. Utilizing proven system concepts.

5. Provision for receipt of municipal solid waste (MSW), based on the types and frequency of vehicles delivering the material.

6. Utilizing manual labor for those operations where current automation technology is lacking, unproven, or but marginally effective.

7. Establishing the throughput capacity, required availability, and desired redundancy for the system.

Materials recovery facilities can be classified into two general types based on the characteristics of the input municipal solid waste; namely source-separated or mixed. Taken here, source-separated wastes refer to those that are collected in singular (i.e., segregated) components or in commingled form (a mixture of several components, e.g., metal and glass containers). Mixed wastes are not separated prior to collection and obviously such a mixture contains numerous components.

Source-separated recyclables do not suffer from the higher degree of contamination from food wastes and other contaminants exhibited by recyclables in mixed MSW. Thus, the percentage recovery of recyclables from source-separated wastes is substantially greater than that from mixed wastes.

The following discussion considers first the design of a MRF for processing source-separated materials. Subsequently, the design of a MRF for processing mixed MSW is considered.

Source-Separated MSW

Process flow diagrams for a 120 TPD materials recovery facility project are shown in Figures 1 and 2, respectively, for a paper processing line and a container processing line. Each of these flow diagrams is also a mass balance showing the tonnages of the various recyclables as they enter and exit the system.

The process design in this example assumes that 25% of the available recyclables arrive at the facility in pre-segregated, singular form (e.g., tin cans) and that the remaining 75% is commingled. Each of the flow diagrams shows provision for redundancy in receiving, sorting, and processing.

Breakage and contamination generally amount to approximately 7 to 10% of the infeed total. Glass breakage during collection and material handling at the facility results in the loss of small particles of glass as residue, if markets for mixed colored cullet are not available. Contamination must be removed within the ranges dictated by the market specifications. Common contaminants include corrugated and magazines included with residential newspaper collections, and low-grade paper (such as envelopes with windows) in commercial high-grade paper collections.

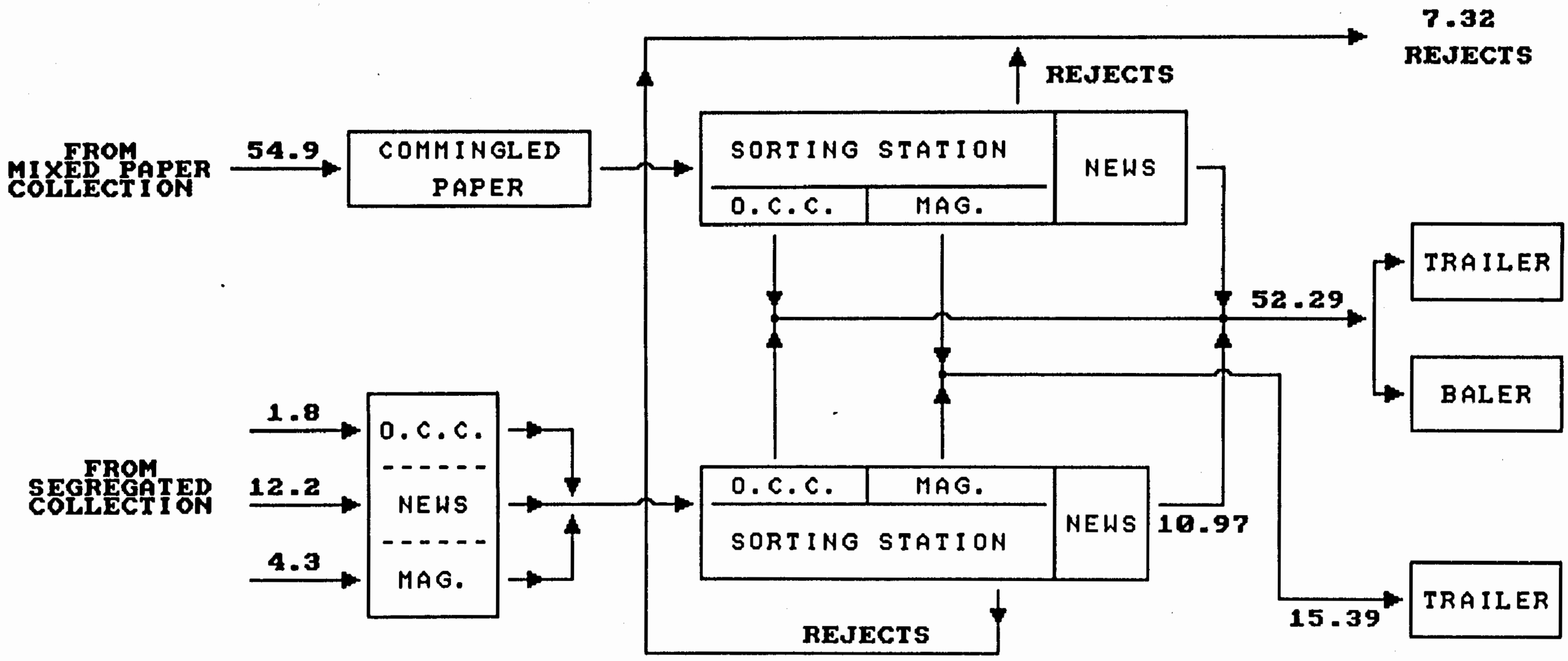
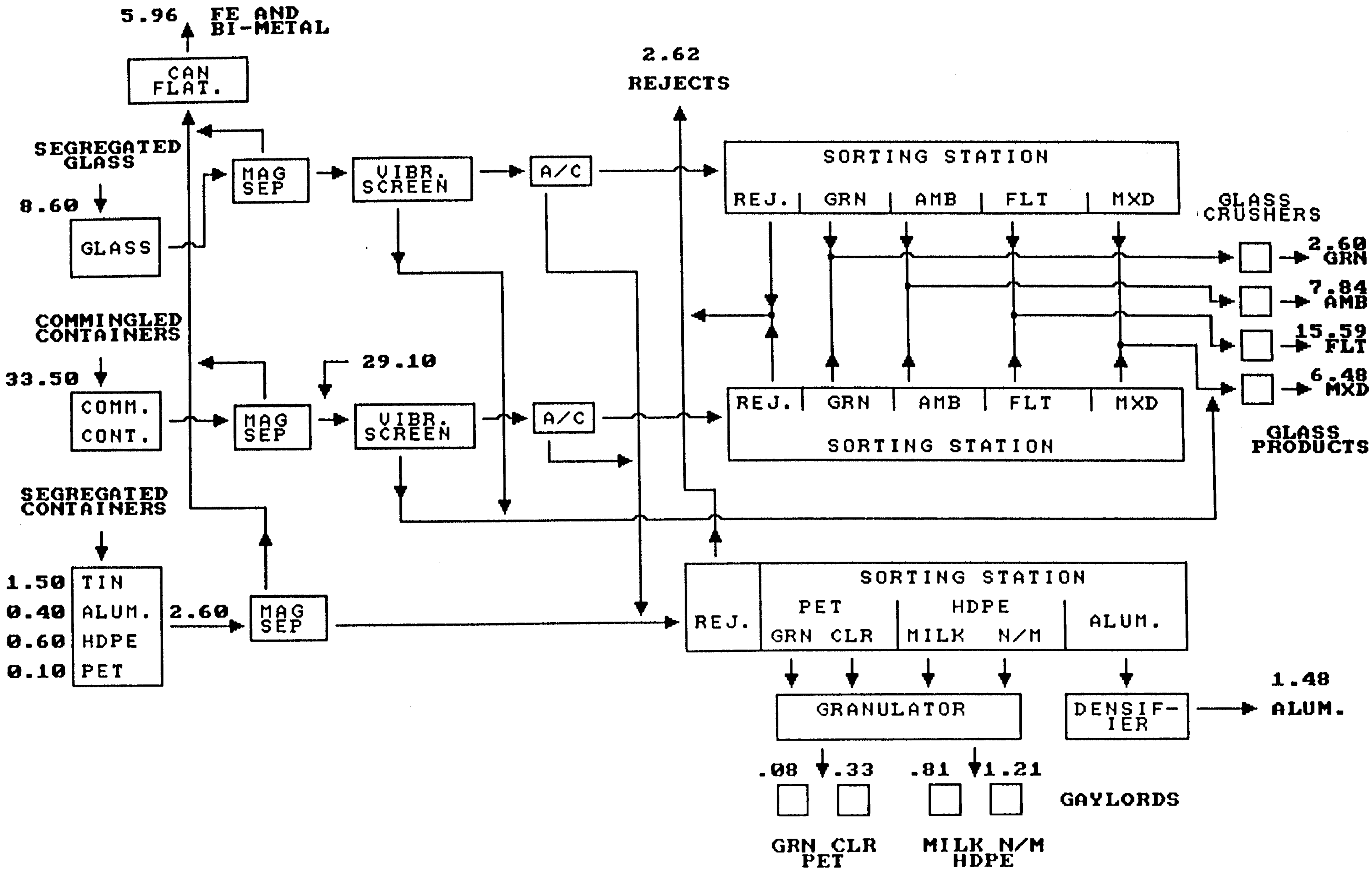


Figure 1. Paper Processing Line / Design Capacity = 75 TPD
75% Commingled Collection
25% Segregated Collection



5.96
FE AND BI-METAL
CAN FLAT.
SEGREGATED GLASS
8.60
GLASS
MAG SEP
VIBR. SCREEN
A/C
2.62
REJECTS
SORTING STATION
REJ.
GRN
AMB
FLT
MXD
GLASS CRUSHERS
2.60 GRN
7.84 AMB
15.59 FLT
6.48 MXD
COMMINGLED CONTAINERS
33.50
COMM. CONT.
MAG SEP
29.10
VIBR. SCREEN
A/C
REJ.
GRN
AMB
FLT
MXD
SORTING STATION
GLASS PRODUCTS
SEGREGATED CONTAINERS
1.50 TIN
0.40 ALUM.
0.60 HDPE
0.10 PET
2.60
MAG SEP
SORTING STATION
REJ.
PET
GRN CLR
HDPE
MILK N/M
ALUM.
GRANULATOR
DENSIF-IER
1.48
ALUM.
.08
.33
.81
1.21
GAYLORDS
GRN CLR PET
MILK N/M HDPE

Figure 3 is an example plan view of a facility matching the flow diagrams described above. The facility is designed to provide a high level of redundancy, both in paper processing and in container processing.

For the paper line, two receiving pits are shown and each line is capable of handling either the maximum anticipated mixed paper waste or the maximum anticipated segregated paper waste.

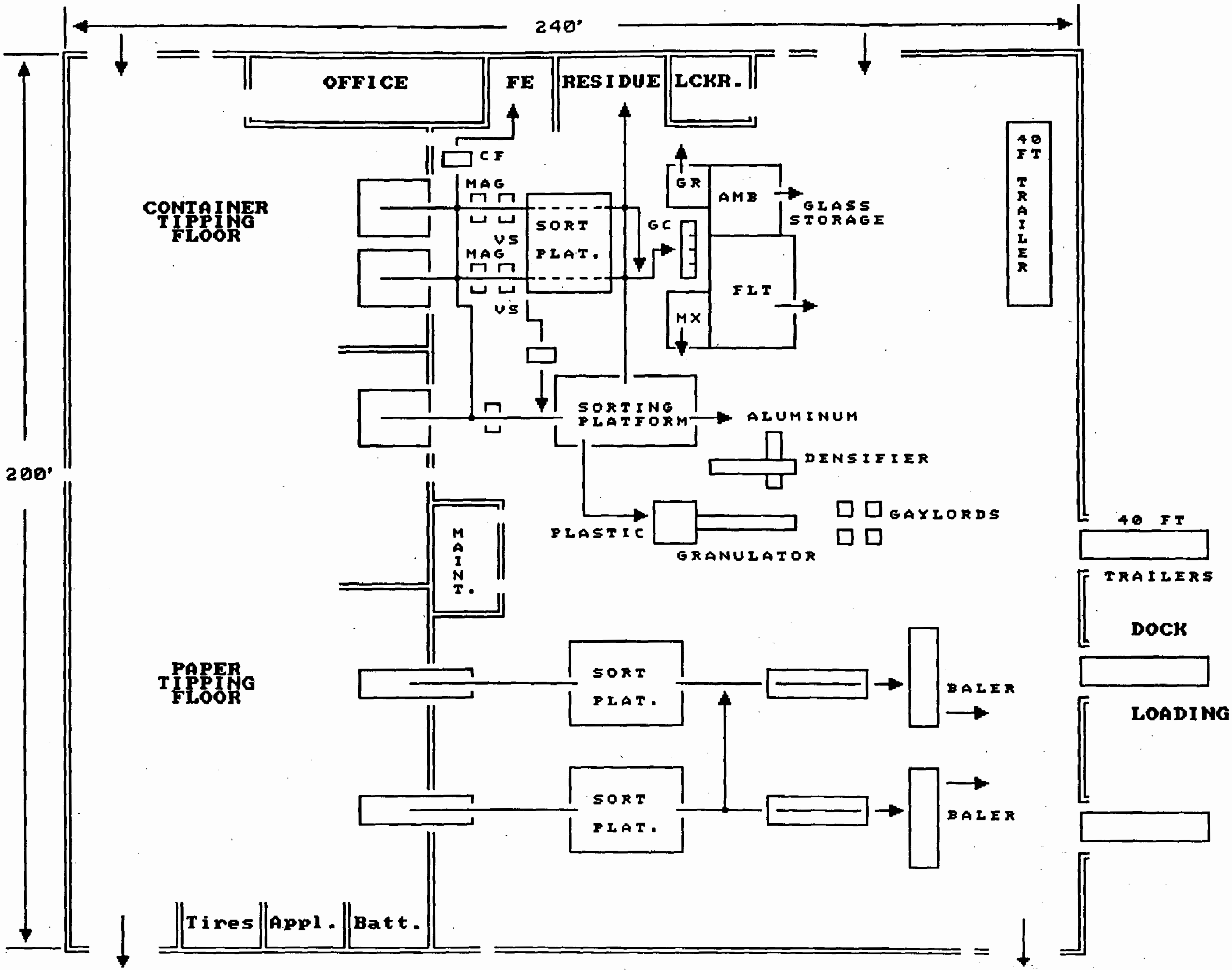
Similarly, for the container line, three receiving pits are shown. Two of the lines are totally redundant, with each capable of handling either the maximum anticipated mixed container waste or the maximum anticipated segregated container waste. The third line is provided to handle segregated plastic and aluminum containers exclusively.

The tipping floor and product storage areas are sized for a minimum of one day's storage of all materials.

This particular design provides for a facility with a minimum risk of downtime resulting from equipment failure. However, the provision of extensive redundancy is expensive. Substantial economies may be realized by eliminating redundant processing capability and operating on at least a two-shift basis. However, in any plant, machinery can and will break down. In the case of a plant with little or no redundancy, plans must be in place regarding how to meet anticipated breakdowns to minimize the effect of an outage.

Mixed MSW

Recyclable materials can be recovered in a mixed MSW processing facility. Such materials recovery facilities segregate and recover the recyclable components from the heterogeneous-mixture MSW. As opposed to MRFs processing commingled and segregated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40 FT TRAILER
CONTAINER TIPPING FLOOR
SORTING PLATFORM
ALUMINUM
DENSIFIER
GAYLORDS
PLASTIC
GRANULATOR
MAINT.
40 FT
TRAILERS
DOCK
LOADING
PAPER TIPPING FLOOR
SORT PLAT.
BALER
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Appl.
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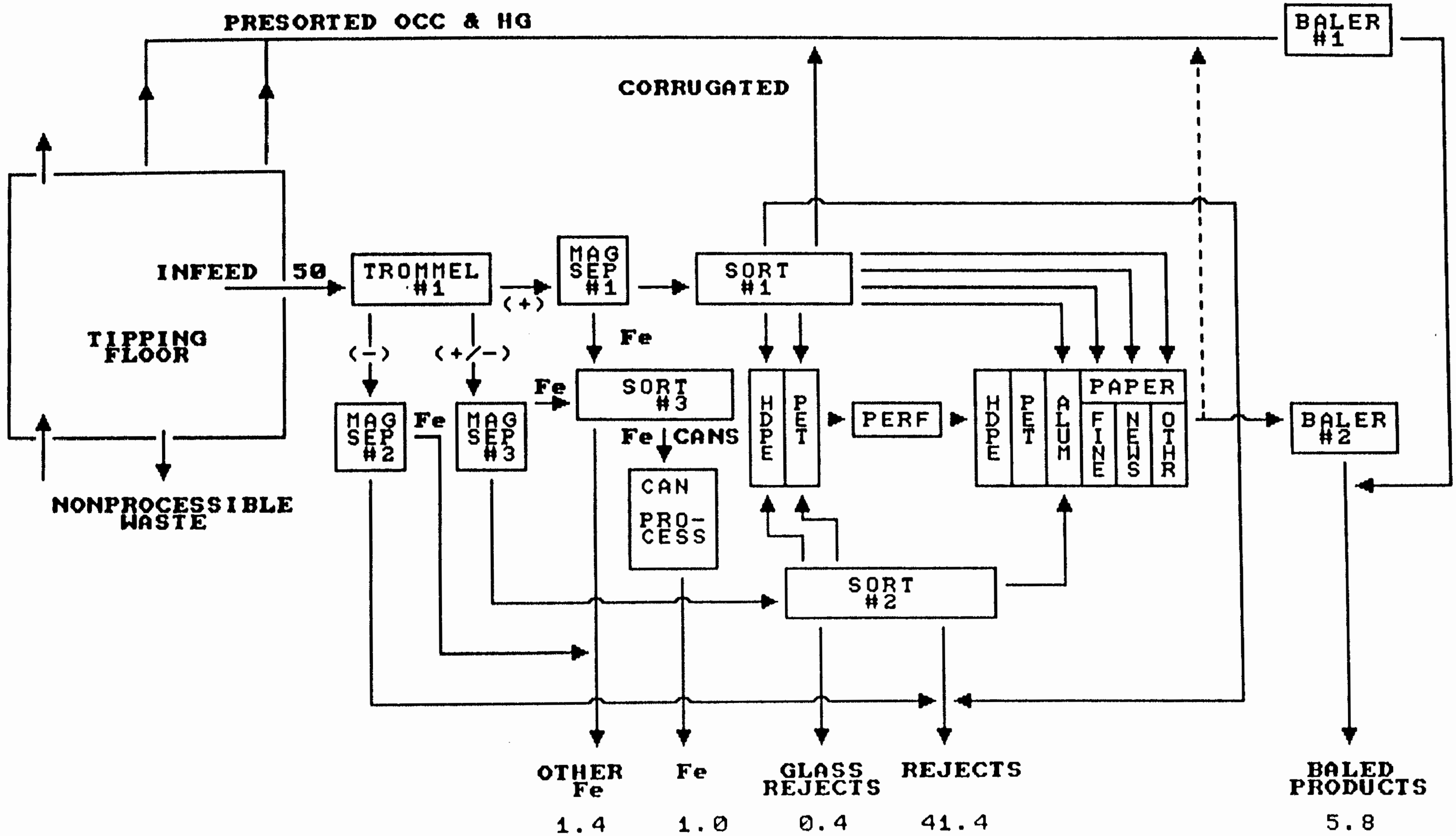
components wherein 90% or more of the input materials are recovered in the form of marketable end-products, MRFs processing mixed MSW can recover approximately 10 to 20% of the input in the form of marketable grades of metals, glass, plastics, and paper. Additional resource recovery can be achieved by integrating into the facility design additional processing operations to recover refuse-derived fuel (RDF) or a compostable feedstock. These options for integration can increase the total diversion to within the range of 75 to 85% if markets for the other materials exist.

An example of a materials recovery facility design configured for the primary purpose of processing and recovering recyclable materials from mixed municipal solid waste, including ferrous, HDPE, PET, aluminum, and several grades of paper, is presented in Figure 4. The processing capacity is assumed to be 50 TPH. The processing system incorporates both mechanical and manual separation processes in order to optimize the recovery of marketable secondary materials. The design recovers approximately 15% of the input mixed waste in the form of marketable grades of recyclables.

Wastes are assumed delivered to the facility via transfer trailers or refuse collection vehicles. A description of the facility design follows.

Wheel loaders and a picking crane are employed to remove large, heavy objects and other nonprocessibles from the waste stream prior to the waste entering the processing equipment.

Provision is made in the facility to segregate corrugated and other marketable waste paper grades by wheel loader that arrive in loads of waste composed predominantly of paper materials. When sufficient corrugated or other paper grades are removed on the tip


PRESORTED OCC & HG
BALER #1
CORRUGATED
INFEED
50
TIPPING FLOOR
TROMMEL #1
(+)
(−)
(+/−)
MAG SEP #1
MAG SEP #2
MAG SEP #3
Fe
SORT #1
SORT #3
Fe
Fe
CANS
CAN PROCESS
H D P E
P E T
PERF
H D P E
P E T
A L U M
PAPER
F I N E
N E W S
O T H R
BALER #2
SORT #2
NONPROCESSIBLE WASTE
OTHER Fe
Fe
GLASS REJECTS
REJECTS
BALED PRODUCTS
1.4
1.0
0.4
41.4
5.8

ping floor by wheel loader and accumulated, the materials are transported directly to a baler, bypassing the mixed waste processing equipment.

Mixed MSW is introduced to a two-stage primary trommel, with the first stage undersize material passing by a magnetic separator for ferrous extraction. The resulting process residue is routed to the output residue stream.

The primary trommel second-stage unders pass through a magnetic separator, where the ferrous is removed and conveyed to a sorting station. At the sorting station, ferrous from the trommel oversize material extracted by a magnetic separator joins the ferrous extracted from the second-stage trommel unders. Ferrous cans are sorted from other ferrous and sent to a can processing subsystem to provide a product with minimal contamination.

After passing through a magnetic separator, the primary trommel overs are conveyed to a second sorting station where HDPE, PET, aluminum, cardboard, and various paper grades are manually separated. When sufficient quantities of these materials are accumulated, they are processed by one of two balers. The second baler serves as a component of processing redundancy for the facility.

A third sorting station receives undersize from the second stage of the primary trommel after ferrous removal. HDPE and PET containers are manually sorted at this station, as well as aluminum and some high-grade paper. The remaining waste joins the waste from the sorting station processing the trommel oversize stream.

Substantial manual sorting is utilized for segregation of plastics and aluminum because manual sorting is efficient for recovering the various plastic polymers and aluminum beverage containers and because of the opportunity for employment development.

Additionally, mechanical and electro-mechanical separation systems for plastic polymers and aluminum materials are developmental for waste processing applications.

Process residues account for about 85% of the incoming solid waste. Much of the process residues are combustible and biodegradable organic materials. These materials require landfill disposal unless processed for energy recovery or converted to a compostable feedstock for subsequent composting. For example, if refuse-derived fuel recovery is integrated with materials recovery, the residue stream could be reduced to 15 to 25% of the input MSW.

Conclusions

The design of materials recovery facilities is dependent upon a number of considerations. One key consideration in the selection of appropriate facility designs is the form of the delivered feedstock, i.e., source-separated recyclables or mixed municipal solid waste. A second key consideration is the level of recycling or waste diversion that is required. Source separation programs (i.e., collection and processing) may achieve 20 to 30% diversion, while mixed waste processing may be required if diversion goals are 30% or greater. Of course, markets must be available for the recovered products in either case.

The impetus toward greater rates of waste diversion from landfills places a greater burden on the designer to efficiently and cost-effectively process and recover additional components of the waste stream. This paper has presented the rationale of process design and examples of facility designs to illustrate the variety of processing means available to achieve waste diversion.

THE DEVELOPING ROAD OF MATERIAL RECOVERY FACILITIES IN MUNICIPAL SOLID WASTE MANAGEMENT

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Presented at the

First U. S. Conference on Municipal Solid Waste Management

June 13 - June 16, 1990

WHY MRF'S

TAKE ADVANTAGE OF ECONOMIES OF SCALE:

- Collect large volumes from various generators
- Increase processing efficiency

- PRODUCE LARGE VOLUMES OF HIGH QUALITY, HIGH VALUE PROCESSED MATERIALS

- SECURE STABLE, LONG-TERM MARKETS

WHAT ARE MRF'S

FACILITIES DESIGNED AND EQUIPPED TO

- ACCEPT COMMINGLED AND SOURCE-SEPARATE RECYCLABLES
- ACCEPT RECYCLABLES FROM VARIOUS GENERATORS
- SEPARATE AND/OR PROCESS RECYCLABLES
- UPGRADE RECYCLABLES TO MEET MARKET SPEC IFICATIONS
- MARKET PROCESSED MATERIALS

FACILITY SITING

- SITE AVAILABILITY
- VEHICLE ACCESS
- INDUSTRIAL LOCATION
- AESTHETICS

FACILITY DESIGN

- BUILDING
- PROCESSING CAPACITY
    - Fibre
    - Commingled Containers
- RECEIVE MATERIALS AS COLLECTED:
    - Fibre
    - Commingled Containers
    - Source Separated
- TIPPING AREAS
- PROCESSING LINES
- STORAGE
- SHIPPING

OWNERSHIP/OPERATION SCENARIOS

- **PUBLICLY OWNED AND OPERATED**
- **PUBLICLY OWNED AND PRIVATELY OPERATED**
- **PRIVATELY OWNED & OPERATED**

DECISION - MAKING CRITERIA

- RESPONSIBLITY & ACCOUNTABILITY

- RISK AND REVENUE

- CONSTRAINTS & OPPORTUNITIES

FUTURE TRENDS

- LEGISLATIVE POLICY
  - Mandatory Programs
  - Taxes/Bans
  - Deposit Laws
  - Waste Management Hierarchy

- MARKETS & PRICES
  - Supply & Demand
  - Import & Export
  - Regional Marketing
  - Procurement

- TECHNOLOGICAL DEVELOPMENT
  - Recyclability
  - Rapid Evolution
  - Mixed Waste Recycling
  - Packaging

- TRANSPORTATION & DISPOSAL COST
  - Tipping Fees
  - Long Haul
  - Environmental Impacts

ECONOMIC FEASIBILITY OF RECYCLING IN THE MIDWEST: RECYCLING ALTERNATIVES IN OKLAHOMA

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Presented at the

First U.S. Conference on Municipal Solid Waste
U.S. Environmental Protection Agency

June 13-16, 1990

Introduction

EPA's Agenda for Action proposes a national goal of reducing municipal solid waste by 25 percent through source reduction and recycling.[1] This goal is reflected in recently proposed amendments to the federal Resource Conservation and Recovery Act (RCRA),[2] but it is not yet clear how this goal will be operationalized through federal mandates or incentives to states or municipalities. It is likely, however, that the costs of achieving such reductions could vary substantially among regions of the country.

In most municipalities in the Northeast, the added costs of recycling are more than balanced by recycling revenues and the avoided costs of diverting wastes from landfills and incinerators. Tipping fees in this region average $45 per ton and range as high as $120 per ton.[3] Outside the densely populated eastern states, however, the cost-effectiveness of recycling is less obvious. Average land disposal costs range from $13 to $16 per ton in states such as California, Texas, and Colorado, and suitable sites for additional landfills are more plentiful.

If federal legislation requires all states to adopt a 25 percent waste reduction goal and mandate recycling programs at the municipal level, political opposition could be substantial in municipalities where a substantial increase in solid waste management costs will result. If the federal law exempts municipalities that can show that recycling is less cost-effective than other means of solid waste management, achieving a 25 percent waste reduction goal may be very difficult. Under either approach, substantial financial incentives may be necessary to offset some of the initial costs of municipal recycling programs if waste reduction goals are to be achieved at the national level.

This paper offers a basis for assessing how achievable such a national goal might be in western and midwestern states. We present the results of a comparative assessment of the cost-effectiveness of curbside recycling and yard waste composting versus current land disposal systems in four communities in Oklahoma. The results also offer a means of estimating the level of financial subsidy that might be required as an incentive for promoting recycling in communities where land disposal remains more cost-effective.

Analyses were also conducted of municipal recycling options that rely on voluntary drop-off sites or buy-back centers. These typically achieve very low diversion rates on the order of 0.5 to 3.3 percent of the total municipal solid waste stream. Results of these analyses are not discussed here because of space limitations and the relatively low impact they are likely to have on achieving waste reduction goals. For details, see Deyle and Schade (forthcoming).[4]

Methodology

This study uses 20-year "life cycle" costs, or net present values, to compare the cost-effectiveness of curbside recycling and yard waste composting with continued operation of the current solid waste management system in each of the four case communities.[5] Community-specific data on current solid waste management systems are analyzed along with data from curbside recycling and yard waste composting programs in other communities across the country. Values for many of the cost and revenue variables extend over a substantial range. Therefore, base analyses were conducted using mid-range values, and sensitivity analyses were performed to assess the effects of varying individual variables.

Case Study Communities

The case study communities were selected to represent the range in conditions that characterize municipal solid waste management in Oklahoma. As shown in Table I, they range in size from the rural town of Fairview, with a population of 3,200, to Oklahoma City, the state's largest metropolitan area. Land disposal costs range from less than $8.00 per ton to about $12.50 per ton. Each of the communities has municipal collection of residential solid waste, with the exception of a portion of Oklahoma City that is served by a private hauler. Three of the communities use commercial landfills to dispose of their wastes. Fairview uses a regional facility operated by a public authority.

The Recycling Scenarios

For each of the communities, the life cycle cost of operating the existing municipal collection and land disposal system over a 20-year period, beginning in 1990, is compared with the life cycle costs of two recycling options:

(1) adding a municipal curbside recycling program to the existing solid waste management system and processing the recovered materials at a municipal materials recovery facility (MRF), and

(2) adding a separate curbside collection program for yard waste and composting the yard waste at a municipal facility.

Table I. Case study communities.

	Name of community			
	Oklahoma City	Norman	Owasso	Fairview
Population of the service area	447,850	79,500	12,000	3,200
Number of households in the service area	130,000	18,550	3,500	1,308
Annual waste generation (tons)	428,000	65,800	18,607	3,276
Proportion of residential waste in the total waste stream	41.6%	36.0%	24.1%	71.0%
Salary of collection workers including fringe benefits ($/year)	$20,400	$23,300	$16,433	$23,000
Average distance travelled per collection vehicle (once weekly pickup) (miles)	7,982	2,919	8,060	5,200
Number of garbage trucks used	33	19	2	1
Unit costs of waste collection ($/ton)	$38.20	$81.78	$71.00	$27.84
Remaining landfill capacity (years)	12	9	12	6
Landfill ownership	private	private	private	public
Average round trip time from a waste generation district to the processing facility (minutes)	45	35	10	50
Tipping fee in 1990 ($/ton) (if private landfill)	$7.69	$12.48	$12.00	$0.00
Unit costs of waste disposal ($/ton)(if public landfill)	$0.00	$0.00	$0.00	$8.79

Twenty years was selected as the period of analysis to account for the savings that will result by diverting wastes from disposal and extending the capacity of a municipally-owned landfill. The materials included in the curbside recycling scenario are aluminum cans, glass containers, and newspapers. Plastics and tin cans were excluded because of the current lack of firm markets in this region. It is assumed the curbside program involves weekly collection of commingled materials using dedicated recycling vehicles operated by a one-person crew. The city provides single recycling containers to each household served by the residential MSW collection system. Processing at the municipally owned and operated MRF includes crushing of aluminum cans and color-separated glass, and baling of newspapers.

The composting scenario assumes that yard wastes, including grass, leaves, and prunings, are picked up weekly on a separate day from other household refuse using existing packer trucks. Yard wastes are assumed to be placed at the curb in plastic bags that must be opened manually prior to composting. The composting operation is assumed to be a low-technology system that uses a front-end loader to create and turn windrows.

Life Cycle Cost Analysis

Life cycle cost analyses were conducted using a Lotus program designed for the project. The life cycle cost of a solid waste management system is the sum of the discounted net annual costs over the period of analysis. The net annual costs are the sum of the annualized capital and operating costs minus revenues. Costs and revenues in years beyond the base year are inflated using specific inflation rates for such cost components as labor, vehicles, fuel, and utilities. The formula for calculating life cycle cost can be represented as follows:

$$LCC = \sum_{n=1}^{N} \frac{[A + OC * (1+c_o)^{(n-1)} - REV * (1+c_r)^{(n-1)}]}{(1+d)^{(n-1)}} \qquad (1)$$

where: LCC = life cycle cost
A = annualized capital costs
OC = operating costs
c_o = inflation rate for operating costs
REV = revenues from the sale of recovered materials
c_r = inflation rate for secondary materials prices
d = discount rate (in percent)
n = year of analysis
N = total period of analysis in years

The annualized capital costs (A) are the sum of costs to retire the debt for initial capital expenditures and payments to a reserve fund for replacing equipment. It was assumed that municipalities issue general obligation bonds to pay for the initial capital costs of recycling. For a more detailed explanation of how these cost components were calculated, see Schade and Deyle (in preparation).[6]

Cost Components

The individual cost components for a solid waste management system include the following:

- MSW collection and transport
- MSW disposal
- curbside collection of recyclables or yard waste
- processing recyclables or composting yard waste
- revenues from recovered materials.

Cost components for the existing municipal solid waste management system only include MSW collection and transport and MSW disposal. The recycling and composting scenarios include these costs, adjusted to account for the diversion of materials into the recycling system, plus costs for curbside collection of recyclables or yard waste, operation of the processing or composting facility, and promotion of the collection program. The recycling and composting systems also include revenues from the sale of recovered materials.

The individual variables employed in the analysis are listed in Table II. For some variables a range of values was used, either because the values are subject to fluctuation over time (for example market prices for recovered materials) or because it was not possible to generate a single value from the available data (for example the unit costs of operating a MRF). Data on the solid waste management systems in the four communities were obtained through interviews with municipal officials. Data for the cost components of the recycling and composting options were obtained through interviews with private-sector recyclers, MRF operators, officials in communities in Oklahoma and other states with existing recycling and yard waste programs, and equipment vendors. Some cost and operational data were derived from published literature.[7] For a detailed discussion of data sources see Schade (1989).[8]

Table II. Life cycle cost variables.

Variable Description	Range
Waste Diversion Rate Factors	
Residential waste composition (% by weight)	
Aluminum cans	1.1 - 3.9 %
Glass containers	7.7 - 12.9 %
Newspaper	9.0 - 15.0 %
Yard waste	7.7 - 19.3 %
Recycling rates (%)	
Aluminum cans	3 - 7 %
Glass containers	10 - 32 %
Newspaper	15 - 58 %
Yard waste	70 - 95 %
Processing losses at the MRF (%)	
Aluminum cans	5 %
Glass containers	30 %
Newspapers	5 %
MSW Collection Costs	
Annual waste generation (tons)	community-specific[1]
Proportion of residential waste in the municipal waste stream (%)	community-specific
Unit costs of collection ($/ton)	community-specific
Collection cost savings from recycling (% of waste diversion rate)	0, 70, 90 %
Collection cost increase with separate yard waste collection	0 - 25 %
MSW Disposal Costs	
Private landfill: 1990 tipping fee ($/ton)	community-specific
Public landfill: 1990 annualized capital and operating costs ($)	community-specific

[1] See Table I.

Table II. continued

Variable Description	Range
Unit cost of disposal after Subtitle D regulations in effect ($/ton)	$18 - $21/ton
Costs of Curbside Collection of Recyclables	
Weekly set-out rate (%)	20 - 70 %
Density of recycled materials (tons per cubic yard)	
Aluminum cans	0.037 tons/cy
Glass containers	0.500 tons/cy
Newspaper	0.275 tons/cy
Public promotion costs ($ per household per year)	$0.75 - $1.50
Workhours per week (hours)	40 hrs
Break time per week (minutes)	150 min
Capacity of recycling truck (cubic yards)	15 cy
Price of recycling truck	$37,000
Fuel consumption of recycling truck (miles/gallon)	3.8 mpg
Diesel fuel price ($/gallon)	$0.65/gal
Maintenance costs for recycling truck ($/year)	$5,200/yr
Productivity of recycling truck (stops passed per hour)	85,100,165 stps/hr
Useful life of recycling truck (years)	9 yrs
Capacity of pickup truck-trailer (cubic yards)	14.25 cy
Price of pickup truck-trailer	$11,000
Fuel consumption of pickup truck-trailer (miles/gallon)	18 mpg

Table II. continued

Variable Description	Range
Gasoline price ($/gallon)	$0.73/gal
Maintenance costs for pickup truck-trailer ($/year)	$850/yr
Productivity of pickup truck-trailer recycling vehicle	69,78,113 stps/hr
Useful life of pickup truck-trailer (years)	9 yrs
Unloading time of recycling vehicle (minutes per trip)	10 min
Price of recycling container	$4.50
Useful life of recycling container	9 yrs
Bond term for recycling equipment	9 yrs
<u>Processing of Recyclables</u>	
Unit capital costs ($ per ton of daily capacity)	$10,000 - $38,500
Unit costs of operation ($/ton)	$20 - $30/ton
Minimum MRF size (tons per day)	5 tpd
MRF design life (years)	10, 17, 25 yrs
<u>Yard Waste Composting</u>	
Unit capital costs ($ per ton of daily capacity)	$7,600 - $13,800
Unit costs of operation ($/ton)	$3.60 - $22.50
Minimum facility size (tons per day)	7 tpd
Debagging costs ($/bag)	$0.02 - $0.04
Compost weight reduction (%)	30 - 50%

Table II. continued

Variable Description	Range
<u>Recovered Materials Revenues</u>	
Materials sales prices ($/ton)	
Aluminum cans	$ 800 - 1,514
Glass containers	$ 70 - 80
Newspaper	$ 15 - 65
Compost	$ 0 - 4
<u>Financial Variables</u>	
Interest and discount rate	8.00, 8.25, 9.25 %
Inflation rate (gross national product)	3 - 4 %
Inflation rate (labor)	3.6 - 4.6 %
Inflation rate (vehicles and equipment)	2.4 - 3.4 %
Inflation rate (machinery and equipment)	3.0 - 4.0 %
Inflation rate (fuel and utilities)	3.7 - 4.7 %
Backup factor for labor	1.2
Overhead (percent of total annual costs)	15 %

Waste Diversion Rates. The amount of waste that is diverted from the waste stream through recycling is dependent on three variables: (1) waste composition, (2) recycling rates, and (3) processing losses at the MRF. Estimates of the composition of residential waste were derived from recent studies in Missouri and several other states in the absence of data for any communities in Oklahoma.[9] Recycling rates are defined as the proportion of the total amount of a material in the waste stream that is collected from the public. This parameter is dependent on participation rates and recovery rates, i.e. the percent of recyclables actually set at the curb by a participating household. Processing losses at a MRF result from contamination of a portion of the collected materials and, in the case of glass, losses from breakage during collecting and handling.

The amount of each material that is finally diverted from the residential waste stream is calculated by multiplying the total tonnage of residential waste by the proportion of the commodity in the residential waste stream and the recycling rate, and then subtracting the estimated processing loss. The total waste diversion rate for the composite municipal solid waste stream is calculated by dividing the tons of all materials diverted from the waste stream by the total tonnage of residential and commercial waste managed in the municipal system.

MSW collection costs are the product of the total amount of residential MSW generated in the service area and the unit cost of collection. If a proportion of the waste is diverted through recycling, the MSW collection costs may be reduced. This collection cost savings is calculated as a proportion of the waste diversion rate. Data from studies in Rhode Island suggest that collection costs decrease in an amount ranging from 70 to 90 percent of the diversion rate.[10] A lower bound of zero is included for a worst-case assumption. This may apply in smaller communities where the net reduction in waste volume is insufficient to eliminate at least one truck and crew from the collection system. For yard waste collection programs, there is typically a net increase in total MSW collection costs, on the order of 8 to 25 percent, with the addition of separate yard waste collection service. Under optimal conditions, it may be possible to break even.

MSW disposal costs are calculated differently for private and public landfills. For a private landfill, disposal costs are the product of the tipping fee paid by the municipality and the amount of residential waste disposed. No extension of landfill capacity is assumed to result from recycling where the landfill is privately owned. We assume that private operators would compensate for reductions in waste disposal from one source by seeking additional wastes from other sources, since their earnings are a function of the volumes of waste they handle.

Where the community operates its own landfill, we assume the annual operating costs are fixed and that recycling does not result in immediate reductions in disposal costs. However, reduced waste disposal is assumed to extend capacity, thus postponing the higher unit costs of constructing and operating a new landfill or landfill cell in compliance with the more stringent standards to be imposed under the federal Subtitle D regulations.[11] The new landfill is also assumed to be designed to handle a lower daily volume of waste that reflects the waste diversion accomplished through recycling.

Costs for curbside collection of recyclables include capital costs for collection vehicles and containers (for commingled recyclables), payments to a reserve fund to replace that equipment, labor, fuel, and vehicle maintenance costs, and the costs of an ongoing public promotion program. The number of dedicated recycling vehicles needed for the curbside program is calculated using an iterative method described by Garrison (1988).[12] The tonnage of recyclables collected is a function of the composition of the residential waste stream, the recycling rate by residences within the service area, and the density of individual materials.

The costs of yard waste collection were not calculated separately since we assume that yard wastes are collected using existing collection equipment and personnel under a revised collection schedule. The net effect of a separate yard waste collection program are reflected in a factor described above under MSW collection costs: "collection cost increase with separate yard waste collection."

The costs of processing recyclables or composting yard waste include capital costs for land and construction of a MRF or composting facility, initial equipment costs, equipment replacement costs, and operating costs.

Revenue estimates from the sale of recovered newspaper, color-sorted glass, and aluminum cans include ranges that reflect markets for these commodities in Oklahoma during the past three years. Prices are those paid by end-users, at the MRF dock. Total revenues reflect the amount of recyclables collected minus processing losses. Revenues from the sale of composted yard waste range from zero to $8 per ton. Commercial markets tend to be local because it is generally not economical to transport compost long distances. In many communities, composted yard waste is not sold commercially but is used instead by the municipality as a substitute for soil amendments that would otherwise be purchased by their parks or highway departments. The revenue range includes the avoided cost of making such substitutions.

Analyses

For each of the four case study communities, three base analyses were conducted: (1) no recycling, (2) curbside recycling, and (3) curbside collection and composting of yard waste. The no-recycling option reflects the current solid waste management system. For variables in Table II with a range of values, mid-points were used in the base analyses of the recycling options; best and worst cases were defined to reflect the highest possible range of variation. Sensitivity analyses were conducted to test the impact of varying individual variables.

For the two larger cities, Oklahoma City and Norman, the curbside recycling collection vehicles were assumed to be 15-cubic yard dedicated recycling trucks. Sensitivity analyses were performed for each of these communities substituting a 14.25-cubic yard recycling trailer hauled by a pickup truck. For the smaller communities of Fairview and Owasso, the base analysis assumed use of a pickup truck-trailer collection vehicle. In these two cases, only one collection vehicle is needed to serve the community, and the decreased collection efficiency of the truck-trailer system is offset by much lower capital and maintenance costs. In the Fairview case, the truck-trailer rig is assumed to be shared with other municipalities in the regional solid waste management authority. Fairview would only need to operate the vehicle one day a week to collect recyclables from its 1,308 households.

The base analyses for Oklahoma City and Norman also assumed that the municipality owns and operates the MRF for processing recyclables. A minimum capacity of 5 tons per day (tpd) was assumed based on interviews with MRF vendors. The Fairview analysis assumes the MRF is regionally owned, with Fairview responsible for 31 percent of the capital and operating costs, which is equivalent to its proportion of the wastes currently handled by the regional solid waste system. A scenario was also analyzed where Fairview only used that portion of a regional MRF that it actually would need for its recyclables. Such an option would require extending the size of the regional system to include other municipalities to fully utilize the capacity of a 5-tpd MRF. A similar scenario served as the base case for Owasso, which operates its own solid waste management system at present but would utilize only about 18 percent of a 5-tpd MRF.

Results

Diversion Rates

Waste diversion rates for the curbside recycling and yard waste composting options depend on assumptions about waste composition, recycling rates, and, in the case of curbside recycling, processing losses at the MRF. The range in potential diversion rates for the residential waste stream are summarized in Table III. Total diversion rates for the composite MSW stream will vary with the mix of residential and commercial wastes managed by a municipal system. As shown in Table I, the proportion of residential waste varies substantially among the four communities studied, from 71 percent in Fairview to 24.1 percent in Owasso. As a result, the total diversion rates for these four communities also vary considerably as shown in Table IV.

Table III. Residential diversion rates.

Recycling Option	Best Case	Base Case	Worst Case
curbside	11.41%	5.79%	1.85%
composting	44.07%	30.96%	12.99%
combined	55.48%	36.75%	14.84%

Table IV. Composite diversion rate ranges.

Recycling Option	Best Case	Base Case	Worst Case
curbside	4.1 - 8.1%	1.4 - 4.1%	0.5 - 1.3%
composting	10.6 - 31.2%	7.5 - 22.0%	3.1 - 9.2%
combined	13.4 - 39.4%	8.9 - 26.1%	3.6 - 10.5%

Cost Effectiveness

Comparison of the 20-year life cycle costs of the current solid waste management systems and those for a curbside recycling program suggests that curbside recycling would be marginally cost-effective in the four communities under conditions somewhat more favorable than the base cases. Composting programs, however, represent a substantial increase in costs except under the most optimistic assumptions.

Figure 1 portrays the life cycle cost differentials for curbside recycling and yard waste collection and composting for the four communities under the base-case assumptions. The bars indicate the percent difference between no recycling and the two recycling options. The curbside programs would entail net increases of two to three percent in 20-year life cycle costs for all but Fairview. If Fairview were able to participate in a regional MRF system where it only paid for the proportion of a 5-tpd MRF that it actually needed, it's life cycle cost differential for curbside recycling would be in the same range, 2.6 percent. The life cycle cost differentials for yard waste collection and composting programs are substantially higher, in the range of 11.5 to 13 percent.

Figures 2 and 3 show the range of possible life cycle cost differentials for the best-case and worst-case scenarios for a curbside collection program and a composting program in the four communities. The best-case scenarios for both recycling options yield lower life cycle costs than the present solid waste management system for all four communities, but the worst-case scenarios represent substantial cost increases, especially for the composting option. Tables V and VI list the assumptions used to define the best and worst cases for the two recycling options.

In Table VII, a more conventional cost figure is used, cost per household per month. These figures only show the first-year net systems costs, so the effects of landfill capacity savings and paying off initial bonds are not reflected. Thus while the best-case scenarios for yard waste composting all show a net reduction in life cycle costs, first-year costs are only reduced for Norman and Owasso. For the best-case curbside option, both the life cycle costs and first-year net costs are lower for all four communities.

Under the best-case scenarios, all four communities would save money from a combined curbside recycling and composting program. The combined first-year net costs for the base-caseanalyses of curbside recycling and yard waste composting range from $1.50 to $2.00 per household. These costs are within the range that municipalities in other parts of the

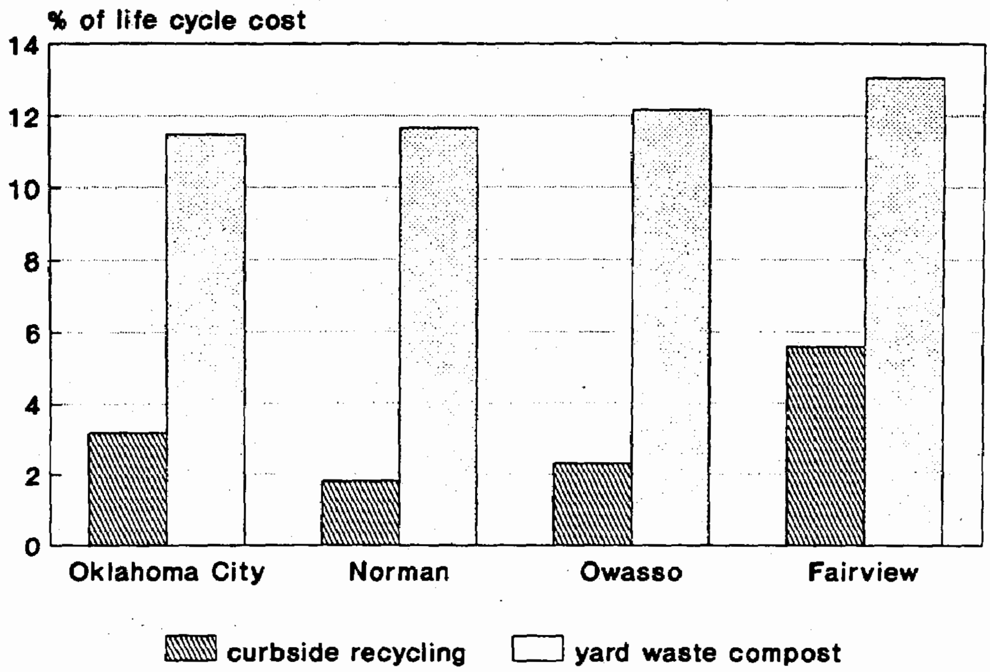

Figure 1. Life cycle cost differentials compared to no recycling.

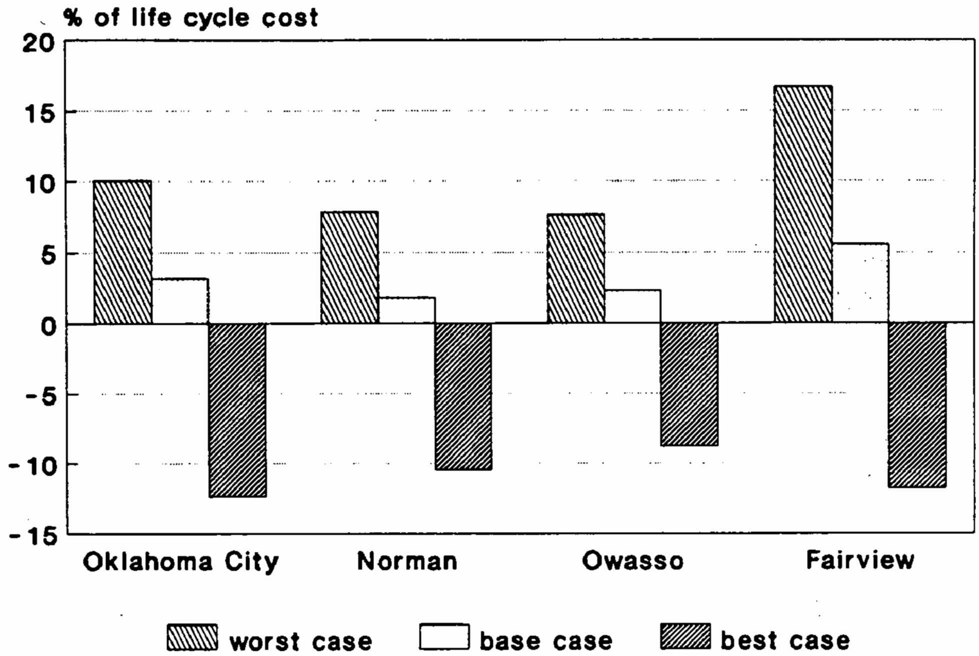

Figure 2. LCC differentials - curbside compared to no recycling.

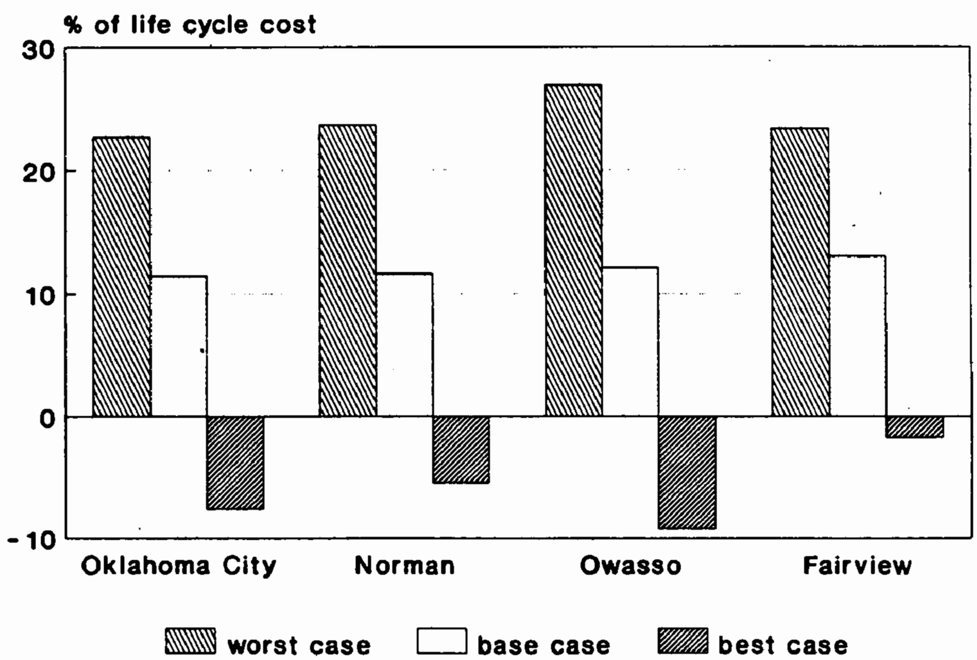

Figure 3. LCC differentials - composting compared to no recycling.

Table V. Best and worst case scenarios for curbside recycling.

Variable	Best Case	Worst Case
Waste composition (proportion of recyclables)	high	low
Recycling rates	high	low
Collection cost savings	high	low
Productivity of recycling vehicle	high	low
Processing costs*	low	high
MRF design life	long	short
Materials sales prices	high	low

* Combined unit capital costs and operating costs.

Table VI. Best and worst case scenarios for composting.

Variable	Best Case	Worst Case
Waste composition (proportion of yard waste)	high	low
Recycling rates	high	low
Collection cost increase	low	high
Composting costs*	low	high
Debagging costs	low	high
Compost weight reduction	low	high
Compost sales prices	high	low

* Combined unit capital costs and operating costs.

Table VII. First-year net costs in dollars per household per month compared to no recycling.

	Oklahoma City			Norman			Owasso			Fairview		
Program Option	Worst Case	Base Case	Best Case	Worst Case	Base Case	Best Case	Worst Case	Base Case	Best Case	Worst Case	Base Case	Best Case
curbside	$0.83	$0.28	-$0.98	$1.10	$0.25	-$1.41	$0.89	$0.25	-$1.10	$1.69	$0.55	-$1.00
composting	1.84	1.22	0.02	3.03	1.69	-0.29	3.27	1.75	-0.43	2.13	1.44	0.38
combined	$2.67	$1.50	-$0.96	$4.13	$1.94	-$1.70	$4.16	$2.00	-$1.53	$3.82	$1.99	-$0.62

country have been willing to pay for the noneconomic benefits of recycling such as energy conservation, improved environmental quality, and less waste of natural resources. However, under the worst-case scenarios, combined costs would range from $2.67 to $4.16 per household per month. It is likely that cost increases of this magnitude would generate political and public opposition in some communities.

Importance of Different Cost Components

Examination of the individual cost components for the different systems shows that collection costs dominate the outcomes for both the curbside and composting programs. Total life cycle costs of curbside collection of recyclables account for 45 to 68 percent of the total costs of a curbside recycling program in the base cases. Costs of yard waste collection are responsible for 60 to 80 percent of the costs of a composting program under base-case assumptions.

Under best-case assumptions, the reduced costs of collecting regular household waste compensate for the increased costs of a separate curbside collection system for recyclables in all of the communities except Fairview. In the worst-case scenario, we assumed no savings in collecting MSW which is more likely in the two smaller communities, and possibly in Norman as well, since significant savings will only occur where at least one truck and crew and can be eliminated.

The best-case assumption for the composting option was that the increased costs of a separate yard waste collection are completely offset by the reduced costs of collecting the remaining MSW from residences. In the worst-case scenario there is a 25 percent increase in net collection costs.

Processing costs account for 23 to 29 percent of the costs of a curbside recycling program in all of the communities except Fairview. In Fairview, processing accounts for 47 percent because of under-utilization of the city's share of a 5-tpd MRF. If Fairview were able to participate in a regional system where it only paid for the proportion of a MRF that it actually required, processing costs would represent a proportion of total costs comparable to that for the other cities. In the base-case composting scenarios, composting costs account for 19 to 36 percent of total program costs.

Program promotion and public education costs are relatively insignificant for both the curbside and composting programs. They range from 8 to 10 percent for curbside recycling and from 2 to 5 percent for composting programs.

Revenues cover 31 to 40 percent of program life cycle costs under the base-case scenarios for curbside recycling. Under best-case assumptions, revenues equal or exceed costs for curbside recycling in all of the communities except Owasso where they cover about 84 percent of program costs. Revenues are much lower for yard waste compost, covering only 2 to 13 percent of program costs under base-case assumptions ($4/ton). Under best-case assumptions, the range increases to 6 to 12 percent, but under the worst-case scenarios we assume no revenues are generated through compost sales or substitution for soil amendments used by municipal agencies.

Sensitivity Analyses

In addition to assessing the effects of best-case and worst-case assumptions, analyses were run to assess the impact on life cycle costs of varying individual variables. The range of variation in life cycle cost differentials associated with the value ranges for the individual variables tested are summarized in Table VIII for the two recycling options.

In the curbside recycling scenarios, results were most sensitive to variation in recycling rates, collection cost savings, set-out rate, waste composition, sales prices, and processing costs. The relative sensitivity of the program life cycle costs to individual factors varied among the communities, primarily because of differences in the unit costs of collecting MSW. Variations in processing costs had a greater impact in Fairview because of its under-utilization of a regional 5-tpd MRF.

In the yard waste composting scenarios, variations in assumed collection cost increases and processing costs have the greatest impacts on life cycle costs. This is due to thegreater extent to which these costs overshadow the potential revenues from compost sales or avoided costs from compost use by the municipality or waste diversion.

Conclusions

Analysis of these four communities in Oklahoma demonstrates that in many municipalities recycling programs must be extended to commercial wastes as well as residential wastes to achieve a 25 percent reduction in MSW through recycling. This study also indicates that curbside recycling programs will probably require some increase in total solid waste management service fees, although these increases are within a range that has been politically acceptable in many communities throughout the nation. The additional costs of

Table VIII. Range of variation in life cycle cost differentials for individual variables.

Variable	Recycling Option	
	Curbside	Composting
Waste composition	3-5%	0-1%
Recycling rates	6-7%	<1%
Materials sales prices	2-5%	1-2%
Collection cost savings	3-4%	n/a
Collection cost increase	n/a	15-21%
Processing costs	1-6%	7-12%
Debagging costs	n/a	<1%
Compost weight reduction	n/a	<1%
MRF lifetime	0-2%	n/a
Set-out rate	3-6%	n/a
Truck productivity	2-3%	n/a
Collection vehicle type	1-2%	n/a
Landfill lifetime	0-1%	<1%
Landfill ownership	0-1%	2-3%
Discount/interest rate	<1%	<1%
Inflation rates	<1%	<1%

yard waste collection and composting may entail a substantial increase in waste management costs, especially if combined with the costs of a curbside recycling program in an effort to achieve a 25 percent recycling goal.

Because solid waste disposal costs are considerably lower in this region of the country, the life cycle costs of recycling or composting are primarily determined by collection and processing costs. The reduced savings that can be realized from the avoided costs of waste diversion and extended landfill capacity also make net costs for recycling options more vulnerable to shifts in markets for recovered materials. Net costs are also more sensitive to such factors as waste composition and variables that affect net recycling rates including participation rates, recovery rates, and set-out rates.

Assessing the cost-effectiveness of recycling in communities such as those analyzed here will, therefore, require very careful examination of opportunities to minimize collection costs and maximize savings from diverting wastes from the regular MSW collection and disposal systems. Particular care must be given to assessing potential markets, and continued effort will be required to maintain high participation and recovery rates through ongoing public education programs. In smaller communities, such as Owasso and Fairview, regional processing facilities, and in some cases, shared collection equipment, may be essential to making curbside recycling and composting programs as nearly cost-effective as possible. Communities of this size, i.e. less than 15,000, account for 25 percent of the total population in Oklahoma and 33 percent of the population living in incorporated municipalities. Another 23 percent of the total population of the state lives in unincorporated areas where curbside collection is not currently provided and where recycling would most likely require use of drop-off centers.

The marginal cost-effectiveness of these recycling options suggests that financial subsidies from states or the federal government may be required to overcome political opposition to the increased costs of municipal recycling programs. Some measure of willingness to pay is needed to assess the cost thresholds beyond which communities are not willing to go for the less tangible benefits of recycling. The computer program designed for this project has the capability to assess the impacts of public grants on first-year net costs and life cycle costs. We expect to conduct such an analysis in the near future.

Acknowledgements

Support for this work was provided from the federal Exxon Oil Overcharge Settlement Fund through a contract administered by the Oklahoma State Department of Commerce.

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MAY 10 1990

FEDERAL FACILITIES RECYCLING

Gail Miller Wray, Moderator
EPA Recycling Coordinator

Jim Nelson
Assistant General Council, Toxic Substances Branch

Elaine Suraino
Coordinator, Toxic Chemical Assesment Desk

Ruth Yender
Environmental Protection Specialist

I. EPA's Success

   A. Sierra Club's Acceptable Six--EPA singled out for praise (Washington Post, New York Times).

   B. Federal Executive January issue.

   C. Federal Times issue.

II. EPA Recycling staff

   A. Office of Solid Waste--Muncipal Solid Waste Office
      1. Policy
      2. Public/Community Outreach

   B. Office of Administration and Resources Management--Facilities Management and Services Division.
      1. Administration of Internal Recycling program.
      2. Assistance to Federal Agencies.

   C. Recycling Workgroup
      1. Advisory
      2. Actual working arm of program

   D. AA Coordinators
      1. Monitoring

III. EPA logistics (detailed on blue handout)
   A. 8000 employees
   B. Three buildings
   C. 1.2 million square feet

IV. EPA program history
  A. "Use it Again Sam!"--1977 campaign.
    1. Failure of 1970's movement
      a. Markets
      b. Slow technological movement and procurement problems
    2. Sluggish continuation of program throughout 1980s.
      a. GAO Report (GAO/GGD-90-3)
        1. Source preparation
        2. Procurement Guidelines

  B. Resurgence of concern--1988
    1. Recycling Workgroup
    2. Agency Coordinator
    3. August Kick-off

V. EPA Waste Stream Analysis
  A. Conducted to survey contents of recyclables in waste stream. Concrete figures are needed to entice vendor interest. (Overhead 1)
    1. Composite of EPA's three HQ building sites
      a. Paper by far the largest is 73 % (weight).
      b. Glass comes in 2nd at 11% (weight).

    [Overhead 2 is a more visual representation of these numbers]

    2. [Overhead 3] details EPA's 1988 disposal and recycling figures.
    3. [Overhead 4] details FY 1989's--you can see the tremendous growth in our paper collection program.
    4. [Overhead 5] gives current FY 1990 statistics, we are currently 77% of last years collection figures (this does include the lower grades of paper).

VI. EPA's Program

  A. Methods of Collection
    1. EPA Region 5 has a box latched onto the side of their waste bins.
    2. EPA Region 7 developed the two-sort grey boxes.
    3. EPA-HQ continued with the cardboard box.

  B. Expansion of HQ Paper program
    1. Three sorts
      a. High grade
      b. Low grade
      c. Newspaper

2. HQ adopted the Region 7 grey box--rationale.
   a. small
   b. asthetically pleasing
   c. large enough for clear labeling
   d. desire to remove "recycle" image away from "garbage" image
3. HQ organized "central collections bins"
   a. Rational for choosing plastic bins.
      1. durability
      2. strength
      3. Health and safety of Labor/Services personnel.
4. Location of storage
   a. Gaylords
      1. Size
   b. Building and Fire codes

5. Marketing of recyclables
   a. Paper--General Services Administration
   b. Glass--
   c. Aluminum--

C. Methods of Procurement
   1. In-House Printing
   2. Agency policy
      a. Transmittal on Submission all contractor reports on recycled paper (1/24/90).
   3. Working with the Joint Committee on Printing (JCP), the General Services Administration (GSA), and the Government Printing Office (GPO).

VII. Expansion to include Glass and metals (D. C. Solid Waste Management and Multi-Material Recycling Act of 1988).
   A. Igloos (provided by Glass Packaging Institute and D. C. Council of Churches).
   B. Aluminum In-house program.

VIII. Recycle--
   A. Education
   B. Collection
   C. Marketing
   D. Procurement
   E. Monitoring and Evaluation

Visual Aids: Overhead graphs
3-part grey boxes
1 red bin

Handouts: EPA In-House Handout (Blue)
OARM Recycling Update (White w/blue ink)

FINANCING A RECYCLING PROGRAM: LANDFILL DIVERSION CREDITS

by Miriam Foshay
Recycling Management, Inc.

Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

FINANCING A RECYCLING PROGRAM: LANDFILL DIVERSION CREDITS

Miriam Foshay

Whenever a municipality is analyzing the cost of a recycling or composting program, one of the factors it must consider is the amount of money saved by diverting waste from the landfill. This saving is called a "diversion credit," and it can often be a significant amount of money. If the municipality is providing both refuse and recycling services with its own staff, then the city recovers this money directly. But very few cities work this way. Most either contract with a private hauler (who may or may not also handle the recycling or yard waste collection) or the citizens themselves contract with several different haulers. How, then, can a municipality recover the savings that comes from diverting waste from the landfill?

The City of Naperville solved this problem in a unique way. Refuse collection is handled by a single hauler in an exclusive contract with the city. When Naperville signed its last five-year contract with its hauler, the local recycling center was beginning a pilot curbside collection of recyclable materials. Written into the contract was a clause requiring that after a period of one year, the hauler, the recycling center, and the city would negotiate a rebate from the hauler based upon the volume of material diverted from the landfill by the recycling center.[1]

In this case, the refuse hauler acquires savings in many areas when waste is diverted from his program. Every ton of material not collected by his trucks saves him tipping fees at the landfill, but there are other savings as well: he makes fewer trips to

---

[1] The text of the contract reads:

> 39. <u>PILOT CURBSIDE COLLECTION PROGRAM</u>
> It is understood between the City and Contractor that the City has entered into an agreement with the Naperville Area Recycling Center (NARC) in which NARC will conduct a Pilot Curbside Collection Program for collection of recyclable solid waste materials from certain areas of Naperville. Contractor agrees to cooperate and assist the City and NARC to evaluate the Pilot Program, and, if renewed or extended, the Contractor agrees to negotiate in good faith with the City to determine a reasonable reduction in the cost per stop per month charge in Section 14 hereof.

the landfill, saving labor and vehicle costs; and he spends less time collecting trash, saving labor costs. The negotiation between the City of Naperville, its refuse hauler, and Naperville Area Recycling Center (NARC) yielded a three-part formula to calculate each of these cost savings.

Before we could develop a formula for a credit, we had to establish equivalent values. For instance, refuse is measured in compacted cubic yards, but recyclable materials are measured in tons. How many tons of recyclables equals one compacted cubic yard of trash? For lack of a better measure, we agreed upon the value of three compacted cubic yards to one ton which is used by the local landfill. In fact, this value would depend upon what materials are collected: newspaper, one of the densest items, might have a density of 3-4.5 cu yd/T, but plastic and corrugated have a much lower density.[2] This and other equivalency assumptions we made are listed in Table 1.

Table 1
ASSUMPTIONS

1 ton = 3 compacted cubic yards = 12 loose cubic yards
one garbage truck = 25 compacted cubic yards
time to load one loose cu yd = 135 seconds

Tipping fees saved. Having established that one ton of recyclables equals three cubic yards of refuse, we can easily calculate tipping fees saved:

$$S_1 = 3 \times (\text{tipping fee/cu yd})$$

where S_1 is savings per ton of recyclables collected. As the tipping fee changes, the value of S_1 also adjusts.

---

[2]Franklin Associates has just completed a study comparing density of materials in the landfill which should be available soon from The Council for Solid Waste Solutions.

Trips to landfill saved. In order to calculate trips to the landfill saved, one must know the volume of a garbage truck. The hauler's trucks all have a rated capacity of 25 cubic yards. Therefore, using the 3 cu yd = 1 T formula, every 8.33 T of recyclables collected would save one trip to the landfill.

But what is a trip to the landfill worth? There are two factors to be considered:

- labor saved
- truck expenses saved

Labor saved depends upon the average round trip time to drive to the landfill plus the average time to unload times the driver's wage plus payroll taxes. In this calculation, benefits were excluded because the refuse company maintained that the benefits paid did not depend upon the number of hours worked, so shaving a few hours of driving time would save hourly wages but not benefit costs. In fact, the recycling program has grown so much that the refuse company's labor requirements have been reduced by nearly two full-time employees, which certainly produces a savings in benefits paid.

Truck expenses saved relate directly to how far the truck must drive in one round trip to the landfill. Truck costs include fuel, oil and maintenance only. Depreciation and insurance costs were not included, because the truck accrues depreciation and requires insurance whether it is driven full-time or not. In fact, the recycling program currently replaces the need for two garbage trucks, reducing the capital outlay required of the refuse hauler.

The savings for each truckload which does not go to the landfill (S_{2a}) can be calculated as follows:

$$S_{2a} = [(\text{driving time saved})\text{x}(\text{hourly wage + taxes + benefits})] + [(\text{RT distance})\text{x}(\text{truck cost/mi})]$$

In order to get savings per ton (instead of per truckload), this number must be divided by 8.33 T/truckload:

$$S_2 = S_{2a}/8.33 \text{ T/truckload}$$

Trips to landfill saved (S_2) adjusts as labor and fuel costs change.

Collection time saved was the most difficult figure to calculate. The hauler must drive by every house whether the homeowner puts out trash or not; therefore, there is no savings in vehicle costs. Is there a savings if the homeowner only puts out one bag instead of two? Will the homeowner put out trash less often if he recycles? We finally agreed to calculate how much time it took to load each bag of trash.

First of all, the hauler collects loose material, not compacted. How many loose cubic yards equal one ton? We established that a garbage truck compacts its load to one-fourth of the original volume. Therefore:

1 ton = 3 compacted cubic yards = 12 loose cubic yards

If we assume that the typical set-out consists of full 30-gallon plastic bags, then every 6.5 bags equals one loose cubic yard. It takes about 20 seconds to load each 30-gallon bag, or 135 seconds per loose cubic yard. This amounts to about one-half hour per ton or four hours to load one 25-yd packer truck.

As above, marginal labor costs including benefits were not included in the calculation; but since the labor savings amounts to two full-time employees, these costs should have been included. Collection time saved (S_3) can be written as follows:

$$S_3 = (12 \text{ loose cu yd/T}) \times \frac{135 \text{ sec} \times (\text{labor cost/hr})}{3600 \text{ sec/hr}}$$

As for trips to landfill saved (S_2), collection time saved varies with labor costs.

Items not covered. NARC collects certain items that the refuse hauler did not include in his contract: used motor oil and white goods. Analysis of NARC's loads revealed that these two classes comprised 1.6% of the total collection by weight. Therefore, the total tonnage collected by NARC had to be reduced by 1.6%.

The total savings accrued by the waste hauler (and payable to the City) can be calculated by summing the above savings per ton and multiplying by the tonnage of recyclables collected, adjusted for oil and white goods not included in the contract:

$$\text{Total savings} = (\text{tons of recyclables collected}) \times F_a \times (S_1 + S_2 + S_3)$$

where F_a is the adjustment factor for items not covered.

Currently, tipping fees are $6.55/cu yd and the City receives about $35/T from its waste hauler in landfill diversion credits. If this figure were adjusted for density of materials, vehicle depreciation and benefits, it could be much higher.

In Illinois and elsewhere, cities are negotiating with haulers not for a single trash collection but often for three separate collections: yard waste, recyclable materials, and refuse. Whether they choose to contract with a single hauler to handle all three services or with separate haulers, city officials should bear in mind the savings that a refuse firm realizes when some of the material it formerly collected is diverted from the landfill. This landmark contract negotiated by the City of Naperville establishes a precedent which should help other cities to establish a similar credit from their waste hauler.

INNOVATIVE COMMERCIAL & APARTMENT RECYCLING PROGRAMS

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13 – 16, 1990

City of Tukwila Recycling Pilot Project Summary

1 INTRODUCTION

This report summarizes activities undertaken by Sound Resource Management Group, Inc. (SRMG) in planning, developing, implementing and evaluating a Recycling Pilot Project for the City of Tukwila, Washington. The pilot project, conducted from June to August, 1989, was intended mainly to gather data on commercial and apartment recycling within Tukwila, and to test the ability of Tukwila's primary solid waste hauling firm to provide recycling services. A secondary purpose was to assess the feasibility of operating a commingled system in which all recyclables are placed into one container for collection.

This document presents results of the quantities of materials recycled during the project, assesses participation levels, and analyzes costs and savings. It concludes with a discussion of some of the challenges the City of Tukwila will likely face in implementing a full-scale recycling program.

2 ACTIVITIES

Summarized below are the activities SRMG completed to implement Tukwila's pilot recycling project:

Planning

- Developed project plan.
- Selected the following two multi-family complexes and four commercial areas as pilot participants:
  1. San Juan Apartments, 6250 S. 153rd Street
  2. Canyon Estates Condominiums, 15138 65th Ave. S.
  3. Small Retail Mall, 16828 South Center Parkway
  4. Office Building, Southcenter Plaza, 14900 Interurban Ave S.
  5. Gateway Corporate Center, 12886 Interurban Ave. S.
  6. Small Manufacturer, Racon, Inc., 12128 Interurban Ave. S.

Development

- Obtained cooperation of property managers and owners.
- Negotiated pilot program terms with Sea-Tac Disposal Company, Inc. (Sea-Tac).
- Designed collection system (type of equipment, and size and location of containers).
- Developed instructional brochures and container labels.

Implementing

- Coordinated timing and placement of collection containers.
- Distributed instructional brochures to participants twice in the first month of the 3-month project.

- Distributed deskside boxes to commercial participants.
- Coordinated activities with janitors when necessary.
- Modified a hand cart for hauling cardboard for an office building tenant.
- Wrote and distributed a news release to local and regional newspapers.

Monitoring & Evaluation

- Monitored garbage and recycling bins on a weekly basis. If excessive amounts of recyclables were found in the garbage bin, or if the recycling bin was contaminated with trash, then the appropriate business tenants or employees were revisited, talked to, and issued another instruction flyer.
- Photographed project and used pictures in a presentation to the Tukwila City Council.
- Developed and distributed a flyer, thank-you note and feedback form to participants.
- Produced a display map showing pilot project locations.
- Summarized data and findings (in this report).

3 WEIGHT, VOLUME & COMPOSITION OF COLLECTED MATERIALS

The table below (Fig. 1) summarizes the volume reduction achieved by each pilot project participant and for the project as a whole. The first column lists the pilot participants. The second column totals the weekly garbage capacity of each participant by volume. The third and fourth columns list the size and hence the designed weekly capacity for collecting recyclables. The fifth column estimates an average fullness factor for each participant's recycling containers, based on Sea-Tac's collection route summary forms. The sixth column lists the actual volume reduction each participant achieved, which was derived by multiplying the design capacity by the fullness factor. The last column translates the actual volume of recovered waste (in cubic yards) into a percentage figure that represents a volume reduction value.

Volume Reduction Summary for Pilot Recycling Project

Fig. 1

Project Participant	Garbage Capacity/Week	Recyclables Capacity/Week		Fullness Factor*	Actual Volume Reduction	
	CUBIC YDS.	CU. YDS.	%	%	CU. YDS.	%
San Juan Apts.	12	4	33	50	2	16.6
Canyon Estates Condos	60	10	16	50	5	8.3
Retail Mall	21	6	28	75	4	19.0
Southcenter Office Plaza	24	8	33	100	8	33.3
Racon Manufacturing	16	2	12.5	75	1.5	9.3
Gateway Corporate Ctr.	28	8	28.6	75	6	21.5
Total	**161**	**38**	**100**	—	**26.5**	**100**
Average	—	—	**24**	—	—	**16.5**

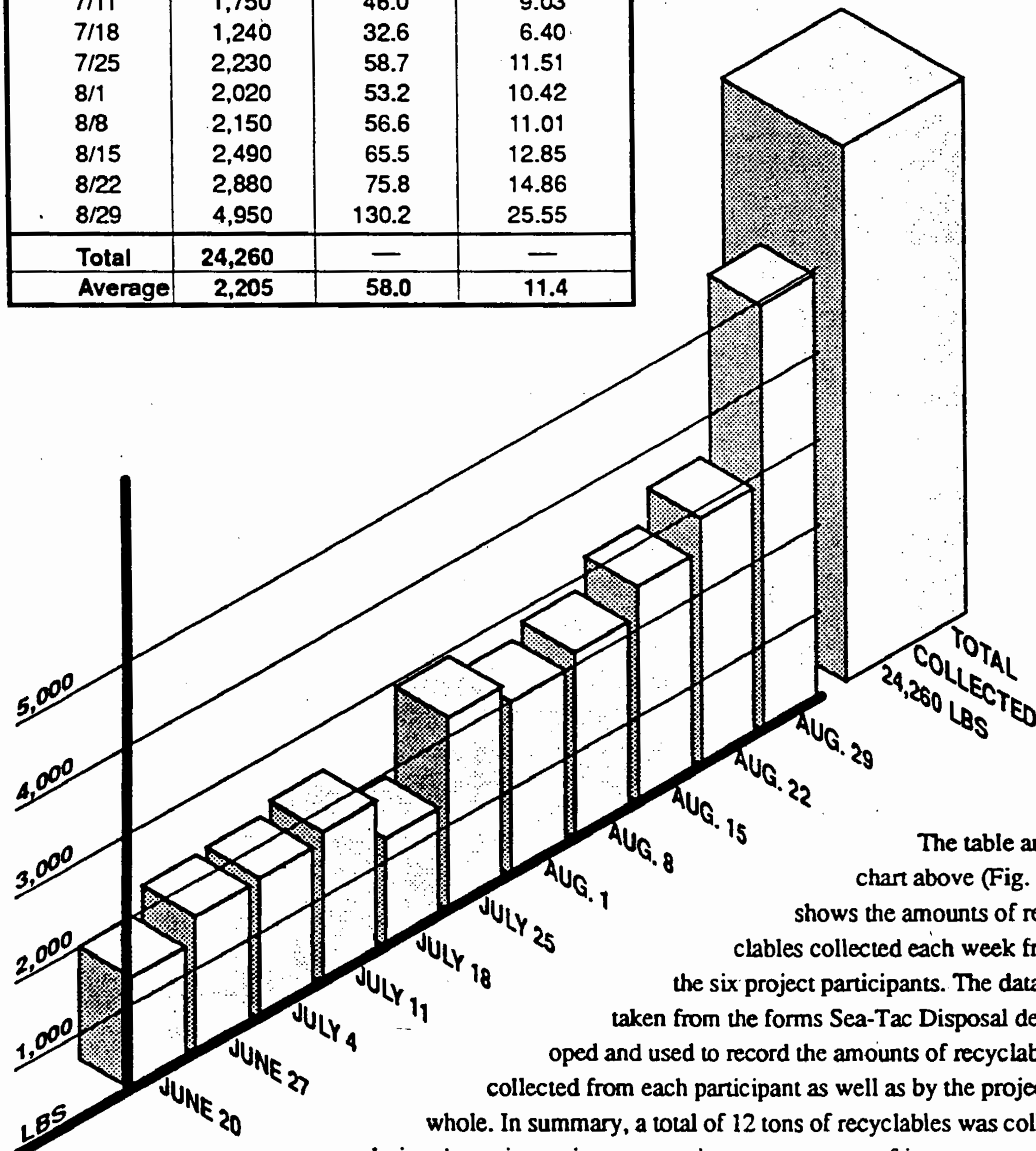
*: Based on Sea-Tac Disposal collection route summary forms.

Recyclables Collected by Tukwila's Pilot Recycling Project

Fig. 2

Collection Date	Pounds Collected	Lbs/CuYd	% Reduction In Weight
6/20	1,310	34.5	6.76
6/27	1,600	42.1	8.26
7/4	1,640	43.2	8.46
7/11	1,750	46.0	9.03
7/18	1,240	32.6	6.40
7/25	2,230	58.7	11.51
8/1	2,020	53.2	10.42
8/8	2,150	56.6	11.01
8/15	2,490	65.5	12.85
8/22	2,880	75.8	14.86
8/29	4,950	130.2	25.55
Total	**24,260**	—	—
Average	**2,205**	**58.0**	**11.4**

Note: **Percent Reduction in Weight** is based on 19.375 lbs/week of solid waste generated by the six pilot participants. This figure was arrived at by multiplying 155 cubic yards of solid waste collection capacity by 125 lbs/cubic yard (supplied by Sea-Tac as an average industry figure for volume-to-weight conversion).



The table and chart above (Fig. 2) shows the amounts of recyclables collected each week from the six project participants. The data was taken from the forms Sea-Tac Disposal developed and used to record the amounts of recyclables collected from each participant as well as by the project as a whole. In summary, a total of 12 tons of recyclables was collected during the entire project, amounting to an average of just over one ton per week, and representing an average solid waste stream weight reduction of 11 percent. Weekly tonnage increased from week to week but varied slightly due to a mix-up in collection on July 18. The unusually large amount collected in the final week was due to the fact that all deskside boxes from offices were collected and emptied.

The pilot project was designed to reduce solid waste volumes by 24 percent. In fact, because not all recycling containers were full when they were collected, the pilot project actually reduced solid waste volumes by approximately 16.5 percent.

In summary, paper of some sort constituted about three-quarters of all material collected during the pilot project. This was especially true for the commercial participants, whose recovered materials included a significant fraction of cardboard and mixed paper. The multi-family project recovered a mix of materials, including cardboard, newspaper, glass containers, cans and plastic bottles.

4

COST/SAVINGS ANALYSIS

Sea-Tac Disposal completed a cost/savings analysis for each of the six pilot participants. *(Attached to the original report were copies of Sea-Tac's work sheets.)* Their analysis indicated:

1. The cost of garbage service for each participant prior to the recycling pilot project.
2. The cost of the level of service offered during the pilot project.
3. The cost of service that accounted for the reduction in garbage service as a result of the amount of materials recycled during the pilot.

Generally, solid waste collection costs *increase* when recycling services are added because additional containers and pick-ups are needed to collect the recyclables. But recycling can decrease disposal costs. A break-even point occurs when savings from not having to pay for disposal equals the extra cost of providing recycling services. From Sea-Tac's data it can be estimated that the break-even point for recycling services occurs when about 30 percent of the waste collected is recycled by volume. In other words, if an apartment or business *recycles less than 30 percent* of its waste, the added recycling service will cost *more* than the savings in dump fees, resulting in added costs. If a business or apartment complex *recycles more than 30 percent* then the recycling program will cost *less* than the savings in dump fees, resulting in a net savings. This break-even point can decrease if recycling containers are substituted for garbage containers.

5

PARTICIPATION RATES

Exact numerical participation rates are difficult to estimate for this project because apartment and business tenants shared a common recycling collection container, rather than each business or residential unit having its own container (as is basically the case with, for instance, single-family residential curbside collection programs). Participation rates in this project are therefore categorized as "low," "medium" and "high." Participation rates were evaluated using the following criteria:

- How full the recycling containers and garbage dumpsters were over the pilot project period.
- What materials were in the recycling container and garbage dumpsters. If large amounts of recyclables were found in garbage dumpsters, then participation in the recycling program was low. Conversely, if very few recyclables were found in the garbage, participation was high.

- Regular visits to business and multi-family complexes. By visiting participants, SRMG personnel could determine if businesses were using their deskside boxes and whether apartment managers were working with their tenants. Personnel inquired about "how the participants felt the program was going," then used the feedback to make changes to encourage and sustain participation.

The following chart (Fig. 3) indicates the participation rate associated with each project participant:

Recycling Participation Rates *Fig. 3*

Location	Participation
1. Office Building	high
2. Racon, Inc.	high
3. San Juan Apartments	medium
4. Small Retail Mall	medium
5. Gateway Corporate Center	medium
6. Canyon Estates Condominiums	low

In general, participation by multi-family residents was lower than participation by commercial employees. The overall low participation rates for multi-family dwellers may be explained by the following factors:

- They did not receive as much personalized one-on-one attention by SRMG personnel as did the commercial participants.
- They did not receive a collection container for use inside their apartment units (the commercial participants received deskside boxes to collect office paper).
- Apartment dwellers have little financial incentive to reduce waste because their garbage fees are typically included in their rent.

The point about apartment dwellers and financial incentives deserves further discussion. The pilot project tested recycling in both an apartment and a condominium. In apartments, utilities are usually included in the rent. In condominiums, most people own their units, and utilities (i.e., solid waste, water and sewer) are included in an additional maintenance fee. It would seem logical that condominium dwellers or owners would have a greater financial incentive to reduce and recycle than apartment dwellers. However, the pilot project results indicate that there was less participation from the condominium dwellers than the apartment participants. Thus, financial incentives alone are apparently not enough to get people to participate. Manager involvement is an essential element to obtaining high participation rates.

Participation in the commercial projects was generally high because:

- Convenient deskside boxes for collecting office paper were provided to commercial participants.
- Janitors were often used to empty the deskside boxes and place the materials into the recycling bin. This made the recycling program even more convenient for some commercial participants.
- The materials, mostly office paper and cardboard, were easy to separate at the source.
- In some cases, the commercial participants had a financial incentive to reduce. This was the case with Racon, which paid its own solid waste collection bills.

Participation in the commercial projects was good overall, but there were also some low spots. Some managers did not want to bother their employees with separating materials, since it was not part of their "jobs." Others did not like the "big, unsightly" deskside boxes. Some participants ignored instructions for collection. For example, many businesses would not break down their cardboard because "it took too much time." Unfortunately, the unflattened cardboard also filled the collection containers rapidly, at times discouraging others from participating. Once this problem was identified and SRMG staff revisited participants, most cardboard was broken down by participants so that more materials could be collected.

6 SUMMARY: FUTURE CHALLENGES

Listed below are some of the challenges the City of Tukwila will face as it develops and implements a citywide recycling program for apartment dwellers and businesses:

- Overcoming current throw-away attitudes and habits.
- Motivating renters and business tenants to participate even in the absence of a direct financial incentive. Or, developing a mechanism that provides a financial incentive for renters to recycle.
- Making people aware of the solid waste disposal problem and about how to contribute to less costly and more environmentally sound ways of managing waste instead of burying it in landfills.
- Working with the large number of actors or decisionmakers in apartment and commercial projects. For the commercial locations, cooperation from the property owners, building managers, janitors and business tenants is necessary for the project to be successful. This is opposed to working with just renters or owners of single-family homes who might participate in a curbside recycling collection program. For apartments, cooperation from the owner, manager and tenants is vital for the project to have any significant impact.
- Integrating legislative, educational and technical assistance activities with a citywide collection program to maximize participation and waste reduction.

7 PROMOTIONAL MATERIALS

The following pages contain reduced images of promotional materials developed for this project, including:

- The pilot project collection container label and instruction sticker.
- Instructional flyer that was handed out to all project participants. (Not shown are all variations which had different site maps and slightly different text.)
- Participant thank-you note and response card.

Fig. 4: Collection container identification label. Red on white vinyl. (36" x 18")

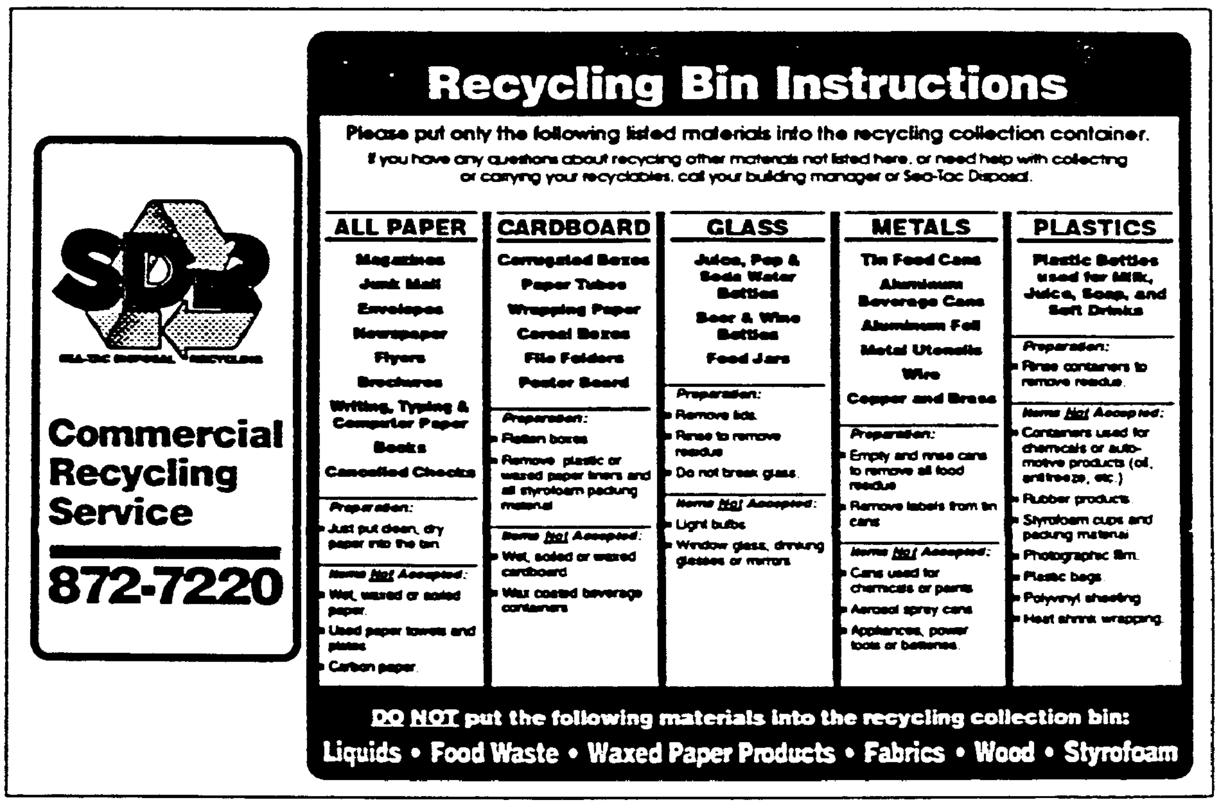
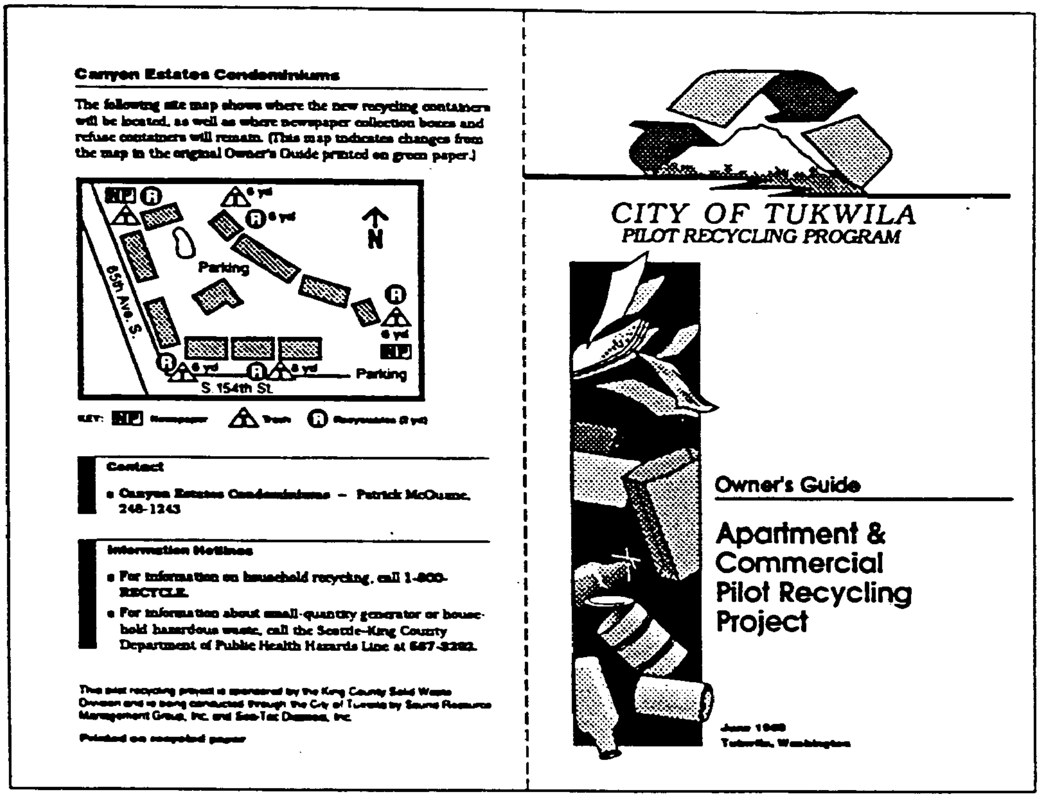


Fig. 5: Collection container instruction label. Red on white vinyl. (15" x 10")



Canyon Estates Condominiums

The following site map shows where the new recycling containers will be located, as well as where newspaper collection boxes and refuse containers will remain. (This map indicates changes from the map in the original Owner's Guide printed on green paper.)

Contact

- Canyon Estates Condominiums – Patrick McOuane. 248-1243

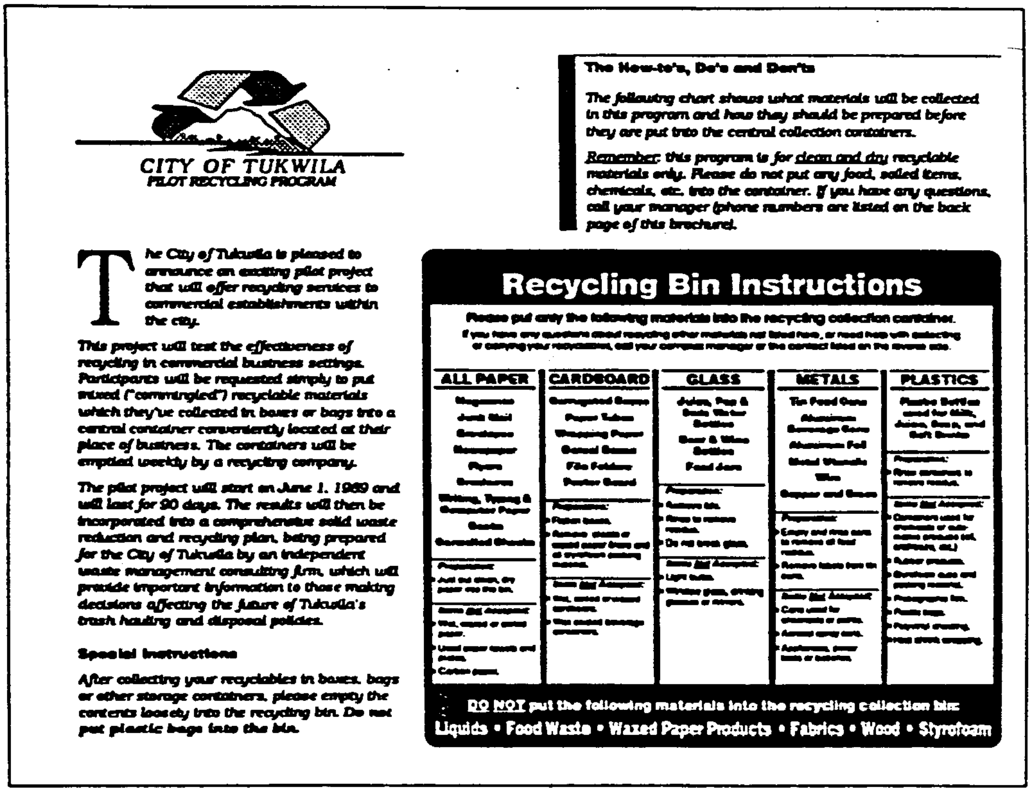
Information Hotlines

- For information on household recycling, call 1-800-RECYCLE.
- For information about small-quantity generator or household hazardous waste, call the Seattle–King County Department of Public Health Hazards Line at 667-3282.

CITY OF TUKWILA
PILOT RECYCLING PROGRAM

Owner's Guide

Apartment & Commercial Pilot Recycling Project



CITY OF TUKWILA
PILOT RECYCLING PROGRAM

The City of Tukwila is pleased to announce an exciting pilot project that will offer recycling services to commercial establishments within the city.

This project will test the effectiveness of recycling in commercial business settings. Participants will be requested simply to put mixed ("commingled") recyclable materials which they've collected in boxes or bags into a central container conveniently located at their place of business. The containers will be emptied weekly by a recycling company.

The pilot project will start on June 1, 1989 and will last for 90 days. The results will then be incorporated into a comprehensive solid waste reduction and recycling plan, being prepared for the City of Tukwila by an independent waste management consulting firm, which will provide important information to those making decisions affecting the future of Tukwila's trash hauling and disposal policies.

Special Instructions

After collecting your recyclables in boxes, bags or other storage containers, please empty the contents loosely into the recycling bin. Do not put plastic bags into the bin.

The How-to's, Do's and Don'ts

The following chart shows what materials will be collected in this program and how they should be prepared before they are put into the central collection containers.

Remember: this program is for clean and dry recyclable materials only. Please do not put any food, soiled items, chemicals, etc. into the container. If you have any questions, call your manager (phone numbers are listed on the back page of this brochure).

Recycling Bin Instructions

ALL PAPER	CARDBOARD	GLASS	METALS	PLASTICS
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

DO NOT put the following materials into the recycling collection bin:
Liquids • Food Waste • Waxed Paper Products • Fabrics • Wood • Styrofoam

Fig. 6: Instruction flyer delivered to all pilot program participants: outside (top); inside (bottom). Six versions printed. Black on blue paper. (11" x 8-1/2")

If you have any questions about this pilot recycling program you would like answered, or have any comments you would like to share, please note them in the space below and return this flyer to the City's recycling consultant: Sound Resource Management Group, 7220 Ledroit Court SW, Seattle, WA 98136. Again, thank you for you cooperation.

Your name and address (optional):

CITY OF TUKWILA

PILOT RECYCLING PROGRAM

Dear Pilot Project Participant,

The City of Tukwila would like to thank you for participating in our 3-month pilot recycling project. We were able to learn a substantial amount about recycling in our city, and are going to be using this information to make decisions next year about how to integrate recycling into our future solid waste management activities.

The recycling container(s) that were installed at your location will be removed at the end of August, and your garbage service will return to what it was before this project began. However, if you would like to continue recycling, you may call 1-800-RECYCLE to find out where there are recycling opportunities in your area.

Sincerely,
The City of Tukwila

THANKS FOR PARTICIPATING!

Fig. 7: Thank-you note and response card: front (right); back (left). Black on yellow paper. (5-1/2" x 8-1/2")

INTEGRATING CURBSIDE COLLECTION COST-EFFECTIVELY

Ronald A. Perkins
Waste Control Systems, Inc.

Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

INTEGRATING CURBSIDE COLLECTION COST-EFFECTIVELY

Ronald A. Perkins
Waste Control Systems, Inc.

INTRODUCTION

Municipal officials nationwide are confronted with increasing competition for limited tax dollars. Recycling advocates should not take for granted that taxpayers will always look upon curbside collection programs as sacred and untouchable. (Although environmentally unconscionable, solid waste management programs **can** exist without recycling.) Thus, those of us who are responsible for the design and operation of curbside collection systems must continuously search for more cost-effective ways to do our jobs. This presentation purports to provide the audience with some proven techniques to achieve the objective of integrating collection of recyclables cost-effectively into existing refuse collection systems.

The ideas promulgated here are based upon the presenter's successful operation of curbside programs over the past five years. "Success" here is measured by waste reduction achieved and program cost; in this case 23-31 percent reduction and a positive economic impact on the total solid waste management program. The particulars associated with these programs are set forth in Table 1.

PURPOSE OF PRESENTATION

1. **Identify aspects of system design critical for cost-effectiveness.**

    - Political and municipal administrative support.
    - Maximum convenience for residents within limits established by market constraints.
    - **Integrate** operational plan to maximize positive economic impact on total solid waste system.
    - Identify optimal equipment/crew size, policies and collection frequency using simulation models.
    - Adjust **refuse** collection system resource requirements (equipment/labor) to reap rewards of **refuse** volume reduction.
    - Monitor refuse/recyclables ratio and adjust resources accordingly.
    - Provide feedback to public for positive reinforcement.

2. **Provide useful tips/based upon "real world" operational experience.**

    - Give strong consideration to collecting **corrugated**; high volume/weight ratio positively impacts **refuse** density and landfill space usage. (There's more than you think!)
    - Whenever practically possible consider collecting **one** material (either source separated or commingled) at a time to allow utilization of conventional refuse collection equipment. This increases collection rate and ability to swap trucks from recycling to refuse routes.

- Collection of a single material at a time also **totally** eliminates problem of under utilizing full capacity of truck which occurs in multi-material collection when one bin typically fills before other.
- Simulation models can be used to **accurately** estimate collection rates and corresponding crew and equipment requirements.
- Do **NOT** believe equipment salesmen; visit existing systems for truth/problems.
- Investment in equipment operator training is well worth it. The biggest budget item in collection of recyclables is **labor**; therefore state of the art equipment (stand up dual drive; mechanical loading) is worth the investment.

3. **Stimulate program planners to give sincere open minded consideration to competing ideas, policies and techniques and TRUTH.**

- Can materials be added/deleted which will have a net positive impact on total system costs?
- Are our collection vehicles **consuming** more energy than they are ostensibly saving due to **too** frequent collection?
- Can we justify making collection of recycling a "jobs" program?
- What are the **true** costs of my program?
- Could the program be operated more cost-effectively by municipal crews or private contractors?
- Are our publicized participation (% of households), productivity (households serviced/hr), and diversion (% of municipal waste stream) rates **truthful**?

CONCLUSIONS

- Curbside programs **can** be implemented at **no extra** cost to a municipality **if** properly **integrated** into existing solid waste management systems.
- Unbending adherence to the goal of **minimizing** labor is essential to attain program cost-effectiveness.
- Everything else being equal, **commingled** programs will achieve higher waste reduction rates than those "inconveniencing" residents by required "separation work".
- Program designers and managers **must** remain totally open minded to new ideas, policies and techniques which will increase program impact and reduce program cost.

TABLE 1.
Recyclable Material Curbside Collection Program
Operated by
Waste Control Systems, Inc.

	Municipality		
	E. Longmeadow	Longmeadow	Montague
Population	13,000	16,000	8,000
Households	4,000	5,200	2,600
Program Cost	60,770	80,040	41,600
Material Collected Annual Tonnage	Mixed paper 1,000	Newspaper 1,300	Newspaper 416
	Bottles/cans 285	Corrugated 260	Corrugated 80
	- -	- -	Clear Glass 80
Cost per ton collected	$47.29	$51.31	$61.54
Collection Frequency	Once/4wks	Once/2wks	Weekly
Average Participation	90-95%	90-95%	50-60%
Waste Stream Reduction	31%	23.5%	17%
P.R./Education Budget	<$500	<$500	<$200
Enforcement	Mandatory	Mandatory	Voluntary
Recycling coordinator	No	No	No
Collection Equipment	Sideload packer RH drive 17 cu. yd.	Sideload packer RH drive 17 cu. yd.	Specialized recycle truck RH drive 31 cu. yd.
Collection Crew Size	1	1	1

"INVOLVING THE CORPORATE CITIZEN IN RECYCLING"

By Dale Gubbels
Resource Integration Systems, Ltd.

Presented at the
First U.S. Conference on Municipal Solid Waste Management
June 13-16, 1990

With rare exception, communities rushing to implement recycling programs immediately set out to target the residential sector. There are several explanations, but I suspect a major reason is that we have been conditioned to accept that people are the root cause of the garbage problem and therefore, we must seek them out in their burrows to make them recycle. Of course, ultimately it is the individual who must be taught to recycle, but I think the issue -- and thus our responses to solve the problem -- require us to scrutinize in what capacity and exactly where individuals are contributing to the waste stream. Given that perspective, government -- local, state and federal -- would be better advised to first target the corporate citizen before targeting citizens in their homes.

There are numerous reasons for this suggestion. An important one surely is that the American workforce generates a lot of waste. I'll come back to that in a second, but I want to stress that an even more compelling justification is that unless the private sector adopts packaging and product design parameters which adhere to the hierarchy of resource conservation, those objectives will never be achieved fully.

I think anyone who has dealt with the problems of finding markets for the recyclables they collected, or has had to cope with contamination restrictions which result in belying any claims that a material is recyclable, will agree with that view. Therefore I won't dwell on why we should target the private sector in recycling programs, but rather I prefer to relate some examples as to how governments can and have accomplished that goal.

But first, referring back to the waste reduction potential by focusing on nonresidential wastes, our experience at RIS is that most communities will find that 40 percent and higher of what enters their local waste disposal systems comes from the commercial/industrial sector. This can include offices, stores, institutions, factories and construction demolition wastes.

Let me give you a little personal perspective on that point. For Earth Day, our office participated in a contest with RIS's other three offices to see which one could achieve the greatest landfill diversion rate. We weighed all of our office's trash -- there were 14 of us -- for a week. We practice waste reduction and reuse strategies -- such as copying all internal forms and communiques on the backs of discarded documents, making scratch pads from used paper, providing mugs rather than disposal cups and using a cloth towel linen service for rest rooms -- so I suspected our numbers were not typical.

With these practices, we generated a per person weekly generation rate of 3.12 lbs, a weekly total of 43.7 lbs. That compares quite favorably with the National Solid Waste Management Association's typical office estimate of 1 lb. per 100 square feet per day. Based on our office square footage and NSWMA's estimate, we would generate 100 pounds of garbage per day.

Of our office's waste stream, a little less than half -- 17 lbs. -- was high grade paper. Low grade paper, corrugated and commingled recyclable containers accounted for another 12.5 lbs. Kitchen wastes were another 8.7 lbs. Because we have markets and an on site compost bin, we were able to divert all of the above, leaving 5.5 lbs. of mixed waste for an overall waste diversion rate of 87.4%. I should add that we won the competition.

But not all businesses are likely to be as psyched for waste diversion as a recycling consulting firm. But with the right types of incentives and direction provided by the local waste authorities -- in some cases, shoves and heavy sticks -- the business community will respond very favorably to waste diversion.

Actually, I think the communities which have developed commercial recycling programs are usually pleasantly surprised at how well received recycling is by businesses. In fact, one of the major reasons I believe they should be targeted before tackling the residential sector is that commercial recycling can be much easier to implement.

Most businesses will gladly cooperate with recycling programs; the savings from avoided disposal costs alone are very tangible incentives, plus firms can enhance their public image and employees' morale. Allow me to share a few anecdotal examples.

Broome County in south central New York has established a 44 percent waste reduction goal by 1992. One of the first things it did to achieve that goal was to raise its landfill tipping fees which had been supported in part by the general tax base and also did not include provisions for closing and monitoring the site. Consequently, the fees went from $12 to $38 per ton. A three hundred percent disposal fee increase got a lot of people's attention.

One person's whose attention was grabbed immediately was the grounds manager for a local factory. His annual disposal costs could have easily increased by $160,000. To this gentlemen's and his company's credit, he had contacted us to help develop a recycling strategy prior to even learning of the county's intentions.

The next thing the county did was to pass an ordinance banning certain materials from the landfill, beginning in December this year. The materials include:

- suitable paper products
- recyclable metal, plastic and glass food and beverage containers
- large appliances
- yard wastes, including leaves, grass clippings and brush
- demolition debris
- tires
- wet and dry cell batteries.

The disposal ban may not necessarily mean that these materials must be recycled at the source by the generator. For some materials, such as tires and demolition debris, the generator may simply pay a premium above the tipping fee at a disposal facility for certain discarded materials that the county may later attempt to recycle.

The legislation covers the commercial/institutional sector as well as the residential sector. Since commercial/institutional solid waste constitutes approximately half of the county's total solid waste, the waste disposal practices of this sector will be targeted, and companies can expect to encounter greater scrutiny. The county is anticipating an "adjustment and education" period of one year, during which time violations will not be subject to enforcement and penalties.

The county has hired a staff person to work directly with small businesses to help them locate markets and meet the new requirements. It has also contracted with us to hold a workshop this fall for further technical assistance.

The city of San Jose, California, was one of the first municipalities to hire a full-time staffer to provide technical assistance to local businesses. The city provides a free inspection -- or waste audit -- to businesses. These onsite visits are a very practical and cost effective means to motivate businesses to recycle. States, also offer advise and information to businesses for little or no charge. Rhode Island is a very good example, and I will touch on it again in regards to its legislation requiring businesses to recycle.

One means for encouraging a win-win situation for businesses and local waste authorities intent on waste reduction would be for the authority to sponsor a loan program whereby it would pay the up front costs for any business wishing to implement a recycling program. Balers, carts, crushers -- consulting services -- would be just a few examples of some of the types of expenses eligible for coverage.

The repayment for these loans could be accomplished by adding the charge to the businesses tipping fee. Where private haulers provide collection, the waste authority could compensate the private haulers for serving as the collection agency by giving them a small percentage for facilitating the transactions.

Once the recycling effort is up and running, the business should experience a drop in its disposal fees. That savings would be applied towards the repayment of the loan.

The initial seed money for starting the loan program could be a number of sources:

- a tipping fee surcharge to finance recycling programs
- state grants (not just recycling or solid waste, but economic development and energy agencies' monies should similarly be sought)
- foundations
- bonds
- businesses and trade groups themselves
- banks and lending institutions.

The latter ones may strike some as bordering on the ridiculous: why would banks want to help fund recycling programs?

For sound economic reasons I assure you. If a business can show that it will reduce its operating costs by recycling and reducing its wastes, why wouldn't a bank consider putting up some of the money? If the local landfill authority agrees to collect payments and assist in finding markets for participating businesses, it seems plausible that given such assurances for repayment, the lending industry would see the merits of providing gap measure funding.

I mentioned Rhode Island's legislation. It requires that businesses with 250 or more employees develop recycling plans for the state's approval. Maine has similar legislation, but in Rhode Island, the state also will serve as the market of last resort. That is to say if a hauler can't find ways to market the office paper, OCC and other recyclables targeted by the state, the materials can be disposed of at the state's Materials Recovery Facility in Johnstown. To date, no commercial wastes have had to go to the facility.

Let's focus again on what local jurisdictions can do, because, in spite of what many may think, this level of government can garner significant contributions and support from the private sector for solving the solid waste problem.

Since markets are the foundations stones of any recycling program, local jurisdictions should diligently pursue strategies which identify and strengthen outlets for their collected materials. Again, the private sector should be viewed as partners in that effort.

We generally recommend to our clients that they form a market development committee whose members would include representatives from both private and public sectors. Their charge would be to review and continually recommend measures designed to increase the recyclability and marketability of the area's waste stream. Both area government and private sector practices should be reviewed by the committee.

Deanna Ruffer will address the importance of involving local recycling firms in a community recycling plan, but my focus includes those businesses not necessarily involved in the solid waste industry.

Prime candidates for serving on the committee are local brokers and end users of recyclables, but I think it just as important to include the large and small generators of solid wastes, bankers, and public relations firms and any other business that has a genuine interest to help find or improve local markets.

I alluded earlier to one reason why these firms would want to get involved -- enhanced company efficiency -- but then there are important considerations.

In these days of heightened public concern for the environment, everyone seems to be jumping on the recycling bandwagon. Let's face it, the environment help sell soup to nuts. I don't think we need to dwell on why the private sector is getting involved; I think we should just be thankful that they are.

Some examples of the objectives, questions and issues which the committee should address include:

- <u>Reviews of government procurement practices.</u>

Is stationery printed on recycled paper? Are public parks using compost? Can the bids that are let for road construction projects require the use of reclaimed asphalt, glassphalt, rubberized asphalt, and cellulose mulches and compost for right of way re-sodding? Do bid specifications for traffic signs and barriers require the use recycled plastics? Do county-sponsored energy assistance programs encourage the use of cellulose insulation? Can the bid for printing of public notices specify that they be printed on recycled paper?

- <u>Encourage local businesses to use recycled products.</u>

Could area manufacturers replace primary resources with secondary resources (recyclables) in any of their operations? Examples include modest low-tech efforts such as using shredded mixed paper or reclaimed plastic "peanuts" for packaging, retrofitting equipment -- e.g., plastic injection molders -- to use recycled resins.

I think we too often forget that recyclables are resources and that our local businesses themselves use resources. An inventory of their needs and your community's ability to fill those needs with its reclaimed resources is a natural. In Broome County, a local landscaper set up a composting operation to handle its yard waste. It soon began helping other businesses by accepting their food processing residues.

- <u>Work with economic development agencies to encourage market development opportunities.</u>

Chamber of commerces, local, regional and state economic agencies, utility companies and business associations are all potential allies. Do they understand that your community's recycling program will be "mining" resources which industries need? Perhaps these agencies would sponsor market research efforts for various troublesome materials, such as tires or used oil.

Financial Commitment

These efforts need not be costly. For example, advising vendors of one's preferences for recycled items may in and of itself lead to options for purchasing less expensive products. Some agencies have found in their review of procurement practices that bid specifications required all products be made of "virgin materials." This stipulation often reflects outdated prejudices based on misinformation.

Further support for using recycled products can be shown by stipulating that procurement agents purchase recycled items even when their costs exceed that of virgin products made. Five to 10 percent price preferences are used by several jurisdictions. One way to give such products preference, but demonstrate fiscal responsibility, is to dedicate the revenues from office paper recycling programs to offset the price difference for using recycled paper.

The purchasing power of governments and businesses can be applied even more directly to secure markets for their recyclables. For example, oil suppliers for the county's vehicles could be required to accept the county's used oil. Similar stipulations could be made for asphalt removed as part of road work and construction demolition. Several of the firms we developed recycling plans for adopted this recommendation, with excellent results. One client in particular found that its vendor not only willing to start hauling back its empty plastic spools, but it could rebate our client since the vendor was allowed to reuse the item.

The voluntary nature of your local committee assures that the only tangible costs for the effort would be administration costs for coordinating the committee's meetings.

I should point out another major reason for businesses to want to get involved locally in this issue, and it ties back to the point concerning the design for recyclability. Industry is getting involved in recycling like never before for fear that they may otherwise be banned from the marketplace.

Contra Costa County, California has a plastics recycling committee, the members of which include representatives of Proctor and Gamble, Del Monte, the Council for Solid Waste Solutions and Dow. These businesses are highly visible in the area and they are all good corporate citizens, but I don't think anyone is so naive to think that the county's review of legislation to limit non-recyclable materials did not motivate these firms to action.

I am not recommending that communities threaten anyone with bans, fines, taxes or any other punitive actions. Far from it. Gaining attention with bans is one thing, but I think there are only so many times you can throw a brick through a window before you are labeled a vandal. I think industry has gotten the message to get involved in recycling. Now society needs to develop constructive ways to channel industry's involvement.

Some positive examples for how companies might collectively get involved exist already. In the Northeast, the Coalition of Northeast Governors' Source Reduction Council created last September is an excellent example. Representatives of major industry and nonprofit organizations has joined with CONEG, a nine state regional group of governors, to focus on the means to reduce, minimize, return, reuse, refill and recycle packaging.

Across our border to the north, the Ontario Multi-material Recycling Industries, OMMRI, is a program funded solely by the private sector to help Ontario achieve its 50% waste diversion goal by 2000. OMMRI's initial members are Ontario Soft Drink Association, the Grocery Products Manufactures, the Ontario Printing Papers Users Group, the Packaging Association, the Council of Grocery Distributors and the Society of the Plastics Industry (all of Canada). Its goal is to take a proactive, cooperative stance with the government to achieve the opportunity to recycle for 80% of all Ontario households by 1995.

It intends to invest $45 million over the next five years, making this money available to local municipalities on a matching grant basis.

A similar group has formed in Europe -- the European Recycling and Recovery Association. It is studying the OMRRI system as its model of operation.

Back in this country, such cooperative coalitions have been slow to develop, but the makings of such efforts are there. Witness EPA's and the National Recycling Coalition's formation of the Recycling Advisory Council. While its purpose is advisory, I have hopes that, because this group involves major CEOs and top environmental and public sector leaders, it can be the genesis for much more tangible support for recycling than the advisory role it has currently adopted. If not the RAC itself, surely it will be exposed to the idea for a broad, multi-faceted and multi-material coalition of industries which works for a common goal to bring about sensible recycling, and resource conservation policies.

If the RAC doesn't discuss this idea, perhaps you can put it on the first agenda of your local business and industry recycling committee.

LOCAL GOVERNMENT RECYCLING PROGRAM DESIGN INTEGRATING EXISTING RECYCLERS

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Presented at

First U. S. Conference on Municipal Solid Waste Management

June 13-16, 1990

Abstract

Markets are essential partners with local governments in recycling programs. While local governments typically focus on determining what markets exist, too often, the existing capability of local recyclers has been overlooked. As a result, recycling programs are designed and, in many instances, material recovery facilities constructed when they may not be needed, costing both time and money, and ultimately competing for the materials that have kept private recyclers in business for many years.

While typically it will be unlikely that existing firms will be providing the materials collection services needed for many local government recycling programs, the consideration of existing recyclers to address processing requirements of the recycling programs can be crucial to the successful, fast track development of recycling programs. Local recyclers can, if considered, be valuable partners with local governments and provide an important component to successful municipal recycling and composting programs while at the same time saving the municipality capital costs and implementation time.

This paper focuses on the questions about capacity, capabilities, and project interest to consider when assessing local recyclers. Discussion is given to approaches to use in "winning" the support and cooperation of private recyclers given a natural reticence to share business information. Ways to begin fostering relationships between local governments and recyclers early on in the program planning and definition process is examined. An outline of practical information to request in an RFP which gives preference to existing local recyclers yet seeks certain guarantees of service is presented based on experience with both local governments and processors. Contract provisions with a single processor processing materials from multiple programs and multiple jurisdictions (i.e., curbside, drop-off, commercial, etc.) and equitable treatments of multiple recyclers is discussed.

All of these ideas are brought together in an innovative approach of demonstrated success. Benefits can include relative ease and timeliness of implementation, low capital costs, relative ease to manage, program flexibility and a spirit of cooperation with the private sector and local business community. All of these are crucial to the success of local government recycling and composting programs in an integrated approach to solid waste management.

Local Government Recycling Program Design
Integrating Existing Recyclers

I. Introduction

II. Private Sector - The backbone of recycling efforts

A. Family Affair

B. "Brokers" "Dealers" and "Processors"

C. Independent Entrepreneurs

1. A strength
2. A weakness

III. Local Government - The new kid on the "recycling" block.

A. Mandates, Goals and Policies

B. The Results

1. Surveys
2. Curbside, MRFs, etc.
3. Markets?

IV. The "fit" with private sector.

A. Services Needed

B. Government Partnerships

C. Contractual Requirements

D. Costs and Implementation

V. Identifying Capabilities

A. What to look for

B. How to get information, support and cooperation

C. Realistic Assessments

D. Fostering relationships early

E. Public-private partnership foundation building

VI. Contracting for Services

A. Structuring the procurement

1. Separation of responsibilities

- collection
- processing
- material/revenue

2. Preferential criteria without sacrificing

- reliability
- cost of service

B. Providing for

1. Security
2. Control
3. Flexibility

C. Monitoring provision of service

VII. Benefits/Weakness

A. Entrepreneurial spirit/reticence to share information

1. During information gathering
2. During procurement
3. During contract

B. Ease and timeliness of implementation

C. Costs

D. Program Restrictions/Flexibility

E. Spirit of Cooperation

F. Responsibilities matched to capabilities

VIII. Conclusions

A. Not for everyone - but should be considered by all

B. Needs to be thoroughly thought out and contractually defined

C. Integration/partnership "attitude" is critical to success

D. Early identification of capabilities and program monitoring are critical to success

MAKING IT WORK: TRENDS FOR HANDLING LANDSCAPE WASTE IN ILLINOIS

by

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(Session: Recycling and Composting - Composting/Yard Waste)

In Illinois, landscape waste is generated at an estimated annual rate of nearly 2.8 million tons. By law, landscape waste, which includes leaves, grass clippings and brush, must be diverted from landfill disposal by July 1, 1990. Management alternatives to be in compliance under this new law include composting and agricultural use.

The Illinois Department of Energy & Natural Resources has taken the lead in providing technical and financial assistance necessary to carry out composting programs in communities throughout Illinois. To date, over 100 local and regional landscape waste programs are well on their way in an effort to meet the landscape waste challenge.

Close to $5 million will be used to assist these programs through grants which can be used for equipment to collect landscape waste separately from refuse and also for compost facility equipment that process landscape waste into finished compost. Emphasis is placed on funding those programs which provide a comprehensive approach to managing yard waste - collection, composting and marketing.

Valuable information can be obtained from funding composting programs. Trends can be identified in all aspects of the composting process. Among the trends are collection schemes in a rural setting vs. a metropolitan area. Also, which composting technology - high, medium, or low - is most appropriate for a particular area? Finally, what are the most viable markets for the finished compost - giveaway programs vs. bag & sell programs; residential markets vs. commercial markets?

MARKET DEVELOPMENT AND BUYING RECYCLED PRODUCTS: PROSPECTS FOR THE 1990s

Richard Keller
Northeast Maryland Waste Disposal Authority

Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

MARKET DEVELOPMENT AND BUYING RECYCLED
PRODUCTS: PROSPECTS FOR THE 1990's

RICHARD KELLER, PROJECT MANAGER
NORTHEAST MARYLAND WASTE DISPOSAL AUTHORITY

Recycling involves three distinct steps: collection, manufacturing and use. These steps are represented by the three arrows in the traditional recycling symbol. The three arrows must be in balance if we are to fully realize recycling's potential for waste management, energy conservation and resource conservation. Merely collecting recyclables is not recycling. Recycling does not occur until a product made from recycled materials is actually used by a final consumer.

In order for the United States to achieve maximum recycling in the 1990's, state and local governments must make sure that markets are available to absorb the new supplies. For some materials, markets will naturally grow as new supplies become available. For other materials, the public and private sector must work together to promote growth in industries that can rely on secondary materials in their production processes.

State and local governments must be concerned about existing and future markets for recyclable materials. We must take steps now to plan for future markets.

One of the most important roles that public officials can play in market development is to ensure that materials collected are clean, separated and meet industry specifications. They should also let potential markets know about the timing and availability of new supplies.

There are a wide variety of market development tools available to public and private agencies to increase the markets for recyclables. The majority of these tools are activities that must be undertaken by the state and local economic development agencies. Recycling must be understood as an economic activity, not as an environmental activity.

The National Recycling Coalition has recently adopted a policy regarding market development. The policy emphasizes the importance of reliable markets and the need for public / private cooperation to expand markets. The policy includes the following market development instruments:

* material processing facilities;
* contracts between suppliers and manufacturers;
* economic development programs (including financial assistance and assistance with facility siting and permit review);
* regional cooperative brokerage and transportation management programs;
* preferential procurement of recycled products;
* information and research programs (such as information clearinghouses, and public, private and university R&D consortia) to develop new recycled products and expand the use of recovered materials in existing products;

* investments in transportation infrastructure and marketing programs to facilitate increased use of recovered materials domestically and overseas;
* reassessment of material and product standards and specifications and consumer and business education programs to expand demand for recycled products;
* revisions in the tax codes, including differential packaging or materials taxes that favor recycled materials; and
* additional market development instruments as innovation and change within the recycling industry require.

PROCUREMENT OF RECYCLED PRODUCTS

According to the National Institute of Governmental Purchasing, government purchases represent approximately 20-21% of the Gross National Product (GNP). This breaks down to 7-8% federal and 12-13% state and local. Governments also have an important role in influencing private purchases, both through leadership by example and through their standards and specifications. Thus, government can influence private groups, from non-profits to Fortune 500 companies, to use recycled products.

At the federal level, the U.S. Environmental Protection Agency (EPA) has published five guidelines (paper and paper products, rerefined oil, retread tires, building insulation products and fly ash in cement and concrete) to provide guidance to federal agencies, and state and local agencies and contractors using appropriated federal funds. The guidelines include information on specifications, minimum content standards, and recommendations on establishing a procurement program. EPA is also examining the feasibility of guidelines for building and construction materials, rubber products, asphalt rubber and yard waste compost. Information on the guidelines and federal implementation can be obtained by contacting the EPA guideline hotline at (703) 941-4452.

At the state and local level, the National Recycling Coalition has identified 38 states, the District of Columbia and 16 local governments that favor recycled products. The 37 states and the District of Columbia represent approximately 221 million Americans, or about 90% of the U.S. population. Just 3 years ago, only 13 states (representing 46% of the population) had been identified. These programs include general statements favoring recycled products, goals, set-asides, price preferences, specification review and other methods to favor recycled products. Regional efforts are also beginning, such as those by the Northeast Recycling Council, the Metropolitan Washington Council of Governments and the States of Minnesota and Wisconsin.

KEY ELEMENTS IN BUYING RECYCLED PRODUCTS

In order to establish a good program for buying recycled products, organizations should include the following elements:

* commitment to buy;
* review purchasing specifications;

* common definitions and percentages;
* variety of products;
* testing products;
* phased-in program;
* price incentives;
* cooperation between solid waste and purchasing officials;
* cooperation among manufacturers, vendors and users
* cooperative purchasing;
* data collection;
* waste reduction and recyclability;
* source separation to ensure adequate supplies.

CONCLUSION

Market forces alone are not sufficient to create adequate demand for recyclable materials. Government recycling programs must include efforts by economic development agencies, procurement agencies, and the private sector to create markets for recyclable materials.

Richard Keller is a Project Manager with the Northeast Maryland Waste Disposal Authority. He is also Vice-Chairman of the Program Committee and Chair of the Market Development Subcommittee for the National Recycling Coalition. He has been involved in promoting programs for recycled products since 1975. He is a frequent author and lecturer on procurement and market development. Mr. Keller also manages the Coalition's peer match efforts. He can be reached at (301) 333-2730.

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MUNICIPAL SOLID WASTE COMPOSTING IN WEST GERMANY
THREE CASE STUDIES

Henry R. Boucher, Principal Engineer
Camp Dresser & McKee Inc.
Edison, New Jersey

Presented at the

First U.S. Conference on Municipal Solid Waste Management

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MUNICIPAL SOLID WASTE COMPOSTING IN WEST GERMANY

THREE CASE STUDIES

Henry R. Boucher, Principal Engineer

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Edison, New Jersey

This is a presentation of a fact-finding tour in 1989 of three municipal solid waste (MSW) composting plants in West Germany. The three plants visited process between 80 and 200 tons a day of mixed municipal solid waste (residential waste only at one plant), producing three basic output streams: compost, recyclables, and residue. The tour pointed out a number of important factors to consider when evaluating a solid waste composting plant, including composition of the incoming waste, recovery of non-compostable recyclables, end uses of the compost product, and residue and reject disposal.

The three solid waste composting plants visited are located in Duisburg, Aurich, and Bad Kreuznach, West Germany. All three plants employ the DANO drum in the composting process. We now look at each one.

DUISBURG, WEST GERMANY, COMPOSTING PLANT

In operation since 1958, the Duisburg composting plant is a 2-drum system which for the last four years has been composting domestic MSW from a select area of the City of Duisburg comprised of about 95,000 residents in single-family and two-family dwellings with relatively large gardens.

The input waste is collected in 120 liter (32 gallon) and 240 liter (63 gallon) containers only. 17,000 to 20,000 tons per year are processed. The plant is operated Monday-Friday with one 8-hour shift. The labor force is 9.

To keep heavy metal concentrations down, household-only MSW is composted. The rest of the City of Duisburg's (pop. 550,000) solid waste is incinerated. Plant management noted that the composting plant was but one part of the city's overall municipal waste management system, whose primary purpose is not necessarily to produce compost but to process a portion of the city's waste.

From November through January, the plant stops composting household refuse and composts the leaves collected throughout the city (about 19,000 cubic yards per year, or about 9,400 tons).

Other wastes processed at the plant are stable manures from the city zoo and a slaughterhouse (about 1100 tons per year) and grass clippings. Because the service area has small lawns and because backyard composting is widely practiced, the quantity of grass clippings is small (about 2200 tons per year).

The plant is situated near residential areas, an in-city location. A sewage treatment plant also exists on the site.

Plant management noted that their main emphasis is on marketing the compost. Major markets for the compost are farmers, nurseries, and as a bio-filter for odor control at other waste treatment plants (about 60 to 70 percent of the compost is marketed as a biofilter). To maintain marketability, much time is spent on process adjustments to ensure that the compost products suit their markets. Storage space equivalent to two years' processing capacity is available onsite. In the years selling compost products made from household MSW, plant management reports that there has never been a time when composting was stopped due to lack of sales.

It should be noted that this plant processes household refuse only; wastes from commercial sources such as corrugated cardboard, office paper, mixed paper are not composted here. Plant management said the DANO drum can process cardboard and other larger pieces but would do so not to produce compost but to pretreat the material for incineration (homogenizing step). This issue relates to collection container size. Limiting container size has been found to be important to successful composting operations because waste from larger containers (e.g., 300 gallons) contains more bulky material which lowers the overall organic content and dictates more sorting before the drum.

Process Description

Incoming waste is weighed and is conveyed past a magnetic separator. A hand-picking operation then removes relatively large and/or non-decomposable items such as bottles, tin cans, and plastic bags.

After hand-picking, the waste is conveyed into the 3.5 m x 26 m DANO drum. Residence time is 36 hours. Recently, according to plant management, sludge has ceased being added to the waste because of concern for dioxins in the compost. To replace sludge, nitrogen is added to the waste (the source of nitrogen being added is discarded fire extinguisher contents).

After the drum the waste passes through two screens, a 16 mm (coarse) and a 8 mm (fine) screen.

The fresh compost is stored in an aerated static pile curing area. The source of air for the aeration system is plant air including the drum. Air passing through the compost is cleansed of odors while maintaining the piles in an aerobic condition. After 3 weeks of curing, the compost is transferred to storage. In storage, augur holes are drilled into the compost piles to create a stack effect and eliminate the need for turning the piles over.

Mass Balance

For 100 tpd in 5 tpd is removed in pre-sorting. 95 tpd into the DANO drum plus 28.5 tpd water addition at 30% minus 28.5 tpd decomposition loss equals 95 tpd out of drum after 36 hours. 38 tpd of rejects from the 16 mm screen leaves 57 tpd to go to compost curing.

Processing cost is approximately $28/ton (including residue disposal). Compost revenue is about $5/ton. (1989 figures).

Comments

- The plant is both a research and testing facility and a component of the city's solid waste management system.

- The success of the plant in producing marketable compost is due to: (1) a pre-selected waste stream (household waste characterized by little bulky waste, high organic content, little cardboard, office paper and other paper products); (2) constant efforts by plant management to adjust process so that compost produced remains marketable; (3) and the marketing and composting expertise of the plant manager.

AURICH, WEST GERMANY, COMPOSTING PLANT

The Aurich plant, which is located in rural northern Germany, is a materials recovery and composting plant serving a population of 175,000. Current throughput is 50,000 tons per year. The labor force is 20. Site size is about 5 acres.

Process Description

MSW from residential, commercial and institutional sources is processed by the plant. Incoming MSW is deposited on a tipping floor and pushed onto a conveyor. The waste is conveyed past a magnetic separator to the hand-sorting area. Here ferrous and non-ferrous metals, glass, mixed paper, light plastics, rubber/leather/textiles and household hazardous waste containers are manually sorted. Except for the rubber/leather/textiles and household hazardous waste fractions, the hand-sorted materials are recycled. A rotating screen before the DANO drum removes over 100 mm material (about 15% of input) as reject.

After the drum, the material is separated into over and under 20 mm fractions. The under 20 mm material is further separated into under 8 mm and 8-20 mm fractions (fine and coarse compost). About 25 percent of the input waste is 20 to 100 mm size and about 50 percent of the input waste is less than 20 mm.

The compost is stored for 2 months and then put on an aeration slab for filtering.

Quantities and Marketing

For 50,000 tons per year input, compost production is 25,000 tons per year. 12,500 tons per year of 8 mm (fine) compost is sold in bulk to nurseries and landscapers ($10-15/ton) and 12,500 tons per year of 20 mm (coarse) compost is sold in bulk to landscapers for soil loosening and conditioning. A small amount is mixed with peat (necessary to meet heavy metal limits) and sold in bags to area consumers. The plant has long-term contracts for coarse compost sales. Sludge addition has been reduced from 40 tpd to 5 tpd because of heavy metal concerns.

Economics

Overall cost (incl. capitalization, transportation, collection, processing and residue disposal) is about $30-38 per ton. Average revenues are less than $5/ton. The construction cost (1982) was about $7 million.

Bad Kreuznach, West Germany, Composting Plant

Located in an industrial sector of the city of Bad Kreuznach, the new DANO composting plant in Bad Kreuznach went into operation in 1987 and was designed to operate as a continuous, highly mechanized facility with several hand-sorting stations for separation of recyclables prior to composting. However, at the time of the plant visit, numerous plant mechanisms were not operating and the plant process train was not functioning as originally designed.

The plant employs a single 4.25 meter x 40 meter DANO drum with a design capacity of 220 tons per day. The service area population is 145,000. The facility is publicly owned but privately operated. MSW from residential and commercial sources is processed.

Process Description

MSW is deposited on an enclosed tipping floor where the material is pushed onto a steel plate conveyor. The waste is separated by a trommel screen into two sizes: under and over 15 mm. The under 15 mm material is sent directly to landfill (about 18 percent by weight of incoming material). This step was implemented because it was thought that the smaller particles were largely responsible for high heavy metal concentrations. This has since been found not to be true and government permission is being sought to eliminate this step since a significant amount of compostable material exists in the under 15 mm fraction. The over 15 mm MSW is then conveyed past a magnetic separator and then past 3 hand sorters who manually remove glass, large pieces and plastic. (The original design called for separating the over 110 mm fraction from the 15 to 110 mm fraction. Each fraction was to go to separate manual sorting stations, plastics, paper and cardboard hand sorting on the over 110 mm line and glass sorting on the 15 to 110 mm line). At the time of the plant visit there was only one sorting line with three sorters manually removing large objects from the waste stream.

After the sorting and magnetic separation, the waste enters the DANO drum. Residence time is 24 hours. At the end of the drum, a rotating 80 mm screen separates the material into over and under 80 mm fractions. The over 80 mm material is landfilled. The under 80 mm material passes through another screen which produces under and over 18 mm fractions. The over 18 mm fraction is landfilled. The under 18 mm fraction is conveyed to a ballistic separator, a device for removing hard material (glass, metal, etc.) from the compost. The ballistic separator was down on the day of the tour and had not worked well in the past (40% efficiency of separation of hard material). The under 18 mm material represents the final product which is transported to the storage area for three months of storage. A short curing step on aerated slabs is not practiced. Storage area onsite is inadequate; as a result compost piles are 3 meters high instead of the recommended 2 meters.

One third of the input becomes compost; another third is landfilled; and the remaining third consists of decomposition loss and metal and glass recyclables.

Operating cost is about $33/ton; capital cost was about $16 million. The labor force numbers 18.

The compost product was relatively coarse (18 mm) and the product contained bits and pieces of metals, glass, plastic, etc.

The Bad Kreuznach operation is basically designed for the unique market it has always had--an erosion control product for the German vineyards (the plant is in a wine-growing region), sold for about $5/ton. For this end use 100% pathogen removal is not required. The product is not approved, nor aesthetically suitable, for household use. To produce clean salable metal, the over 110 mm material removed by the magnetic separator must be re-sent past the magnetic separator. Sorted glass has been difficult to recycle because of high broken glass content.

Findings and Conclusions Based on the Three Plants

- Compost marketing is the most important challenge for plant operators. (One operator reported that the majority of his time is spent on product marketing).

- The West German solid waste undergoing composting exhibited important differences from typical Northeast U.S. waste. Based on observations, the following differences were noted:

- Less newspaper
- Fewer aluminum cans and glass bottles
- Substantially less paper and plastic packaging material
- Little bulky waste
- Less junk mail
- More food waste (no kitchen food disposers)
- Little corrugated and office paper in compost plant waste streams

o On average, forty to fifty percent, by weight, of material entering the plants was screened out be landfilled or incinerated.

o Since the DANO composting plants visited in W. Germany are processing a different waste stream than typical U.S. MSW, caution should be exercised about transferring the results achieved at these West German plants to the U.S. situation.

o The hand-sorting materials recovery process was not producing a large, high quality recyclables stream. Substantial amounts of recyclables were not being removed by the sorting step before the drum.

o Odors were not a major nuisance during the plant visits. Odor controls such as biofilters are used to control odors.

- o Provisions for leachate control were not evident at the plants.

- o Substantial site area is devoted to compost storage.

(337/LM)

SUMMARY

CONFERENCE ON MUNICIPAL SOLID WASTE

NEW JERSEY MARKET DEVELOPMENT PROGRAMS

BUSINESS RECYCLING LOANS

Business recycling loans, ranging from a minimum of $50,000 to a maximum of $500,000 or higher for certain projects that are deemed necessary by the Department, are available to qualified businesses. The maximum term of the loan is 10 years at fixed rate of 3 points below the prime rate. A minimum 10 percent equity contribution of the total cost of the project is required from the businesses.

New Jersey businesses which collect, separate, process and convert post-consumer waste materials into new or marketable products are eligible for these loans. Recyclable materials include: paper, metal, glass, plastics, textiles, tires, food waste, motor oil, leaves, wood and wood products, asphalt, brick and concrete.

RECYCLING EQUIPMENT TAX CREDIT CERTIFICATIONS

The Recycling Act provides for the availability of a 50 percent tax credit to corporations operating in New Jersey that purchase recycling equipment. The recycling equipment tax credit is applied directly (dollar for dollar) against the NJ State Corporate Business Tax. To be eligible:

1. Recyclable materials must be post-consumer in origin;

2. Recycling equipment must be purchased as of October 1, 1987, or thereafter, and used exclusively in NJ;

3. Equipment purchased must be certified as eligible by the Department; and

4. Not more than 20 percent of the total tax credit can be applied in any one year.

STATE PROCUREMENT OF RECYCLED PAPER AND PAPER PRODUCTS

The Recycling Act required that not less that 45 percent of the dollar amount of paper and paper products purchased by the State after July 1, 1989 be spent for recycled products. Priority purchasing must be given to products with the highest post-consumer material content. In 1988, 59 percent of State expenditures for paper and paper products were for recycled products. State expenditures for paper products containing 50 percent recycled content or more was $1,997,641.43.

RECOVERY AND RECYCLING OF

POST-CONSUMER PLASTIC FILM

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13 - 16, 1990

RECOVERY AND RECYCLING OF POST-CONSUMER PLASTIC FILM

INTRODUCTION

One of the most visible issues in the world of MSW management is the need to recycle plastics. Programs to collect plastic bottles are proliferating rapidly and several facilities for reprocessing these bottles have been built. However, the recycling opportunity that is being neglected in the push to recycle plastics is the potential to also recycle plastic film.

Plastic film production is currently much higher than plastic bottle production -- approximately 7.2 billion lbs./yr compared to around 4.5 billion lbs./yr. Essentially all of this film is discarded after a single use, significantly adding to the volume of MSW. This paper presents a brief summary of how much film is being produced, current recycling efforts, processes available for recycling post-consumer film, and barriers to increased recycling.

PLASTIC FILM PRODUCTION AND USE

Domestic consumption of plastic resins in 1987 was around 44 billion pounds, and approximately 16 percent of this was used in manufacturing film. As shown in Figure 1, film production is dominated by low density polyethylene (LDPE) and linear low density polyethylene (LLDPE), which account for over three-fourths of the film produced. Consequently, the discussion of film recycling must focus primarily on LDPE and LLDPE (which are referred to as LDPE in the balance of the discussion).

Figure 2 illustrates how LDPE film is used. Half of this film is used for packaging, which includes non-food (industrial liners, shipping sacks, etc.) and food (produce, bread, etc.) applications. Trash bags, at 19 percent of total consumption, represent the next largest category followed by shrink or stretch film at 10 percent. The remaining film is used for construction, agriculture, or other non-packaging applications.

FILM RECYCLING

Film recycling rates are highest for scraps generated in manufacturing processes, which are also known as "home" or "prompt" scrap. While nearly 100 percent of this scrap is recycled in many facilities, it is estimated that overall recycling rate is only 60 to 80 percent. Factors influencing how much a processor recycles include whether coatings are used in the manufacturing process, how much space is available to store scraps, whether the film is laminated to other materials, and equipment capabilities.

Recycling of post-consumer film scrap, in contrast, is very low. This is particularly true if it is dirty or if the supply contains a mixture of different resins. It is estimated that the average recycling rates for film discarded by large users (i.e., large industrial or commercial firms and agricultural sources) is between 5 and 20 percent, but the rates for small firms and individuals is under 1 percent. Note that at present most of the post-consumer film that is recovered for recycling is exported rather than processed in the U.S.

Recyclers of post-consumer plastic film are most interested in low density and high density polyethylene. When the film is used to produce mixed plastic products (e.g., lumber, playground or parks equipment, pallets, traffic control barriers), the polyethylene serves largely as the "glue" that holds the mix together. In these applications, a small amount of dry dirt or other types of resins are generally acceptable.

To generate a higher value product from the recycled film, it must be cleansed to remove dirt, organic material, and other types of resins such as polypropylene and PVC. The resulting clean blend of recovered LDPE and HDPE can be used to manufacture film products (for trash bags, agricultural, construction use) or extrusions (pipe, conduit, gutters, etc.). The balance of this discussion will focus on these higher value applications.

RECYCLING PROCESS

The five basic steps in the recycling process used to generate high value plastic resin are:

- o Collecting the material
  - Purchase bundles or bales of film from high-volume generators or materials recovery facilities (MRFs)
  - Extract it from the mixed waste stream
- o Cleaning and Separating
  - Wash to remove dirt, product residues, paper scraps, organic material, and other contaminants
  - Separate the materials by resin type and possibly color
  - Dry the cleaned material
- o Melting -- to generate a liquid, homogeneous material in an extruder
- o Filtering -- which may be required to remove contaminants missed in washing

o Pelletizing -- to produce cleaned pellets for blending or direct use

While most users prefer pelletized resin, it may be possible to bypass the melting, homogenizing, and filtering steps if the feedstock is only lightly contaminated. In these cases, the clean shredded scrap would be fed directly to the end users extrusion system in which the final screening would occur.

AVAILABLE SYSTEMS

Several manufacturers offer systems for processing post-consumer film and several systems are in operation in Europe. In addition, several firms are processing post-consumer film in the U.S. or have announced plans to do so. Figure 3 lists a few of the leading equipment vendors and processors.

While the systems produced by these firms are largely similar, they do differ in some significant ways. The first of these is the film collection method. All of the manufacturers can process baled film, but only Sorain Cecchini can extract film from the mixed waste stream[1]. The second way they vary is in the use of proprietary equipment. Each process includes some proprietary components, most commonly in the areas of washing, separating different types of resins, drying, and filtering.

In practice, all manufacturers configure their systems to meet the specific requirements of each application. For instance, a line dedicated to processing only lightly

[1] A brief Description of the Sorain Cecchini technology which can recover plastic film from mixed municipal waste is enclosed as attachment 1.

contaminated commercial/industrial scrap may not require a heavy duty washing and filtering systems.

BARRIERS TO POST-CONSUMER FILM PROCESSING

The most significant remaining barriers to expanded recycling of post consumer film plastics are:

- Lack of domestic processing capacity -- only a few firms are processing (or plan to process) post-consumer film, and most of these will only process relatively clean scrap.

- Fluctuating resin prices and demand -- as illustrated in Figure 4, virgin resin prices (and corresponding recycled resin prices) have fluctuated considerably over the last several years.

- Cleaning cost -- to produce material that can replace virgin resin, it is necessary to remove:
  - Dirt and grit -- soil, metals, glass, ceramic.
  - Organic material -- food wastes, paper.
  - Other contaminants such as adhesives, coatings, labels and non-polyethylene plastics.

- High collection cost
  - If selling directly to brokers/processors, users with low generation rates must provide considerable space to store the material until a large enough volume is generated.
  - Equipment required to extract film from mixed MSW.

- Need for a stable supply of feedstock -- the value of the product will be higher if fluctuations in composition and availability can be eliminated.

- Potential contamination with photo- or bio-degradable materials -- which is cause for rejection by most users.

CONCLUSIONS

The capability to regenerate film-grade resin from post consumer plastic film exists and has been fully demonstrated. Given that plastics is a significant contributor to the growing solid waste disposal problem, it is essential that U.S. efforts to recycle plastic film be expanded. Recommendations for increasing recycling of film include:

- o Construct facilities to recover and reprocess post-consumer film -- existing capacity is limited and most facilities are only processing clean film.
- o Stop production of bio- or photo-degradable films
- o Establish purchasing preferences for products containing recycled plastics
- o Expand public education efforts -- to increase awareness of the potential to recycle film

Figure 1

Plastic Film Production

1988 Total – 7.2 Billion Lbs.

Source: 1989 Facts & Figures of the Plastics Industry

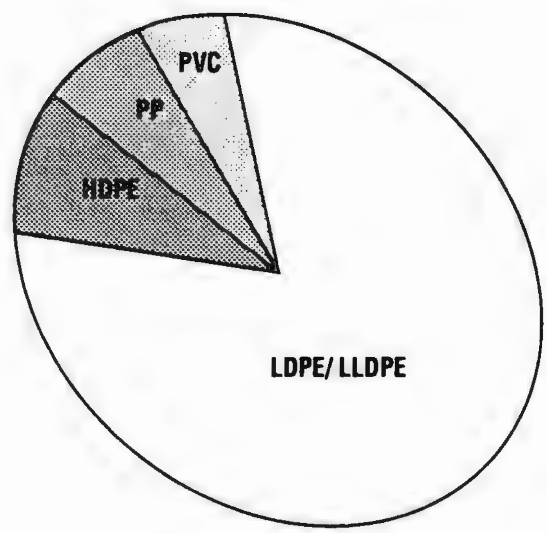


Figure 2

LDPE Film Uses

Source: 1989 Facts & Figures of the Plastics Industry

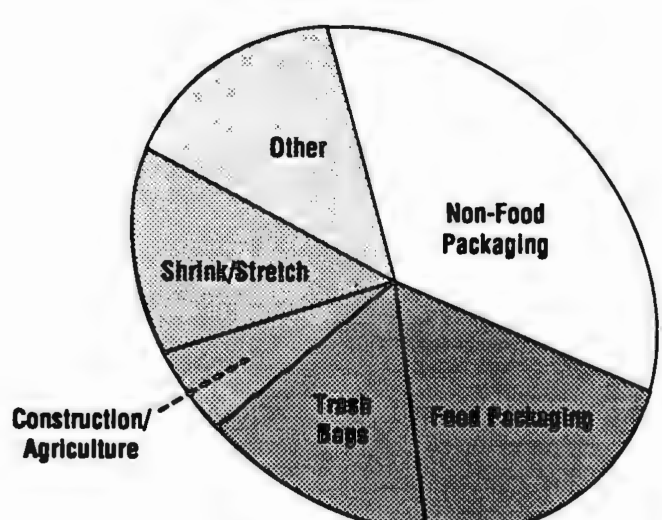


Figure 3

Film Regeneration from Dirty Scrap

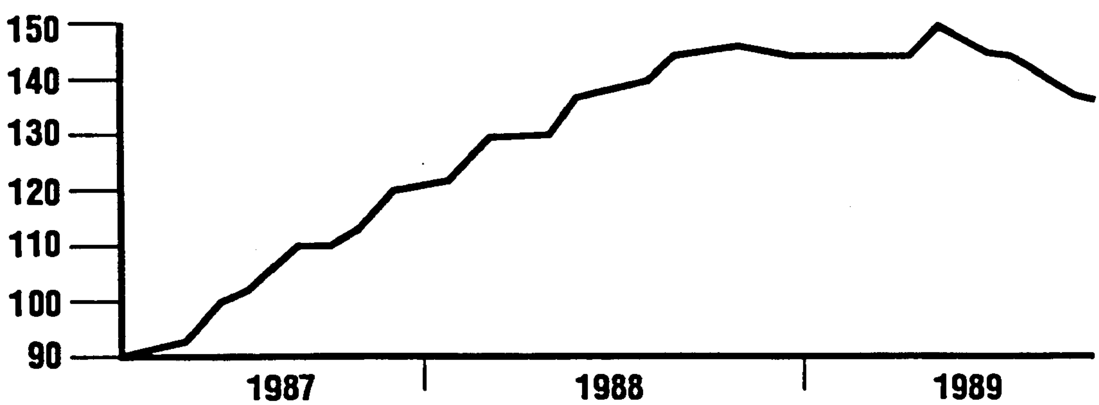
Equipment Vendors	Domestics Processors
Sorain Cecchini	Union Carbide*
American Leistritz Extruder Corp.	Mobil
Herbold Granulators USA	Polysource (AKW)*
Transplastek	Sonoco Graham*
	Selected small Processors

*Planned but not yet operating

Figure 4

Resin Price Trends

Source: Plastics World, Composite index for PE, PS, PP, and PVC



ATTACHMENT 1

SUMMARY DESCRIPTION OF SORAIN SOLID WASTE RECYCLING TECHNOLOGIES

INTRODUCTION

American Recovery Corporation's Sorain technologies have a proven track record in solving the problems associated with waste handling, processing and disposal. Sorain has been involved in the field of Municipal Solid Waste (MSW) management for over 45 years. Development of the Sorain MSW processing and recycling systems began in the early 1960s and the first facility using this technology was placed in service in 1964. Sorain presently owns and operates municipal waste collection equipment, street cleaning equipment, transfer stations, composting facilities and one of the largest landfills in Europe (Rome) with a daily capacity of 4000-5000 metric tons per day. The knowledge obtained through actual operating experience has played a key role in the development of the current state of the art Sorain technologies.

GENERAL DESCRIPTION

The proven Sorain systems are capable of processing waste materials from residential, commercial and light industrial sources. Each facility is specifically designed to meet the customer's requirements, based on the following parameters:

- Waste composition
- Materials to be recovered
- Availability of a domestic or international market for the recovered materials
- Current cost of alternative disposal methods

All Sorain processing plants require a waste receiving area and the primary processing system, while the recovery systems are determined by the site-specific parameters described above.

Should the site have the ability, both physically and economically, to support a full-scale Sorain facility, the plant would have the following processing and recovery systems:

- Waste Receiving
- Primary Processing System
- Plastic Film (Polyethylene) Recovery
- Corrugated Recovery
- Newsprint Recovery
- Mixed Paper Recovery
- Office/Computer Paper Recovery
- Aluminum Recovery
- Ferrous Recovery
- Organic Materials Recovery
- Combustible Material Recovery

In addition, the following processing and refining lines could be installed:

- Fully automated Composting Systems for the composting of the mixed organic fraction and/or yard waste.
- Plastics Regeneration Systems for the processing of the Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) plastics into LDPE and HDPE plastic pellets.
- Ferrous Refining System for cleaning and densifying the recovered ferrous materials
- Aluminum System for densifying the recovered aluminum materials.
- Baling System for the recovered paper materials.

The recovered components and products listed above can be recycled and used in the following manner:

- Newsprint, mixed paper, office, computer and corrugated materials as feedstock for the paper industry.
- Plastic pellets for the production of plastic trash bags, pipe, conduit or molded objects
- Compost material as a soil conditioner in parks and gardens
- Ferrous metals in the steel industry
- Aluminum material in the aluminum industry

PROCESS DESCRIPTION

WASTE RECEIVING AREA

Municipal waste can be brought to the facility by truck or rail. It is weighed as it enters the facility, and then proceeds to the tipping area. The tipping area can consist of either a conventional tipping floor or a pit.

When a tipping floor is used the material is handled and moved to the infeed conveyor with the use of front end loaders. A tipping floor director is responsible for instructing the truck drivers where to place their loads and for initial screening and inspection of the load for non-processible materials. The front end loader operator then moves the processible waste over to the infeed area of the primary processing system and directs the non-processible material to the reject area for landfill disposal.

When a pit is used the material is segregated by the pit's overhead grapple crane operator. Reject material is directed by the grapple crane operator to a reject area and the processible waste is placed in the infeed area for subsequent loading into the primary processing system.

PRIMARY PROCESSING SYSTEM

The primary processing system is the basis for each Sorain facility. This system takes the raw waste from the receiving area and processes it for subsequent material recovery. The system is modular, with each module capable of processing 50 short tons of waste per hour.

The infeed conveyor delivers the processible material to the bag breaker. The bag breaker, a patented and time proven device, has the function of opening up the waste containers and of providing preliminary sizing of large pieces of cardboard and other bulky items. This sizing function, and the method by which it is accomplished, allows easier recovery of the recyclable materials, without the contamination experienced with shredding systems.

The waste material leaving the bag breaker is then mechanically sorted by its physical characteristics (size and weight) using a patented self-cleaning trommel and patented air classifier. This mechanical sorting operation concentrates materials into specific materials streams which allow for subsequent material recovery.

FERROUS RECOVERY AND REFINING SYSTEMS

Ferrous is recovered using a magnetic conveyor system. Raw ferrous material recovered from MSW by magnetic separation contains a degree of contamination which can affect the marketability of the recovered material. Therefore a Sorain ferrous cleanup system is recommended for refining this raw material into a quality product. This system economically cleans the raw ferrous and produces a high grade product, with a nominal 2 inch diameter, that is clean of paper, plastics and other contaminants.

ALUMINUM RECOVERY SYSTEM

Aluminum is recovered using either hand picking or a fully mechanical eddy current system. Recovered aluminum enjoys one of the highest recovered materials marketing prices. The recovered material is densified or baled for market.

PLASTICS RECOVERY AND REFINING SYSTEM

Plastic film, Low Density Polyethylene (LDPE) is mechanically recovered from the waste stream using unique, patented equipment and can then be processed by the plastics refining system. The patented refining system will shred, wash, dry, extrude and filter the recovered Low Density Polyethylene material into a high grade plastic pellet. The pellets produced by the process are of such a high grade that they can be refilmed into new plastic trash bags. The plastics refining system can also be configured to allow the direct infeed of agricultural and other industrial film plastic into the plastics washing line without first sending it through the primary processing equipment. High Density Polyethylene (HDPE) can also be processed separately to produce HDPE pellets. The system produces a nominal 1/4 inch pellet which can be marketed in either bagged or bulk form.

Sorain also has experience in the use of this recovered Low Density Polyethylene plastic in the manufacture of new plastic bags, piping and conduit. Sorain currently owns and operates separate plastic bag and pipe production facilities located in Pomezia, Italy.

PAPER RECOVERY SYSTEM

Paper is usually recovered in the form of corrugated, newsprint and/or mixed paper. Newsprint and corrugated paper recovery is accomplished by hand picking, after initial mechanical processing has concentrated the paper material. Mixed paper is recovered by mechanical process. These products are then baled and marketed. Sorain can also provide a paper pulping system if a market exists for a pulped product.

PREPARED FUEL SYSTEM

The system can be configured to produce a fuel product which can be burned in mass burn, Refuse Derived Fuel (RDF), kilns or fluidized bed boilers for steam and/or energy production. The type of burner used will determine the processing system's configuration. Fuel heating values can be controlled through the process to accommodate the very specific fuel properties required for the type of combustion method used. Sorain also has experience with the production of pelletized and semi-densified fuel products.

COMPOSTING SYSTEM

The composting system is a self-contained process which can accept organic material separated from the MSW by the primary processing system or from direct outside sources such as segregated yard wastes. The current Sorain composting system (fourth generation) represents over twenty years of research and operating experience with MSW composting, and is covered by two patents. The composting process takes 28 days, and the bed reaches a temperature of over 150° F during that period. This provides a material that is clean of bacteria. The material leaving the composting bed is sent through a final refining process where glass, small plastic and paper fragments, and other contaminants are removed.

The composting system is computer controlled and can be operated with a minimum of staffing. This system provides for significant weight and volume reduction of the amount of material entering the landfill. The compost material can be used for landscaping or can be enhanced with chemicals for use as a fertilizer and soil conditioner.

DENSIFICATION SYSTEM

Depending on the final processing system configuration, a densification system can be installed to enhance the volume reduction capabilities of the facility. After material recovery, the remaining material is processed through a densifier, which provides a significant reduction in volume of the reject material to be landfilled.

STIMULATING MARKETS FOR RECYCLED PRODUCTS

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Presented at

The First U.S. Conference on Municipal Solid Waste Management

"Solutions for the 90's"

June 16, 1990

Washington, D.C.

It is government's responsibility to set an example for the public and private sectors by purchasing recycled products. The most important point to remember is that the demand for recycled products is what drives the markets for the materials being recovered. Not enough attention is given to the market issue. This morning I will describe some of the successes we have experienced in Illinois regarding recycled products.

Our accomplishments are the result of a lot of hard work, research, and substantial staff commitment. Following is an overview of our activities. Central Management Services (CMS), Illinois' administrative agency, is purchasing recycled bond paper, tissue and toweling, corrugated and has an open contract for FSC stock forms. The 1989 Illinois income tax booklets, 1990 state phone directory, and budget books are all printed on recycled paper. Illinois is working on incorporating USEPA standards into our state definition for recycled paper. Illinois is the only midwestern state represented on the ASTM project to develop national state purchasing standards. The Illinois Department of Transportation will be testing recycled plastic products manufactured by DuPont. Our education outreach includes planning a technical workshop for state purchasing personnel on buying recycled paper and paper products. We will be developing a corporate waste reduction program for Illinois companies. In Illinois, as elsewhere, increasing attention is being directed to source reduction. As you can see, our efforts are varied. Our approach has been to identify opportunity and need, then pursuing a results oriented strategy.

I. We are here today to better understand and to stimulate demand for products made from recycled materials. Increasing volumes of discarded waste material, coupled with increased efforts to recover recyclables mean there must be increased demand for products made from these materials.

II. Legislation is traditionally passed in response to a problem. Solid waste is clearly one of those public policy issues that has received substantial attention in Illinois and elsewhere. Illinois law provides the basis and framework upon which our solid waste programs have been developed.

A. Illinois Solid Waste Management Act of 1986

1. Established hierarchy of disposal options: waste reduction, recycling, incineration, landfilling.

2. Called for recycling market development efforts by ENR. This mandate is the basis for our market development efforts which includes "buy recycled" programs.

B. The past couple of legislative sessions in Illinois set a record in the number of bills introduced to address the issue of solid waste, many of them controversial and most don't become law. However, this activity clearly points to the fact that solid waste is a major public policy issue.

III. I'll briefly describe the procurement legislation that has passed and become law.

HB 1085 (PA 86-452) While not procurement legislation, this law will provide for eventual availability of products or fuel sources derived from tires. It calls for the recycling and development of markets for tire-based products and provides financial assistance. (The funding source is a 50¢ increase in vehicle titles, deposited into the Used Tire Management Fund beginning Jan. 1, 1990.)

HB 1692 (PA 86-777) Amends the Solid Waste Planning & Recycling Act. As part of the planning process, requires counties to develop programs for promoting the use of products made from recycled materials to county businesses, newspapers and local governments. (The law states that recycling goals mandated in the county plan are subject to viable markets.)

HB 2326 (PA 86-246) Amends Purchasing and State Printing Contracts Act. Requires buying and using recyclable paper whenever possible, including not using colored paper that is not recyclable.

HB 3389 (PA 85-1196) requires all state agencies to maximize the use of recycled paper products. The total volume of recycled paper is to be 10% by June 1989 (that goal was exceeded with a 13% level), 25% by June 1992, and 40% by June 1996. Procurement consideration is to be given products with the highest percentage of post-consumer waste material. It requires the use of compost on state owned lands where feasible. (Another law bans landscape waste from being deposited in landfills as of July 1, 1990).

This summary does not include legislation under consideration this session, which ends June 30, 1990.

VI. Regardless of any laws, buying recycled products and examining ways to reduce the amount of solid waste we generate in our offices and schools is gaining increasing momentum:

A. Government, at all levels needs to set an example: federal, state and local government; school districts, colleges and universities. Private businesses have a major role to play as well. There are 3 reasons why we should do this.

1. This combined buying power is substantial and will make the difference in making recycling programs successful.

2. We cannot expect to establish recycling (collection) programs in our government offices, colleges and universities or company offices without looking at ways to close the recycling loop by purchasing recycled products.

3. Our vision is short-sighted if we look only at office paper, i.e., fine and writing grade papers in our procurement policies. Certainly that is a noble pursuit and a very visible display of our recycling ethic. But we must not stop there. There are other recycled products to consider as well.

B. Common myths for not buying recycled:

1. Recycled products don't exist

2. Too few sources

3. Quality is inferior

4. Costs are too high

I have observed that lack of information is a major deterrent.

C. Some action and explanation is in order to dispell the above myths.

1. Recycled products do exist, refer to the Recycled Products Guide available on an annual subscription basis from American Recycling Markets. Product listings are free.

2. Too few sources? This may be the case for some products, but competition has been increasing. Many companies are monitoring state procurement laws and general buying trends to assess how serious we are in buying recycled.

3. The quality is not inferior. True, for some recycled papers, the brightness may not be as high as virgin paper for example. The question is, do some of the standards need to be modified?

The benefits, I believe, outweigh the faults. For recycled paper and other recycled products, it is the end use, the application that we need to address. If products serve the intended use, are readily available from reliable vendors and at a reasonable cost, then buy them.

4. Regarding cost, some recycled products are less expensive, last longer or reduce our landfill disposal costs. Life cycle costing (or full cost accounting) is not receiving the attention it should. In fact, we are working with the Illinois Department of Conservation where they will do a life cycle costing analysis on recycled plastic lumber used to build park benches, outdoor toilets and boat docks. Funding is provided through our market development program.

VII. Lack of information is one of the biggest barriers to the problem. Some ways to overcome this:

1. Statewide recycled product procurement sessions. We sponsored the first one during the Spring of 1989 in Illinois with 250 state and local government procurement officials attending along with recycled product vendors who had the opportunity to display their products. Other states have since duplicated that program.

2. Subscribe to the <u>Recycled Products Guide</u> and if you have the funds, make it available to procurement officials.

3. Target potential high volume purchasers of recycled products and conduct a testing program for the products, which we have done in Illinois State Government. We tested continuous computer stock forms made from recycled newsprint by an Illinois mill, FSC. We have also tested recycled fine and writing grade paper. The intent of the testing program is to help overcome institutional barriers.

4. Target agencies and organizations that indicate a strong interest in buying recycled. Remember, it only takes one individual to get something started. If you can identify that individual and provide assistance, you are well on your way to success.

5. Get testimonials from users of recycled products and publicize heavily.

6. Conduct a promotional campaign that ties in with Recycling Week, for example. Last fall we co-sponsored a Fall Recycled Paper Promotional which included presentations at various state government subcabinet meetings. Agency directors were given a hands-on experience, trying to guess which paper sample was recycled. We also provided information on appropriate applications of recycled paper for each agency and how to buy it. We coordinated the promotional with the Governor's Office and Central Management Services.

VIII Recycling Market Development Program.

Low interest loans are available for:

1. Manufacturing operations that utilize recycled material in the production of new products. It is important to stimulate markets for the increasing volumes of materials being collected which will result in useful products for purchase.

2. Marketing of recycled products

Grants and loans are available for:

3. Procurement and testing of recycled products. We are providing funds to the Illinois Department of Conservation for the purchase of recycled plastic lumber. The Department will construct picnic benches, boat docks and outdoor privies. They will then test them for their resistance to animal destruction. If the project proves successful, they will expand the project and save substantial man hours in annual repairs and replacements.

Closing the loop--government procurement plays a critical role in this public policy issue.

Your participation here today can make a difference. You can be part of the driving force to make recycling, "buying recycled" and buying for source reduction part of the mainstream, the norm in our purchasing decisions.

UK MARKET BARRIERS AND OPPORTUNITIES FOR RECYCLING MATERIALS FROM DOMESTIC WASTE

John Barton
Warren Spring Laboratory

Introduction

As a manufacturing country with limited indigenous material resources, the UK has always had a thriving reclamation industry geared to recovery values from wastes whenever economically feasible.

However, reclamation activities have tended to centre on arisings from the industrial, trade and commercial sectors rather than the waste materials discarded by the householder. Where materials from domestic wastes have been recovered, this has largely been due to the efforts of charity and voluntary groups (eg scout collecting paper, clothes sent to Oxfam) rather than a systematic or integrated approach to place recycling as a fundamental element in the management of domestic refuse.

Obviously there have been exceptions to this general picture, the UK has a number of nationally available recycling schemes, eg bottle banks for glass, and many local authorities (eg Leeds Save Waste and Prosper) have developed facilities for the public. In addition a limited number of pilot collection schemes (eg Sheffield recycling city) have been implemented to study separate collection of recyclables directly from households. However, at the present time, not more than 5% of dustbin type household waste finds its way back into the recycling loop through these activities.

Once in the dustbin and collected as mixed waste, some of the waste management treatment systems recover values, eg energy from mass burn incineration plant and fuel and materials (mainly metal, some compost) from waste sorting/refuse derived fuel plant. Again less than 5% of mixed waste is so treated, the remainder is either incinerated without energy recovery (8%) or landfilled (87%).

Frankly, in today's world this is simply not good enough. Whilst there are technical/financial/geographic factors which go some way to explain the current position, few would argue that the UK was making best use of resources or that recycling levels from the domestic waste were at optimum levels in broader economic/environmental terms.

Neither is this situation acceptable politically, a point clearly recognised in the summer of 89 when our Prime Minister commended a target of 50% recovery of recyclables on domestic waste by the end of this decade. This target calls for a dramatic change in attitude and direction for the wastes management industry, for industries concerned with converting scrap to reusable and marketable products and the purchase of these products at the manufacturing, retail and consumer levels.

In the UK, our Department of Industry has the leading, co-ordinating role in material resources and recycling but obviously our Environment Department, with responsibility for local authorities, wastes management and environmental quality has a major role in terms of unlocking the gate. Essentially the task is to transform the dilute, diverse and widely dispersed state materials are found at the household level to the concentrated, high volume and high quality flows needed for industry to effectively reuse these materials as feedstock to the processes and products required by the economy.

In order to assess the requirements needed for a rapid expansion of recycling in the UK to meet the Prime Minister's target, DTI and DoE initiated the UK strategy group for recycling. This group was drawn together from across the various sectors and included local and central government, the voluntary sector, environmental groups, the reclamation and primary industries, retailers, fillers/bottlers, trade organisations, economists and leading academics and researchers working in the environmental and recycling field.

The remit for the group was clear; for each main commodity in domestic refuse, eg paper, plastics, textiles etc, review the current practices, identify barriers, propose solutions for overcoming the barriers and arrive at commodity recycling targets considered achievable over the next decade. The group's recommendations were then to be forwarded to Ministers in order to inform their thinking and policies, with particular reference to the new Environment White Paper due to be published this Autumn (1990).

The Potential

To assist the strategy group in their task, Warren Spring Laboratory, the UK's government owned Environmental Technology Agency, prepared a series of 'fact sheet' reports covering the main commodities. As most will be aware, 'facts' in the waste and reclamation industries are not easy to come by. Not only are weight and compositional flows frequently estimated rather than measured, but definitions of what constitutes 'domestic waste' are many and data from the reclamation and primary industries frequently fail to differentiate sufficiently with regard to the source of 'recycled' feedstocks and materials.

Despite these problems, by considering commodity production and use data and comparing these with the limited but specific weight and compositional data for domestic wastes available from research institutes such as Warren Spring, a broad picture of the loss of potentially recoverable materials was drawn up. A waste generation figure of approximately 600 kg per houeshold per year for <u>dustbin</u> waste was used (ie excluding large items such as fridges, cookers, furniture and garden wastes which are normally collected/delivered for disposal separately). This equates to -16 million tonnes* per year for the UK as a whole.

The 'typical' composition of UK <u>dustbin</u> waste was known and furthermore estimates could be made of the quality and contamination levels associated with the materials. These are reported elsewhere[1] and, excluding options such as energy and compost recovery, it was estimated that some 40% of the UK dustbin could in theory be recovered as a 'clean recyclable' material. How this 'amount' compares with UK consumption, production and current scrap use for each commodity is very illuminating. Table 1 provides the estimates and a number of simple points can be noted.

* For some commodities, UK consumption significantly differs from production, eg UK imports over half her paper and board materials from abroad.

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* note, weight as received, ie with associated moisture content of -30%, dry weight -11 million tonnes.

TABLE 1. - UK Scrap Use and Potential Effect of Recovering Clean Recyclables from Domestic Refuse

	UK Consumption tonnes x 10^6	UK Production tonnes x 10^6	Current Scrap* tonnes Use x 10^6	Export of Scrap tonnes x 10^6	Potential*** Available from Domestic Refuse tonnes x 10^6	Current Scrap Use as % of Production	Factor Increase Resulting from Recovery of Domestic Recyclable
Paper and Board	9.97	4.32	2.45	0.42	2.5 - 3.0	57	x 2.2
Steel/iron	15.86	20.36	8.86**	3.61	0.8 - 1.0	44	x 1.1
Aluminium	0.53	0.41	0.13	0.11	0.09 - 0.11	32	x 1.8
Glass (containers)	1.75	1.73	0.28	<.01	0.6 - 0.8	16	x 4.8
Plastics	3.25	1.91	0.15	<.01	0.3 - 0.4	8	x 6

* includes imported scrap

** includes in-house scrap (not post consumer)

*** 'clean recyclable' estimate

* Some industries, eg paper, steel and aluminium, are well aquainted with using scrap materials (albeit mainly from non domestic sectors), other industries, particularly plastics, are not.

* The size of the production industry has a direct bearing on home market capacity to reuse scrap but for higher value materials, UK also exports scrap and provides a market for scrap collected abroad.

* For all commodities other than steel, the effect of recovering recyclables from domestic waste significantly increases amount currently available/used. For paper and aluminium by a factor of 2, for glass and plastics by 4 to 6 times.

If nothing else, these data clearly illustrate that even at 50% recovery of recyclables, major infrastructure changes are needed within UK industry to accommodate such flows and a major impact on import/export of commodities would result. When it is also considered that in addition to current scrap flows, unrecovered potential exists in other non domestic but similar waste streams (particularly commercial and retail trade sectors) then the need for direction/co-ordination and promotion at a national level is readily apparent. Switching on the system cannot occur overnight, the barriers and problems need thorough analysis and positive action.

In the above comments the definition 'recyclable' has so far only been applied to materials, the majority of domestic refuse is not suited to reuse as a commodity. For these residues treatment plant for composting, fuel and energy recovery will be additional tools for recovering values from domestic refuse. Such process guarantee significant weight and volume reductions and ensure the remaining solid residues are stabilised prior to landfilling. Thus the effect of upstream materials recycling and the requirements for more widespread use of such systems were also topics covered by the strategy group. However it is beyond the scope of this paper to comment in detail on the role of such systems.

The Problem

Although the initial report by Warren Spring identified many of the market barriers to reuse, the experts on the recycling groups provided a more focused view of the issues as well as new or amended information based on more recent development either within the UK or abroad.

Common to all commodities was the issue of collecting materials in merchantable quality and quantities at an affordable cost. Industry viewed an assured supply as an essential prerequisite to investing in the transport and processing capacity infrastructure required to reuse the materials, irrespective of the need to resolve the technical and marketing problem they would encounter in completing the recycling loop. Local authorities, with the statutory duty for providing the householder with a cost effective waste disposal system, were clearly anxious to ensure that revenues and avoided disposal costs would fully justify instituting the collection systems that might be required.

Both were well aware that although the traditional 'bring systems' such as bottle banks and paper igloos were affordable due to reliance on the public to bear the cost of first stage separation and concentration, they were also unlikely to achieve the high recovery rates across the full spectrum of material types. They were also clear that in terms of existing UK waste collection and disposal costs, collection at the household, in simple cash terms, did not look attractive for all but a small number of authorities. However, putting the financial issues to one side, as these were critically dependent on environmental standards and costs of disposal which were undoubtedly increasing, for most materials the groups agreed that household based collection systems for recyclables were the practical way forward and set about considering the technical and market barriers to reuse.

At this point the issues and problems facing the various commodities began to become much more industry specific. Table 2 attempts to group and list the issues for each commodity in broader terms and provide a star rating in terms of priority/seriousness of the problem. Low start ratings indicate relatively few problem, high star ratings indicate more severe difficulties were anticipated. Considering the headings used;

TABLE 2. - Barriers to High Recycling Rates for the Recyclables in Domestic Refuse

	Identification or Grading	Collection Storage Handling	UK Production Capacity	Technical Problems in Reprocessing	UK Market for Reclaimed Material	Non UK Market
Commodity						
Paper and Board	**	*	**	*	**	**
Ferrous metal		*		*		
Aluminium	*	*	*	*		
Glass	*	*	**	*	**	***
Plastics	***	**	***	**	**	**

* Identification or grading problems are concerned with the preliminary stage of achieving a recognised merchantable quality, for example there are 11 different grades of waste paper, most household waste is of lower fibre quality and to maximise reuse and revenues, quite strict sorting and grading is required, hence a two star rating.

* Collection/storage/handling problems are concerned with achieving merchantable quantities, plastics with very low bulk densities and low weight arisings per polymer type per household have more problems than most.

* UK production capacity covers scale of new plant investment needed to process the reclaimed material and experience of the industry in building such plant.

* Technical problems in reprocessing reflect industries expertise at reusing such scrap arising and includes problems such as degradation, achieving high specification, residual contamination build up.

* Market for products made with reclaim reflects perceived consumer resistance to recycled material, degree of change necessary in purchasing perference, institutional or health and safety barriers.

* Non UK market options indicate degree to which a commodity is traded on the international markets, for example, high star rating indicate market undeveloped due to low value.

In this paper I will take only one material, glass, to illustrate the type of problems highlighted by the working groups.

Glass is excellent example because, on the surface at least, most people would consider it to be one of the most easily recyclable; it is easy to identify, containers are simple in construction with only limited amounts of 'other' materials associated with them, glass melts and can be reformed with minimal degradation of physical/chemical properties and the industry worldwide has plenty of experience in using post consumer cullet, in fact a number of countries in Europe achieved 50% recycling rates last year.

For the UK, the recycling rate was 17% in 1989 and, although the rate is currently running at ~22%, some significant problems are on the horizon.

From Table 1 it can be noted that 'consumption' of glass is broadly in line with 'production' at about 1.7 million tonnes, however UK production is 69% by weight clear glass, 16% by weight green and 15% by weight brown or amber whereas the cullet collected from bottle banks, fillers and waste from float glass production (total ~310,000 tonne in 1989) was 25% clear, 37% green, 6% amber and 32% mixed (mainly green and amber). This difference in colour balance reflects export/import of filled containers, predominantly clear for UK products abroad (eg whisky, gin) mainly green for imported products (eg wine, lager). This is compounded by higher returns of bottles (mainly coloured) as opposed to jars (mainly clear). Obviously the existence of mixed colour collection (usually from commercial premises but also for many bottle bank systems operated for the public) does not help as this mixed glass can only be used in green glass production. Amber glass is less tolerant than green to other colours (due to chemical incompatibility with green and clear) and for clear glass, colour contamination must be strictly controlled. The net effect of the colour imbalance problem can be seen by considering the amount of cullet used for each colour, last year clear glass production contained only 10%, amber glass less than 10% whereas green glass made in the UK already contains in excess of 50% cullet.

While improvements in colour separation at the collection point and better returns of jars will enable overall recycling rate of perhaps 35% to be achieved, rates beyond this will require measures such as export of coloured cullet or changes in colour purchasing policy by UK fillers (eg bottling more production in green, particularly for export). Even at current recovery rates, the distribution of glass making capacity in the UK, particularly the existence of only one green glass furnace in the South East (the most populated area of the country) is starting to require long haul transportation of green cullet to Northern furnaces and hence is reducing the financial incentive for recovery.

Given their own high recycling rates, the likelihood of our European neighbours having excess capacity to accept green cullet is very low (though perhaps not as low as expecting French red wines to be bottled in clear glass!) and thus I suspect a significant change in colour purchasing and marketing policy will be needed by UK fillers if UK glass recycling rates are to match or exceed the 50% level.

The recycling strategy group also identified a number of other problems, some technical, some institutional, some economic but concluded that these were all surmountable given the commitment. However it was not just a 'collection' and a 'glass industry problem', all sectors of the economy needed to adjust and change to ensure success.

Routes to Success

The last section gave a broad overview of the problems illustrating the different nature of these problems for the different commodities, particularly in the technical and market areas. Furthermore, as for any other country, the UK has her own specific issues to resolve.

Of major importance is the lack of financial incentive; for the collection of recyclables the methods that ensure the highest recovery rates, eg separate collection at the household for the main commodities, are the most expensive. Experience to date in the UK suggests costs of £50 to £150 per tonne of recyclable material collected and sorted and these data are not in variance with reported experience abroad, what is in variance with reported costs abroad are the avoided disposal costs of implementing such a scheme. For most of the UK transport and disposal costs are less than £15 per tonne for domestic refuse (albeit rising fast). These are much lower than the £50-£100/tonne quoted for some parts of the USA or the £30-£60 tonne for many parts of Germany. Obviously there are some savings to be made by reduced collection costs for the residual refuse (typically 70% remains for collection) but clearly markets and revenues from the sale of the materials collected are very important for a household based scheme to be financially viable in the UK. For 'recyclables' separately collected from the household, it can be estimated that the maximum theoretical revenue, assuming materials meet merchantable quality, would be between £30 and £40 per tonne.

A compositional breakdown of the 'tonne' and merchant prices are as follows:

Commodity	Weight kg	Estimated Price £/tonne	Revenue £
Paper and board	515	15-25	7.70-12.90
Plastics	70	25-75	1.75- 5.30
Glass	280	20-30	5.60- 8.40
Ferrous	120	20-30	2.40- 3.60
Aluminium	15	600-800	9.00-12.00
TOTAL	1000	-	26 -42

Clearly paper, glass and aluminium provide the main revenue sources and stable markets and prices for these materials are a minimum requirement. If too rapid an introduction of collect schemes is attempted without corresponding development of the industrial capacity to use the materials the effect of the inevitable price reductions, possibly to negative levels if materials have to be put onto world markets or simply dumped/stored, will leave the collection scheme unviable unless/until disposal costs savings rise significantly above current levels. While it can be argued that this situation can be tolerated for a period if it ensured/stimulated industrial capacity to use caught up with supply, it is obviously better to co-ordinate and balance supply and demand for these commodities as far as possible. It was to this end that many of the recommendations and suggestions were targetted over and above the specific commodity based requirements or the general need to ensure careful evaluation and development of collection systems to identify where improved efficiency and cost reductions could be realised.

The following list gives some of the more general conclusions and ideas suggested by the strategy group, some were widely held, some had only minority support.

* Waste collection and disposal cost saving must be fully credited to the recycling system.

* Detailed and comprehensive recycling plans must form an integral feature in waste management plans drawn up by the responsible local authority body.

* Purchasing policies, particularly in the public sector, should be geared to buying products with a high recycled material content.

* Review and elimination of unreasonable specification requirements which prevent use of reclaimed materials - adequate for the purpose definitions needed.

* Consideration to be given to assisting investment in industrial processing capacity designed to accept reclaimed materials (eg tax breaks, grants).

* Consideration be given to supporting 'buffer stocks' to assist in stabilising markets/prices.

* Consideration to using differential taxes for virgin as opposed to recycled materials.

* Consideration of legislation/regulation targetted to assist recycling eg mandatory facility provision for collection, minimum recycled content for certain products.

* Use of deposit systems for certain products to ensure return.

In this paper I do not intend to make predictions with regard to actions that might be taken or how and with what impact such actions might be implemented. The proposals do however illustrate a recognition that existing market forces alone were not considered sufficient to achieve the high recycling levels considered necessary in a world acutely conscious of the environmental degradation and resource depletion problems caused be waste. On the other hand following the experience of undertaking and being involved in the studies, few were arguing for blanket mandatory measures or blanket and arbitory targets. There was a general recognition that these could well result in a net resource/environmental losses. It is a simple truth that attempting to achieve '100%' efficiency in one element of a chain inevitably leads to inefficiencies elsewhere. It is generally accepted that the major environmental problems faced by the world today illustrate the failings of trying to maximise material wealth at the expense of sustainable development. Similarly, recycling is but one element in the effective use of materials and energy starting with primary extraction of materials and ending in ultimate disposal of waste. Furthermore, household waste is but one potential source of such materials and little benefit would be achieved if they merely displaced materials recovered from other waste sources. Recycling has been an undervalued element in that chain for many years but this does not mean that optimum recycling rates in environmental and resource terms are the same for different materials or products, the same for different localities or countries, the same over time. Bearing this in mind, there was no doubt that the overall conclusion was that positive action to significantly increase recycling rates from domestic waste could and should be taken.

The recycling strategy group has gone some way in the process of formulating action plans, for many sub divisions within a given commodity (eg newsprint within the broad heading paper and board, plastic bottles within plastics) and for some commodities in total (eg glass containers, ferrous and aluminium can stock) recycling levels in excess of 50% recovery and reuse from households were deemed eminently achievable within a 5 to 10 year time frame. Identifying the problems in achieving these levels provide the basis for effective action to resolve them, not an acceptance of the status quo. For materials still discarded to household refuse, methods of treatment and recovery of energy and other waste derived products (eg composts, aggregates) will still have a significant, and for the UK, growing role to play in reducing the weight, volume and environmental impact of domestic refuse disposal.

The UK Government has a vital role to play in setting the framework for this to happen, but it is society as a whole, business and consumers which has to be involved and committed to ensuring recycling of materials and energy from domestic waste takes its proper place in an integrated and structural approach to resource conservation and wastes management.

1. Barton, J.R. Recycling for Packaging; Source Separation or Centralised Treatment.

IWM Seminar "Packaging and Waste Management and the Consumer" 4 October 1989, London.

THE USE OF INCENTIVES IN SOLID WASTE PLANNING: SEATTLE AS A CASE STUDY

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

Over the past three years, Seattle has redesigned its solid waste system. The system was redesigned to be based on the local and state hierarchy of planning goals which make waste reduction first priority, then recycling, then use of incineration or landfill. In redesigning its waste system, decision makers wanted to concentrate on providing voluntary programs and taking advantage of incentives in order to change customer behavior. This paper will describe the types of incentives that were used to convert the vast majority of Seattle customers to a recycling-based solid waste collection system.

OVERVIEW OF SEATTLE'S PROGRAMS

Seattle's Solid Waste Utility (SWU) is an enterprise fund which means that it is run like a small business and revenues from rates and other sources cover all expenses. Programs are not supported by the City's general fund. Having a rate structure has been a benefit to the Utility in designing programs because it has been possible to give customers an economic signal to encourage changes in behavior. The SWU is responsible for collection and transfer of waste. Currently Seattle hauls its waste 30 miles to a county landfill. Seattle had two landfills which are now closed and being cleaned up as Superfund sites. Seattle has a population of 490,000 and a collection base of 150,000 customer units. Our transfer stations accept residential and commercial self-haul waste. In addition, the commercial haulers collect 225,000 commercial tons per year which are taken to private transfer stations. These tonnages have been dropping dramatically as a result of a total set of solid waste programs. The SWU is a division of the Engineering Department with an annual budget of $60 million for operations and an additional $5-10 million for capital expenses depending on what aspect of the landfill is currently under construction.

As a result of a comprehensive planning process in 1988, the City made a decision to establish a goal of 60% for recycling by 1998. In order to achieve this overall goal, specific goals were established for a series of City recycling programs. Curbside recycling was to achieve 7.8%; the self-haul dump-and-pick program, a reduction of 4.8%; curbside yard waste, a reduction of 4.8%; apartment recycling, a reduction of 2.4%; source reduction programs, a reduction of 1%; and backyard composting a reduction of 2%. In addition, in order to achieve the 60% recycling, the City had to hold on to the 24% private recycling which had been going on previous to the time curbside recycling was initiated; and, has to achieve an additional 10% of new commercial sector recycling.

When decision makers were reviewing options for achieving levels of recycling reduction, a decision was made first to try voluntary programs. If voluntary programs did not succeed, then the City was willing to move to mandatory programs. The decision to try voluntary first came primarily because the City does charge rates for garbage collection. The City's rate structure is volume-based, which means the more garbage you produce the more you pay. People have an option of choosing a mini-can for weekly garbage pickup service for $10.70 per month or they can go up to a three-can service (a 90-gallon container) that would cost $31.75 a month. The types of incentives that the City considered in trying to change public behavior were: giving customers a choice, making programs convenient, and giving an economic signal that by changing behavior customers could save money.

The use of incentives seems to be working. Now, two years after having started its curbside recycling program, Seattle has 80% of its customers voluntarily signed up for recycling. 62% are signed up for yard waste collection services. Seattle is currently recycling 36% of its wastestream, and last year the tonnage to the landfill was reduced by 22% from the previous year. Programs that have already been initiated are 76% of the way to achieving their 1998 levels.

TYPES OF INCENTIVES

A. Choice

Both the rate structure and the service structure of the Seattle system were designed around the belief that customers would be happier if they could select their own services and, therefore, set their own bill. The premise behind the integrated garbage collection and recycling service is that by having volume-based rates customers are encouraged to have less garbage. Therefore, if other services such as recycling and yard waste which divert tonnage out of the garbage can are provided at a low or reduced cost price, customers will select those services. If fact, the system has worked. Seattle now has 86% of its customers on one can or less of garbage pickup a week. Over 80% of those customers are using recycling services regularly; over 62% are using yard waste set-out service regularly.

For the garbage system, customers are given a choice of the size can they will use. The types of choices they have are a mini-can (20 gallon), one-can (30-gallon), two-can (60-gallon), three-cans (90-gallon). As they increase the size of their can the cost of their weekly pickup increases. Another choice customers have in customizing their garbage service is to decide if they want curb/alley or backyard service. Previous to 1989, the entire City of Seattle was on backyard pickup service. In 1989, with the new rate structure and garbage system, customers were encouraged to move to the curb or alley, but were offered backyard service. However, backyard service is offered at a 40% premium. The effect of this choice is that 97% of the customers have chosen curb/alley service.

For the yard waste program, starting in 1989, the City required separation of yard waste out of the garbage can. In other words, you were no longer allowed to put any of your yard waste into your garbage can. However, there were three different methods customers could use to divert their yard waste. First they were offered a curbside pickup service where yard waste would be picked up regularly at their home at the curb. Secondly, they could take yard waste at a reduced fee to the transfer station. Thirdly, they could compost yard waste in the backyard. The City offers a backyard compost program where it will deliver a customer a free compost bin and give an hour of free instruction in effective methods of composting. In addition, customers still have options for managing their yard waste such as choosing a gardener or cementing their entire yard in order not to have yard waste. Our recent garbage composition analyses are indicating that now less than 1% of waste left in a garbage can is yard debris. A year ago yard waste was up to 20% of the waste in a garbage can.

Seattle, working with the region, has also developed a comprehensive household hazardous waste management plan. At the same time that household hazardous wastes are banned from the garbage can, options are being planned for disposing of those wastes. The region started with a number of roundups. A roundup is a one day collection where all household hazardous wastes are collected at centralized sites. Now the region is moving to having permanent sites in reasonable locations, and mobile collection vehicles that can move from site to site. Seattle currently has one household hazardous waste collection site and is siting a second one. Household hazardous waste materials are collected at the transfer station at a subsidized fee in order to encourage people to bring their materials to that site.

The theory in a waste reduction/recycling based concept of solid waste management is that for all elements of the waste stream you provide customers with a way to manage that waste other than place it in the garbage stream. Consequently, the City has spawned a number of programs to handle specific elements of the waste stream. Again, the purpose of these programs is to give customers a choice. We believe that if customers have a choice they will make the right decision about how to dispose of a material. Bulky items (such as white goods -- refrigerators, stoves, etc.) can be picked up at the curb for a small fee. They may also be delivered to the transfer station. At the transfer station mercury switches or capacitors are removed from white goods so they can be recycled for metal. In addition at the transfer stations, customers can deliver mattresses, waste oil, wood waste, lawn mowers, cardboard, motor oil. All of these items can be delivered free to the transfer station where they are sold as recyclables.

B. Convenience

A second major belief in an incentive-based system is that for customers to change behavior programs need to be easy and convenient. We believe that if programs are designed to be "user friendly" more people will participate. For the curbside recycling program, this means that we provide all customers with bins and we give frequent pickup of those bins. Bins were all delivered to a customer's door with a packet of information on how to use the materials. For garbage collection all customers were provided wheeled containers for curb service. The belief was that if it was easy to manage a wheeled container, people would not object to wheeling it to the curb. To encourage participation in the compost program, customers are given a free compost bin and a free hour of education. Yard waste programs were designed so that people could put materials out on the curb in plastic bags knowing that that was the preferred method customers already have of disposing of yard waste. Seattle is now reconsidering the use of plastic bags and looking for possible alternatives, one of which would be providing customers for a wheeled bin that would be used for yard waste.

One fear of having high garbage rates was that there would be an increase in litter and illegal dumping. In response to this concern, the City instituted a comprehensive series of neighborhood cleanup programs. The City has a Conservation Corps which is staffed by at-risk, older teenagers who need to develop job skills. The Conservation Corps runs the neighborhood cleanup programs. All neighborhoods in the City are scheduled for cleanup. On the appointed day, customers can leave items on the curb where they will be picked up and dumped free in the transfer stations. By having free neighborhood cleanup days, customers are encouraged to save materials for that day and not to litter or dump.

C. Economics

1. Rates/Fees

The linchpin of Seattle's entire recycling and waste reduction program is a volume-base rate structure. The underlying belief of such a rate structure is that customers will change behavior more rapidly and more substantially if they save money from the changes. Seattle instituted volume-based rates in 1980. At that time the basic garbage pickup rate was low and the difference between one, two or three can was minor. In 1986 and 1987, Seattle customer had two rate increases which brought rates up more than 82%. At that point, the differential between can sizes became greater and behavior began to shift dramatically. Now customers have a choice of a small mini-can (20 gallons) for $10.70 per month; 1-can (30 gallons) for $13.75 a month; 2-cans (60 gallons) at $22.75 a month; 3-cans (90 gallons) at $31.75 a month. This steeply inverted rate structure combined with diversion options for citizens has led to 86% of the City being on one can or less of garbage pickup. Seattle is now experimenting with the idea of charging "garbage by the pound." The concept is that customers would have cans that are bar-coded with their name and billing address; the bar-coding could be read by a laser scanner on a garbage truck and the can would be weighed and then dumped. Billing would be done by the weight of the garbage in the can. The idea behind this concept is to encourage those customers who can further reduce their waste to do so because they would be charged only for the amount of garbage in the can.

Other aspects of the volume-based rate system are that people are encouraged to select curb/alley collection. Therefore, even though they are offered a service of backyard collection, they are charged a 40% premium for that backyard service. Customers who are handicapped or elderly and unable to get a container to the curb are allowed backyard collection at curbside rates. Low income and elderly customers are given a rate break. Another aspect of the volume-based system is that waste reduction and diversion methods -- recycling and yard waste -- are provided free or at a low cost. In Seattle recycling is free and yard waste pickup is charged at the rate of $2 per month for nearly unlimited curbside pickup.

At the transfer station the concept of encouraging customers to separate recyclable waste is carried out in the fee structure. The fee for dumping clean yard waste is reduced from the normal dumping fee, recycling is free, and charitable groups receive a special low-cost dumping rate. Finally, the household hazardous waste dropoff is a subsidized rate. The City is considering moving to free dumping of hazardous waste to encourage further separation of hazardous wastes from the waste stream.

Another program in Seattle using economic incentives to encourage behavior change is a battery deposit program. Whenever a person purchases a new automotive battery, a special fee is charged for disposal of that battery. If the customer brings back an old battery, the fee is eliminated. For the commercial sector, economic incentives include a lower rate for the collection of recyclables than for garbage. However, the rate differential is not great enough at this time to encourage the kind of behavior change desired. The City is working with the Utilities and Transportation Commission (UTC) to provide a more steeply inverted rate structure for commercial collection.

2. <u>Incentive Grant Programs</u>

The City has initiated a number of grant programs to gather ideas or to encourage creativity. The belief is that creativity and involvement in problem solving are fostered by encouraging agencies and individuals through grant programs. The City's school recycling program is based on a competitive grant process. Elementary schools compete for grants of $5000 to design waste reduction/recycling programs for their individual schools. They are given a series of bonuses for achieving certain levels of recycling. Once they achieve a level of 7 pounds per student and faculty, they are eligible for special funds for field trips. They also receive bonuses for PTSA involvement in order to encourage parents and teachers to be involved in the recycling programs.

Another experimental program started by the City is called the Environmental Allowance Program (EAP). The EAP program was designed to be a research and development program to get private sector involvement in solving problems. One idea that developed from this program is to develop a latex paint recycling program. Recyclable latex paint is separated at the household hazardous waste shed from non-recyclable paint and after processing and mixing is turned into an industrial grade reusable paint. The EAP has experimented with co-composting of sludge and solid waste, with methods of cleaning glass used for recycling, with public information on issues such as use of cloth vs disposable diapers, and currently is involved in setting up a commercial audit program. Some of the programs originally designed by the EAP have then become integrated into regular solid waste programming.

The same concept was used to encourage City departments to begin new recycling and waste reduction behaviors. Departments competed for grant funding for projects to initiate recycling and waste reduction programs. The Parks Department as a result of this program is starting to compost garden materials; the Seattle Center (similar to a large central urban park) is experimenting with methods of collecting recyclables on outside grounds. Departments have also bought compactors and capital intensive pieces of equipment necessary for recycling cardboard or other materials.

3. <u>Mitigation</u>

One of the unique problems that Seattle had in designing its programs was to retain existing levels of private recycling that had been going on in the City before the curbside programs began. Retaining those high levels of private recycling is highly cost effective for the City because people entered into those recycling behaviors at no cost to the City. In an effort to keep private recyclers in business, the City tried to work on effective ways to maintain existing recycling through mitigation programs. One initiative is to publicize small recyclers' activities and to provide them with grants to do market research. A second type of mitigation is to find new program areas that can be saved for smaller recyclers. The City designed an apartment recycling program geared to be provided by existing recyclers. However, the diversion credit price that was offered in the program was too low and the private recyclers chose not to participate. Mitigation has not been entirely successful in Seattle and a number of private recyclers have gone out of business. However, Seattle is still working on ways to maintain and support existing recyclers in business.

CONCLUSIONS

The use of incentives has been an important element underlying Seattle's waste reduction/recycling programs. Clearly, giving people economic incentives to change their behavior is the most effective way of getting change. The fact that Seattle charges a rate for garbage has turned out to be an unusual benefit in the design of its solid waste programs. Although the most influential method of changing behavior has been providing economic incentives, giving customers choice and making programs convenient have also been important additives to a volume-based structure. Peer pressure and environmental ethic are the "frosting on the cake" that encourage people to make good environmental decisions, but by themselves will not affect the vast majority of the public. Finally, the fact that programs are voluntary and people are given the choice to select the services they want to meet their own solid waste disposal needs (and, thereby, to customize their bill) seems to have contributed to customer satisfaction with programs. By using incentives Seattle has been able to rely on voluntary programs and is well on its way to achieving its 60% goal for waste reduction and recycling of its waste stream.

VARIABLE RATES IN SOLID WASTE: APPROACHES FOR PROVIDING INCENTIVES FOR RECYCLING AND WASTE REDUCTION AND A MORE EFFICIENT SOLID WASTE SYSTEM

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THE WASTE DISPOSAL CRISIS

Landfill space is becoming a major nationwide crisis. Almost 40% of respondents to a recent survey conducted by the American Public Works Association indicated that their landfill space would run out within 5 years.[2] In addition, this survey indicated that 74% were currently doing nothing to reduce solid waste volume. There is a nationwide disposal crisis, and it is affecting jurisdictions that are large and small, urban and rural, all across the nation.

Locally, the crisis can manifest itself in rapidly increasing disposal tipping fees, in the need to haul waste hundreds of miles for disposal, in mandatory recycling programs, in struggles to comply with changing landfill standards, in public opposition to the siting of needed new disposal facilities, or in barges filled with waste with no place to dock.

What can jurisdictions do to solve this crisis? Traditional options include:

- o building a new landfill,
- o building an incinerator in hopes of extending the life of existing landfills.
- o more recently, jurisdictions have begun imposing mandatory recycling programs.

Many jurisdictions are facing very significant economic investments in either closing landfills, building new ones, or building incinerators. And the out-of-

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[1] This work was partially funded by grants from the Environmental Protection Agency. The work was conducted by the author while employed at the Seattle Solid Waste Utility.

[2] Solid Waste Collection & Disposal: 1987, by American Public Works Association (APWA), 1987.

pocket costs of these huge investments don't include the significant problems of siting, changing regulations, public pressure, and long lead times.

IS THERE ANOTHER SOLUTION?

The problem would be reduced if residents could be induced to reduce waste, increase recycling, and do a number of other "good things". However, there are many citizens who simply will not react to the crisis unless there is an economic, or "pocketbook", reason to do so.

In most parts of the country, garbage is removed once or twice a week with the revenues coming from one of two places:

- from a portion of the property tax, or
- from fixed bills for unlimited pickup (bills that do not vary with respect to the amount of garbage taken away.)

Neither of these methods gives residents any incentive to reduce their waste. In fact, with the property tax method, residents never even see a bill, and generally have no idea how much it costs to remove their garbage every week. Areas with these methods of payment have often had to resort to mandatory recycling programs in order to try to reduce their amount of garbage.

> **Residents in several jurisdictions around the country have come to recognize that you can achieve remarkable successes in recycling and waste reduction without any mandatory features through one simple measure: volume-based garbage rates.**

WHAT ARE VOLUME-BASED RATES?

In volume-based rates, the level of payment varies with a measure of the volume of waste disposed. Customers who use more service pay a higher rate, and those who use less pay less. There are several possible volume-based rate designs which provide the same principles -- customers putting out more waste pay higher fees. Seattle uses a subscribed variable can system. Several other jurisdictions use a pre-paid bag system. Briefly, a variable can system involves having customers select subscription levels based on the number of cans of garbage they need to dispose of each week. The jurisdiction usually offers subscription levels in standard 30-gallon increments (one can, two cans, etc.). Seattle and Olympia, Washington also offer smaller service levels that hold 19 and 10 gallons respectively as a reward for small waste generators. Higher service levels are charged higher rates.

Jurisdictions that employ a bag system charge a fee for each "official" bag that includes the cost of disposal.[3] Under a bag or tag system customers purchase special garbage bags (or tags) from the jurisdiction or from outlets at a price that includes the cost of disposal. The more bags of waste they put out, the more they must pay.

The key under both these systems is that the amount that customers pay increases significantly as they use higher levels of service. Customers are not limited in what they may dispose, but they are required to pay for what they use.

<u>VOLUME-BASED RATES ARE AN EFFECTIVE RECYCLING INCENTIVE</u>

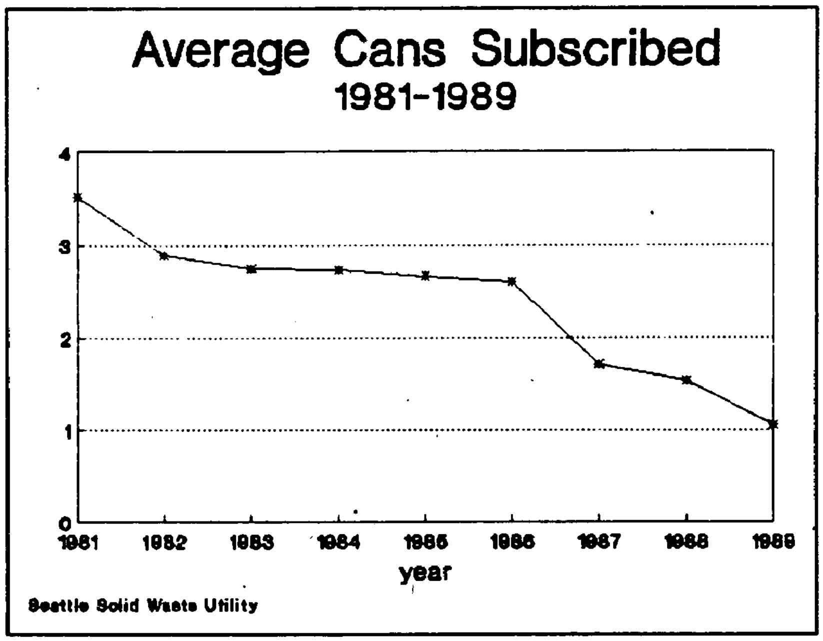

Figure 1

Volume-based rates have proven to be an extremely effective recycling incentive. Since Seattle's introduction of variable can rates in 1981, Seattle's customers, eager to reduce their bi-monthly garbage bills, have reduced the average number of cans subscribed from 3.5 down to just over 1 can. And the recycling percentage (in terms of actual tons of waste diverted, not just participation rates) was over 24% <u>before the introduction of any City-sponsored recycling programs.</u>

Volume-based rates have also contributed to the quick success of Seattle's city-operated recycling programs, which provide customers a convenient opportunity to reduce subscription levels by recycling materials they might otherwise have

[3] The charge usually includes at least the cost of disposal. Some jurisdictions also include a share of the system's fixed costs.

thrown away. The City has achieved an amazing 75% sign-up rate in its curb/alley recycling program. More important than sign-up statistics, however, is the amount of waste diverted by the program. The program currently collects about 3,500 tons per month, or an average of 63 pounds per participating household. Over 60% of Seattle's customers subscribe to the City's new yardwaste collection and composting program. This year alone, the curbside program is expected to divert about 27,000 tons of residential waste to a composting facility.

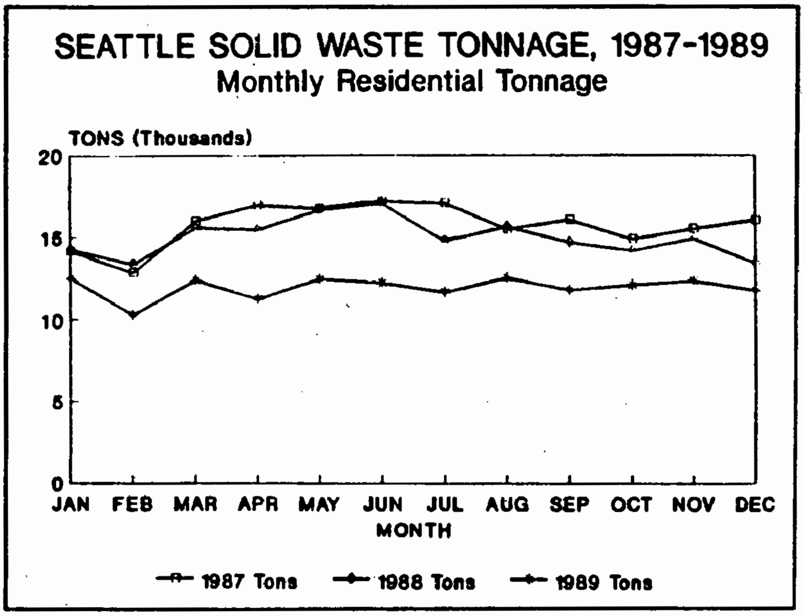

Figure 2

In addition, based on an analysis of numerous factors, the Utility has determined that the introduction of variable can rates has helped slow the growth of disposed tonnage. There have been two factors assisting this result. First, the level of Seattle's rates increased to a point at which customers took notice. In addition, the rate structure provides clear rewards for reducing waste. The steep rate structure adopted at the beginning of 1989 has been particularly effective in achieving this goal. Customers can achieve real savings on their garbage bills by participating in this program, and Seattle's customers understand and take advantage of this.

Incentive-based rate design goes hand-in-hand with recycling and waste-reduction programs, and is a critical part of integrated solid waste management. In Seattle, the combination of rate incentives and additional recycling and diversion programs has allowed Seattle to decrease the amount of waste it brings to the landfill by 24% compared with 1988 levels (see Figure 2). Similar and dramatic reductions in landfilled tonnage have also been noted at jurisdictions that have instituted bag systems. Perkasie, Pennsylvania for instance, noted a 35-45% decline in tonnage brought to its transfer stations after the introduction of their bag system and recycling program.

WHAT OTHER BENEFITS DO VOLUME-BASED RATES OFFER?

> Volume based rates can benefit a community in a number of ways:
>
> o Customers receive an incentive to reduce disposal.
> o The rates are fair.
> o Incentives support recycling programs.
> o Mandatory recycling can be delayed or avoided altogether.
> o Fees make customers aware of the environmental consequences of their actions.

This system gives customers a very clear reward for reducing the amount of waste that they dispose of: they pay a distinctly lower bill. An additional benefit of the system is that it does not favor any particular method of reducing waste. Other benefits of volume-based rates include:

- Volume based rates are fair -- customers who dispose of similar amounts of waste pay similar amounts of money. Those who dispose of less, pay less. Customers get <u>control</u> over the bill they pay. In addition, the rates reward all methods of reducing waste including waste reduction and recycling.

- Implementation of any City-sponsored recycling programs will be much more successful with these rate incentives in place. The combination of variable rates and convenient recycling programs makes for a much more integrated garbage system, and gives customers good alternatives and choices.

- Customers get a chance to show what they can do through voluntary rate-induced waste reduction. Your programs need not be mandatory and therefore your enforcement burden can be reduced, and you may still invoke mandatory programs later if you don't achieve the goals you need.

- This method gives customers a better idea of the actual cost of disposing of waste and provides a better relationship between customer behavior and rates. Masking the cost of garbage service all these years has made

the cost associated with new landfills and incinerators particularly hard to justify to customers in some areas. It is difficult to condemn customers for making unwanted choices in their waste disposal behavior if they are not given the information (generally costs of disposal) to make intelligent choices. Customer education is key to getting customers to work <u>with</u> the system.

- Pricing garbage services in this manner puts solid waste on an equal footing with the way water and electricity services are priced. Customers pay based on the amount of service they use, and have economic reasons to conserve.

- Using volume-based rates to reduce waste is quicker to implement than building new capital facilities to handle additional waste. The rates provide an environmentally sound alternative and can be implemented in a variety of situations. In addition, they integrate well with programs and can help lead to lower long-run system costs.

<u>WHAT DO WE GAIN?</u>

From a city management perspective, volume based garbage rates can gain the City:

- **Time** to site new disposal facilities.
- More **options** in terms of recycling vs. disposal investment
- **Support** of low volume dumpers and recycling groups

Volume-based (specifically, variable-can) rates, and the additional awareness of the solid waste issue that they have brought, have allowed Seattle to seriously propose a set of non-mandatory programs that will bring it to an aggressive 60% recycling goal by the year 1996. Rate design is an integral part of this program. Seattle considers its volume-based rates its <u>most</u> effective recycling program. It can be yours too!

In addition, implementing volume-based rates is quicker than building new capital facilities. Even if capital facilities are also needed, volume-based rates may help buy extra time, and accustom customers to the idea of paying on the basis of service provided. Implementing variable can rates (and recycling programs) can help win support for additional disposal facilities because customers may recognize that the jurisdiction has made a good faith effort to avoid siting additional disposal capacity and is taking an integrated planning approach to the issue.

Volume-based rates can be implemented to reward voluntary reduction of waste by customers. The jurisdiction can still hold out mandatory measures as a threat if customers do not achieve the needed goals voluntarily. However, allowing customer choice and emphasizing voluntary programs often produce less ill-will than proceeding without giving customers a chance to "show what they can do".

Volume-based rates can produce a closer relationship between the costs and revenues for a solid waste jurisdiction. Rather than a rate system that generates revenues that do not vary with the amount of waste disposed, charging volume-based rates will tend to generate higher revenues for customers that cost more to serve.

Finally, volume-based rates are fair, provide excellent recycling incentives, are environmentally sound, and can help slow or even reverse growth in tonnage disposed.

WHO CAN IT WORK FOR?

Because the economic concepts underlying volume-based rates are universal, a volume-based rate structure can help a wide variety of jurisdictions, including those:

- o with collection performed by contract, franchise, municipal, or private arrangements,
- o that cover large, medium, or small numbers of customers, and
- o in any part of the country.

Whether variable can rates make sense depends on an assessment of specific circumstances, including those related to cost, timing, and political factors.

WHAT AFFECTS WHETHER IT WILL WORK IN OUR AREA?

Although costs are obviously a key factor, there are a number of other situations that help make adoption of a volume-based rate system simpler and more politically appealing:

- o Hauling contracts, franchises, rates, or billing systems are up for a change.
- o The jurisdiction faces any of a wide array of landfill or disposal problems, including a shortage of landfill space, high tipping fees, changing landfill regulations, or public opposition or other difficulty siting new landfill or disposal options.
- o Jurisdictions in which the community wants to create recycling incentives to increase participation in an established or planned recycling program or satisfy local recycling advocates.
- o The existing system is perceived as unfair and encourages abuse.
- o The jurisdiction is running out of tax authority and can use the establishment of separate rates to free up tax revenues.
- o Medium to larger jurisdictions may have some advantages in being able to spread implementation and fixed costs over more customers.

It may also be helpful if the solid waste jurisdiction is legally established as an entity that must cover its costs via fees, e.g. a utility or enterprise fund.

Although the factors mentioned above can make adoption of volume based rates simpler, none are essential. A volume based rate system may be appropriate anywhere.

WILL IT PAY/CAN WE AFFORD IT?

The question is whether you can afford not to do it!

Continuing to landfill is becoming more and more expensive, especially if the true costs of landfilling are considered (that means including costs of closing, difficulties of replacement of the landfill, etc.). Extending the life of existing landfills pushes the closure (and siting) costs out to later years, and means real dollar savings now that can be invested in recycling programs, etc. with actual benefits to the solid waste jurisdiction and its customers.

The final judgment of whether the new system will pay depends on a comparison of the costs vs. the savings of the new system.

The types of costs that will be incurred with the implementation of volume based rates may include:

- o Contractual changes
- o Public information, outreach, and PR
- o Billing system changes
- o Cost of designing the rate system
- o Staffing increases, especially in customer service and field inspection crews.

The operation of a solid waste system funded with volume based rates is almost certain to be more expensive than a flat fee or tax-funded system. Thorough planning involves examining potential cost increases and compare them with potential savings.

Savings resulting from the change may include:

- o Savings on current disposal costs
- o Savings from extension of the life of existing disposal sites
- o Savings in crews and overtime at transfer, hauling, and disposal facilities
- o Improved utilization (and improved economies of scale) of recycling programs.

The "benefits" described above are often referred to as "avoided cost". Avoided cost refers to money that does not have to be paid as a result of some activity. Considering avoided cost allows a complete comparison of alternative investments, and allows planners to design their least-cost system.

Using avoided cost analysis in 1988, Seattle found that the status quo system (landfilling at a local site) was more expensive than investing in very aggressive and expensive recycling programs, and long-hauling the remaining waste to an alternate site.

Local factors affecting cost-effectiveness may include:

- o Costs and lifetimes of specific landfill or disposal alternatives
- o Access to and strength of regional recycling markets
- o How rural vs. urban the collection area is -- distance between stops, distance to landfill, distance to recycling markets
- o The portion of collection cost that varies with volume of waste collected.

ISN'T IT A LOT OF TROUBLE TO IMPLEMENT?

A volume-based system is more complicated than some alternative rate systems. However, the steps involved in implementation are manageable. They include:

- o Determining whether state law empowers your agency to bill for solid waste on the basis of volume.
- o Establishing an ordinance that makes solid waste service, or at least charges, mandatory
- o Establishing an ordinance that bans (and penalizes) illegal dumping and burning of waste
- o Establishing the solid waste entity as an enterprise fund (not essential, but can be helpful)
- o Assuring that there are convenient recycling alternatives (public or private)
- o Creating a sensible system of rates on the basis of system costs and desired changes in disposal behavior.
- o Extensive public education/information efforts
- o Preparation for some changes within the solid waste agency, including increased staff in some areas (particularly billing and customer service), changed responsibilities for some employees, and a possible refocusing of the services that the utility offers.

Of course, establishing **local political support** is a key ingredient in the process.

Some obstacles to successful implementation are peculiar to individual volume based systems. For example, variable can rates can require a complex billing system, and pre-paid bags or tags may require a retail distribution system.

WHAT LEGAL POWERS DO I NEED TO WORRY ABOUT?

New recycling and landfill legislation has helped make a volume-based rate system an appealing option in many states. Existing law can affect the level of difficulty associated with a move to a volume-based rate system.

The legal powers necessary for a solid waste agency to charge for refuse collection on the basis of volume generally either already exist or can be created through a local ordinance, if the local political climate permits. Some states may limit local agencies' power. Unfortunately, therefore, legal questions must be answered on a state-by-state basis.

Several legal situations can affect the ease with which a volume-based billing system can be implemented. Ideally, a jurisdiction considering such a change would have the following powers:

> Legal Powers Needed:
>
> o Power to bill or set/approve rates
> o Flexibility to perform non-traditional services
> o Power to prevent illegal dumping.

- o **Power to bill (municipal or contract system) or to set (or approve) rates for refuse franchisee.** This power must include some means of enforcing payment of bills. The power to make refuse service mandatory can also be helpful.

- o **Flexibility to perform services other than traditional collection and disposal of refuse.** Laws that strictly limit ways in which refuse system funds must be spent can complicate recycling efforts. Limited recycling options can affect the desirability of a volume-based rate system.

- o **Power to prevent illegal dumping.** Although the solid waste agency will probably not enforce illegal dumping laws itself, there must be a strong penalty for disposing of waste outside the system.

The powers listed above are generally available to jurisdictions that currently provide refuse service. Flow control may also be needed for a smoother system.

WON'T IT CAUSE A LOT OF PROBLEMS?

Changing from fixed fees for unlimited pickup, or from a system where fees are collected via taxes may not be a simple, problem-free process. However, most of the potential problems are manageable, especially if you expect them.

> Communities considering implementing volume based rates should be prepared to address several of the following problems:
>
> - Confusion with the new system
> - Resistance from customers who are not used to paying bills or who are unwilling to change behavior
> - Illegal dumping or burning of waste
> - Enforcement of the system
> - Complaints by the poor
> - Contractual or legal limitations on the flexibility of the solid waste agency
> - Change in the responsibilities of your agency and staff
> - Need for increased staff (some temporary increases for analytical tasks, and longer term increases needed in customer service, etc.)

CAN THESE PROBLEMS BE HANDLED?

The answer is that the problems can be significantly reduced -- if you anticipate them and prepare for them.

Customer Confusion and Resistance: Working with the press and preparing mailers can help customers understand the reasons for the change, can help with resistance to behavioral changes, and can help explain the new system. Initial stories about local problems related to solid waste, and about solutions that have worked in other jurisdictions, can help increase understanding of solid waste issues. Repeated mailers, television spots and bus cards can be helpful in reinforcing the new behavior.

Illegal Dumping and Burning: Some increase in illegal dumping and burning can sometimes be associated with variable can rates. Making sure that there are convenient opportunities for customers to recycle waste and imposing regulations that provide penalties for illegal dumping are helpful. Requiring a minimum level of service and minimum fee for all households can help reduce the problem. In addition, getting a public attitude change that says illegal dumping isn't socially acceptable (like the recent changes in the social perception of drunk driving) can go a very long way in mitigating problems of illegal dumping and burning.

While many areas have had trouble with illegal dumping in response to sharp increases in refuse rates, Seattle does not appear to have experienced a significant problem with illegal dumping or burning of waste. Other large cities have had problems. However, it is difficult to get a very accurate or quantitative handle on the problem. Seattle does not have a comprehensive program to pick up illegally-dumped waste. Rather, some incomplete information is provided by street cleaning crews, and are subject to complicating effects from seasonal labor availability and other problems. Also complicating the problem is the fact that waste can easily be dumped across jurisdictional lines, and burning can be difficult to detect or trace to its source.

There are several factors that may contribute to Seattle's relatively small problem in this area: 1) there are few vacant lots in the City, 2) the Northwest has a strong environmental ethic, 3) the areas has many private recyclers, city programs, and other legitimate ways to reduce the amount of waste that needs to be disposed, and 4) volume-based rates are not new to the area, so customers have had time to modify their behavior.

Enforcement: Enforcement may or may not be needed. For many years, Seattle's Solid Waste Utility relied on an honor system for enforcement of service levels. Although it is clear that some customers put out more waste than they were paying for, on-site inspections indicated that the levels of abuse were not high, and were in fact, offsetting.

Seattle's new collection system is much simpler to enforce. The contractors provided 'official' semi-automated toters sized to the subscription level paid for. This system greatly simplified enforcement, because any waste that is not in the official toter is not paid for and is generally not collected, unless it has a pre-paid sticker on it. A decision on enforcement in a particular jurisdiction may be able to be deferred until after the system is in place for a while. However, provisions for enforcement should be included in any contracts, etc.

Low Income Assistance: Because an economic incentive to reduce waste disposal below a minimum level can lead to illegal dumping, volume-based rates require the introduction of mandatory charges. These separate and discrete charges can be a burden to low income customers. However, establishing special rates for low income citizens, or building "lifeline" components into the rates will mitigate the impact of mandatory rates on customers with fixed or low incomes. Some jurisdictions offer carry-out service for curbside rates.

Staffing Considerations: In-house problems can be reduced if management prepares staff for changes in emphasis of the job, for instance realignment of staff toward recycling efforts and away from traditional collection and disposal. Management also need to prepare staff for growth in some areas in particular, some of which will involve permanent increases and some more temporary. Management may be able to cope with some of the burden in areas with temporary workload through the use of temporary labor, or with loans of municipal employees or staff from other sister agencies, or with consultants.

Although these steps take planning, they can set the stage for a very effective solid waste system.

AREN'T THERE OTHER RATE OPTIONS OUT THERE THAT ARE JUST AS GOOD?

No. Volume-based[4] rates are equitable and provide better incentives than rate designs that do not vary the charge with some measure of the amount of service provided. They provide customers with choices, integrate well with new recycling and yardwaste programs, encourage participation in recycling programs without making them mandatory, and can lead to an extension of the life of existing landfill space.

As a comparison, many jurisdictions are considering offering recycling credits, which reduce garbage bills for people who participate in recycling. While credits may be better than nothing, they are not the best alternative because the amount of the credit is fixed, and does not give customers an incentive to

[4] Another experimental alternative, a weight-based rate system, is discussed later in this paper.

recycle more. In addition, credits for participating in "official" recycling programs do not encourage careful buying in the first place (many jurisdictions' first priority for waste reduction), backyard composting, re-use, or recycling through private firms.

WHAT ADDITIONAL CONSIDERATIONS ARE INVOLVED IN RATE DESIGN?

System Design Decisions

- o Choice of Bag/Tag vs. Variable Can System
- o Subscription vs. Usage
- o Steepness of Rates
- o Payments for "Extras"
- o Curbside vs. Backyard Differentials
- o Charges for Recycling or Diversion Programs
- o Rates for Multi-family Buildings
- o Rates for Compacted Waste
- o Alternatives for Low Income Households

Choice of Variable Can vs. Bag/Sticker Systems: The selection of the type of volume-based rate system will depend on the evaluation of the tradeoffs of several factors in the context of the jurisdiction's situation, including:

- o Equity
- o Simplicity, implementation considerations, and cost, and
- o Revenue Stability.

There are pros and cons for each of these systems, and jurisdictions need to weigh their particular needs.

A 'variable can'-based system may be a good option for areas using semi-automated toters, areas with problems of animals or rapid spoilage, or places already using a can system where customers may already own their own cans. Variable can rates also show customers the full cost of disposal in one bill. Can systems may provide more stable revenues than bag systems, and may be easier to forecast. Especially important is the fact that variable can rates also allow a great deal of flexibility in the pricing increments between can subscription levels. The jurisdiction can implement rates that provide very aggressive recycling/waste reduction incentives with this system.

However, a variable can system has fairly high implementation costs, particularly because of the complexity of the billing system needs. A fairly complex computer system is needed that will keep track of each customer's selected subscription level, and will calculate bills accordingly. In addition, customer service costs may be higher, and some confusion on the part of customers is fairly likely because subscription levels will need to be selected.

Bags or pre-paid stickers generally charge for smaller increments of waste than a variable can system, letting customers pay more precisely for the amount of service they use. This provides a better link between customer behavior and the bill they pay, and allows a better waste reduction/recycling incentive. In addition, the purchase of the bags may provide a more immediate price signal to customers. The billing system is much simpler, and customer questions and confusion can be lower than with a variable can system. Enforcement may also be simpler. Although bags are generally easier for collection staff to dump, allowing the bags or stickered waste to be placed inside cans may help alleviate animal problems where that is a difficulty.

Selection Between Variable Can and Bag/Tag System

<u>Variable Can System</u>	<u>Bag/Tag System</u>
o Full cost on bill	o More usage-based
o Relatively stable revenues	o Immediate price signal
o Flexibility in pricing incremental 'can' levels	o Limited flexibility in pricing incremental bags
o Relatively high billing, customer service, and enforcement implementation costs	o Fairly easy to implement and enforce

A bag or tag system will require the jurisdiction to set up a distribution system for pre-paid garbage indicators, but allows the jurisdiction to avoid the cost of a billing system.[5] The jurisdiction must also establish and communicate (and presumably enforce) clear limits on the size of items that may have stickers

[5] Seattle employs a combined approach -- a "can" based system, with special stickers for occasional "extras". These stickers, or "Trash Tags" may be purchased from the Utility or at retail outlets like 7-Eleven and grocery stores.

attached. However, a bag system limits the agency to equal price differentials no matter how many bags are put out by a household. This restricts the jurisdiction from charging increasingly higher rates for additional waste.[6]

If the jurisdiction attempts to charge for all the costs of disposal through the price of the bag, it runs the risk of not recovering the system's fixed costs. It may be more prudent to charge for the fixed cost of the collection/disposal system through a separate charge to customers, and keep the cost of the bags closer to the 'variable' cost of the system (generally disposal). In this latter case, the "fixed" portion of the system costs would be recovered through a "customer charge" on a regular periodic bill, or through a tax mechanism[7]. Then bags or stickers could be purchased for an additional fee that would reflect the "variable cost" of the system, and would show customers a savings if they dispose of less waste (use fewer bags or stickers). Charging separately for the fixed portion of the collection/disposal system assures that the fixed costs of the system will be recovered, and the system will remain solvent. Attempting to charge for all costs on the price of bags can lead to revenue instability and potential financial insolvency.

Choice of Subscription vs. Usage-based system: The best incentives are provided by systems that charge customers based closely on the actual amount of waste disposed. In this way, the customer's behavior is more directly associated with the amount paid. However, such a system requires either recording the number of items at each pick-up, or requires the use of pre-paid bag or stickers.

Pre-paid bag or sticker systems are a good option, especially in that they may offer charges based on smaller increments of waste and make it easier for customers to vary the amount of waste they put out. However, the system must allow for the recovery of fixed costs in some manner, perhaps through an additional "customer charge".

Subscription systems may provide an incentive to completely fill up the cans or bags paid for, and may decrease the recycling incentive. However, subscription systems can also work to remind customers to reduce to that subscription level

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[6] This can be mitigated to some degree if the household is issued a fixed number of bags per year at a certain rate, but then additional bags are available at a higher rate.

[7] The jurisdiction could charge this customer charge through its existing revenue mechanism.

on weeks when waste might be higher. Subscription systems are often easier to implement than systems that require the recording of items for each pick-up, and provide revenue stability. Providing the option for pre-paid stickers or bags in conjunction with subscription systems can improve the flexibility of the system for customers with occasional higher garbage levels, and may reduce the risk of illegal dumping.

Steepness of the Rate Structure: The steeper the extra charge for additional waste, the greater the incentive to recycle. Jurisdictions may wish to steer clear of excessively steep rates for two reasons, however:

1. An increased incentive to dump illegally.
2. Volatility of revenues.

Fixed costs of the system are incurred no matter what level of waste is disposed. Because the revenues for higher levels of waste are generally less certain (and indeed, through recycling, etc. you are trying to reduce these higher levels of waste), many of these fixed costs must be recovered through the customer charge or integrated into the "first-can" rate to assure the agency's financial solvency. The more of these costs that are put on the first service level, the less steep will be the rates.

> Selecting the steepness of the rates requires balancing:
>
> Increased recycling/waste reduction incentives
> vs.
> Increased incentives for illegal dumping
> and revenue uncertainty

In addition, pure cost-of-service pricing would not necessarily justify steeply increasing rates. This can be a difficult trade-off. This situation can arise for several reasons. One of the largest costs of providing solid waste service is getting the trucks and labor to the house, a cost that will not vary much with how much waste is put out for collection. In addition, many landfills are not priced at a level that reflects the full cost of providing service.[8] This will tend

[8] Many jurisdictions do not charge appropriately for all the costs associated with adding tonnage to a landfill. Costs that are often undervalued or omitted include

to reduce the steepness of the rate structure because a large component of the variable cost (the landfill fee) is underpriced compared to the long-term fully-inclusive price of disposal.

Seattle instituted rates that are higher than cost-of-service for higher subscription levels, and this approach was favored by the Utility, policy-makers, and citizen groups. The amount of excess funds that were projected to be collected from customers subscribing to higher can levels were used to reduce the rates for lower can levels. This approach allowed Seattle to enhance its waste reduction and recycling incentive in two ways: first, by implementing an enhanced 'penalty' for large amounts of waste; and second, by increasing the 'reward' for disposing of small waste volumes.[9]

Payments for "extras": "Extras" are cans or bags of waste that customers dispose of in excess of their subscription levels. Under a subscription or variable can approach, a system of payment for extras must be established to allow honest customers to dispose of occasional extra garbage without illegal dumping.

Care must be taken to assure than the price of one "extra" is greater than one-fourth the cost of an additional permanent monthly service level (with weekly service, or four pickups in the month). This becomes more complicated if the dollar differentials between service levels are not constant across service levels, and if the differentials vary for curbside vs. backyard service.

Differentials for Curbside vs. Backyard Service: Generally, backyard or carry-out service is more expensive to provide than curbside or alley service. Allowing customers to select -- and pay for -- the service arrangement of their choice can save your system money and provide more service options to customers. The savings may help pay for the switch to volume-based rates.

Jurisdictions currently show a wide range of differentials for these service differences. Some charge only cost-of-service differentials (perhaps 10%). Others charge as much as four times as much for backyard service. Seattle charges 40% more for backyard service, and found that over 95% of customers selected curb/alley service. Allowing customers to choose the service type gives

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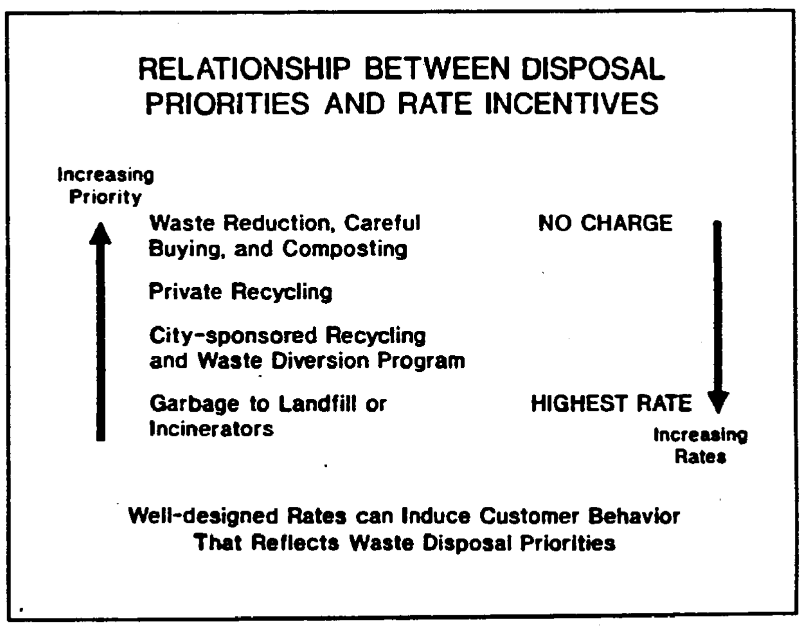
ultimate landfill closure costs and the cost of siting a replacement landfill.

[9] However, care must be taken in implementing this 'enhancement'. Recall that the revenues for higher subscription levels are less certain, while subscriptions at lower can levels are very certain. As the subsidy increases, the agency increases the chances it will not recover the fixed revenues needed to run the system.

them control over the size of their bills and continues the principle of providing a direct relationship between customer behavior and the size of bill.

Charges for Recycling or Diversion Programs: One controversial area is whether jurisdictions should charge separately for recycling or diversion programs. If these services are provided, but not separately charged, the costs will be included in the basic garbage rates. Not charging may enhance incentives to sign up for these programs.

However, there are strong arguments that this may not be an equitable system. Customers who do not use the program are charged. Although the jurisdiction may seek to penalize customers who do not use the City's programs and do not recycle or work to reduce their garbage, it is less clear that they would want to extend those penalties to customers who reduce their garbage through private recyclers or who reduce waste through careful purchasing or re-use. If the charge for recycling programs is included in the basic customer charge, then the likelihood of recovering the program costs is high, but these inequities are exacerbated. If the charges are put on higher subscription levels, the penalties are directed more accurately at customers who dispose of a great deal of waste, but the program costs are less likely to be recovered, affecting financial stability.



Indeed, as the solid waste jurisdiction is more successful in diverting waste from the landfill disposal stream to recycling and diversion programs, it reduces the revenue base (number of cans or bags) over which to spread recycling costs, so the extra cost per unit must increase. The result could be a system in which, as people recycle more, they pay higher and higher garbage fees.

To avoid finding itself in this situation, the jurisdiction should consider charging a separate (but relatively lower) fee for City-sponsored recycling, yardwaste collection/composting, and diversion programs. The fee may not recover all the costs of the programs, but should provide an incentive for taking care of the waste through careful purchasing (so that the waste is never produced in the first place), private recycling programs, or other ways to remove the waste from the city's waste and recycling system.[10] As the job of the solid waste jurisdiction changes from one of solely disposing of waste to an integrated system of waste disposal as well as waste diversion and recycling, it may be appropriate to charge customers some portions of the cost of these additional services, since a fee-for-service approach provides greater long-term financial stability and gives customers greater control over their bills. However, that doesn't mean it is inappropriate to provide some level of subsidy to these programs from garbage revenues. This approach reinforces the waste disposal priorities that have been adopted in most jurisdictions.

Seattle provides a curbside recycling program for no additional charge,[11] but charges a $2.00 monthly subscription fee for the City's weekly curbside yardwaste collection and composting program. This charge is considerably below the $9.00 charged for an additional subscription level.

Rates for Multi-family Buildings: Rate options for multi-family buildings can be complex for any utility, but may be especially so for solid waste service. The problems include:

- The tenant, or garbage-producer, is often not the bill-payer, so the rate incentives are diluted and indirect.
- Garbage is usually disposed of in a joint area, so tenants may not feel responsible if they over-dispose of waste because of the problem of determining which tenant is responsible.
- Rate equity can be difficult to maintain if two different systems (cans or bags; vs. dumpsters) are available.
- Maintaining equity between multi-family and single-family rates as well as between large and small multi-family buildings can be complex.
- The fact that some costs may be properly allocated on a building basis (e.g. the stopping of a garbage truck), some on a household basis (e.g. landfill closure), and some on a volume-basis (e.g. disposal) makes designing rates for multi-family applications much more complex than for single-family buildings.

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[10] This approach may also mitigate the amount of harm to any existing private recycling enterprises, and the potential for political fallout.

[11] The cost of the recycling programs and planning are covered through the garbage fees.

- o Offering a high degree of choice in subscription levels may complicate both billing and enforcement.

It would be possible to bill multi-family buildings on a fixed-fee basis (either per-building, or perhaps more fairly, per-household). However, that approach would eliminate any possibility of providing signals to either the property owner or the tenants that reducing waste is a benefit.

Although it may seem difficult, there are at least two possible volume-based approaches that may be practical in multi-family buildings:

1) A bag or tag system, with a per-household customer charge,[12] or
2) A variable can subscription approach.

Either system could be set up so that the owner is generally charged based on the volume generated per complex. However, the former system has the possibility of passing some of the direct incentives to the tenants. A per-household charge could be assessed through a bill or through the property taxes. Then all the waste that is in official pre-paid bags or that is tagged with pre-paid stickers would be picked up. Presumably tenants could be made responsible for paying for the bags. This system would tend to get some of the waste reduction incentives inherent in the rates to the waste producers.

However, realistically, some buildings may need enforcement efforts to try to reduce the amount of waste that is disposed in unofficial bags or waste that is not tagged. This may be a problem, and the relevant ordinances may need to make the landlord ultimately responsible for paying for this waste.

A variable can system is another alternative. Seattle's system of multi-family variable can rates is complex and imperfect. The City's billing system maintains records of the number of apartment units in each multi-family building and requires the building owner to select a subscription level.[13] The multi-family rates are charged with a structure that is identical to the single family rates for

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[12] The customer charge would probably be billed to the building owner.

[13] The system gives owners two options. They may either sign up for a number of cans that is equal to or larger than the number of units in the building (a five-plex may sign up for five, six, seven, etc. cans). Alternatively, the entire building may sign up for the mini-can service (that same five-plex would pay for and receive five mini-cans of service per week).

each apartment unit.[14],[15] The system is very complex and inflexible. However, the biggest weakness of this system is the fact that if one tenant is a strong recycler, he/she cannot generally reap the benefits of that behavior -- the system is unable to get the recycling incentive directly to the tenant.

Some non-rate options may need to be employed. Passing an "opportunity to recycle" ordinance requiring each complex to provide a convenient recycling opportunity may assist in increasing recycling by these customers.

Rates for Compacted Cans or Dumpsters: There may be a case for charging differential rates depending on whether waste is compacted or not. If landfill charges are weight-based, this may be especially appropriate.[16] However, in many cases, compacted waste may not incur extra disposal charges, and therefore may be priced the same as uncompacted waste.

In cases where a differential is appropriate, practical considerations may make it impossible[17] to charge additional amounts for compacted waste in cans, but may allow additional charges for compacted dumpsters. This is the case in Seattle. The Utility pays per-ton fees for landfill disposal and the Utility charges an additional fee for compacted dumpsters, which brings dumpster rates closer to cost of service. Seattle deals with compacted cans through a weight limit, which allows the City to deny pick-up to gross weight-limit violators.

Alternatives for Low Income Households: When mandatory fees are required, social concerns may make special rates for classes of low income customers appropriate. The jurisdiction may want to consider:

- alternate eligibility criteria -- all low income, low income with children, low income elderly or handicapped, medical eligibilities, etc.

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[14] Prior to 1989, Seattle charged multi-family rates lower than those charged to single-family households to account for savings related to fewer stops and the 'clustering' of cans. However, the most recent analysis showed these savings were very low and the lower rate was eliminated.

[15] Therefore, a five-plex building subscribed to six cans would pay for five full one-can subscriptions (including five customer charges) plus one additional can rate.

[16] However, for the most part, transfer and hauling costs may vary more on the basis of volume more than weight.

[17] Weight-based rate systems, discussed later in this paper, may eventually eliminate this problem.

- o the effect of alternate rates on billing system cost and efficiency
- o how to determine eligibility.
- o whether the rates should be lower throughout all volume-levels or whether discounts should be truncated after a "basic" level of service.
- o whether aid should take the form of lower rates, special services (such as free backyard collection), or emergency funds.
- o which classes should pay for the rate subsidy, and which rate subsidy design is most equitable to all customers.

BUT VOLUME BASED RATES AREN'T PERFECT, ARE THEY?

No. Metered systems, or systems that allow customers to pay for the exact amount[18] of waste they dispose, would be better. Systems based on smaller increments of waste are better, and could provide recycling incentives that are more volume-sensitive. In addition, the more immediate the payment, the more reinforcement provided. A more immediate payment for solid waste service provides a stronger message to customers.

However, trade-offs with ease of implementation and understandability must be made. Workable compromises include Seattle's system of subscribed cans augmented (for flexibility) with pre-paid stickers, or the pre-paid bag systems used in other jurisdictions.

ARE THERE BETTER METHODS AROUND THE CORNER?

One of the major objectives of variable rates is to establish a link between a customer's solid waste disposal choices and the bill that the customer pays. This is the key to providing an incentive to reduce the amount of waste disposed through waste reduction and recycling. Variable rates systems, unlike tax methods or systems with fixed bills for unlimited service, provide these incentives.

The volume-based methods of variable garbage rates discussed above are in place now in a number of communities. However, volume-based rates have some weaknesses.

- o Existing variable can rate systems charge on the basis of subscription, not usage. Under a variable can system, if a customer uses less than the

[18] and even type of waste

subscribed level of service in a particular week, that customer sees no savings reflected on the bill. The variable can system is not geared to the actual amount of service used by the customer.

- o Customers are charged on too large an increment of service. With either variable can or bag/tag systems, one of the problems is that the increments on which customers are charged are generally quite large -- either a "can" or a "bag" of waste. In order for customers to save money on their bill, they must reduce or recycle a full can or bag of waste. If customers have waste that even partially fills a service level, they have every incentive to fill it up because they will be pay for that entire service level.

- o Both types of systems can be inconvenient. On the customer's part, they must decide on a "normal" subscription level, and make calls for changes. They must purchase and have on hand an adequate supplies of bags or tags. The solid waste jurisdiction may need large inventories of cans of different sizes, and have a network for providing bags or tags as needed.

Some modifications to the current volume-based methods could be considered. Variable can systems could be modified with a variety of smaller can sizes -- half cans, quarter cans, etc. A variety of bag sizes could be introduced. However, this would not solve the inconvenience problems that exist, and would not necessarily provide the flexibility needed to maximize the waste reduction and recycling incentives.

However, with grant funding from the Environmental Protection Agency, experimental work is currently being done to test the feasibility of an innovative new idea in garbage rates -- a field-test called "Garbage by the Pound".

WHAT IS "GARBAGE BY THE POUND"?

The concept behind the Garbage by the Pound experiment is to test whether it would be feasible to introduce a system that would charge customers by the amount of solid waste service they use based on the pounds of waste disposed. The project is designed to test the mechanical, operational, and customer-related feasibility of a solid waste collection system that would weigh customer cans and charge on the basis of the weight of waste removed. This system would be flexible for the customer and the collection system, and would decrease the size of the increments by which customers are charged for solid waste service. Special cans or bags would not be needed. Requests for service level changes would no longer need to be coordinated. This approach is closer to "metered garbage service", bringing the delivery and charges for solid waste services into closer alignment with that provided for other utilities like electricity, gas, and water. Charging by the pounds of waste actually disposed each week would dramatically improve the link between behavior and bill, and thereby improve the customer's waste reduction and recycling incentives. And although it is true that landfills do not fill up because they are too heavy, and many jurisdictions pay for disposal based on a volume measure (cubic yards), a weight-based approach shows particular promise because: 1) quick measures of small volume measure increments would be difficult to implement and may require judgment on the part of the field staff, and 2) technologies to accurately measure small increments of weight are convenient to use, well-accepted, and proven in the marketplace (scales).

The objective of the project is to do a field test of a system of this type to begin to determine whether such a system might be feasible. This project has several major tasks.

- Identify and install weighing/scanning equipment. The preferred system would simplify or minimize changes to current collection procedures. More complex collection procedures would lead to higher long-term labor costs for collection and adversely affect the cost-benefit analysis. The initial system that was considered was a truck-mounted automatic scanning device to read bar-codes on the individual garbage cans, with the weight for each can automatically recorded, to be downloaded into a billing computer. This automatic approach would minimize the collection system changes, requiring generally one step to register the weight.

- Field test the system on customer routes. This includes modifying the installed system as operational or mechanical difficulties are found. A three-month field test was envisioned.

- Customer studies. Customers on the selected routes will receive bi-weekly statements that summarize for them the amount of waste they disposed. This phase of the project includes an evaluation of customer behavior pre- and post-to see if the dummy bills caused them to reduce waste, evaluating a survey to determine effectiveness of the approach based on socio-demographic and behavioral factors, and to elicit feedback on the system.

- Estimate costs and benefits of the system. This part of the project includes an evaluation of the system costs, accuracy, time/convenience, learning skill, reliability and durability, results regarding collection and system changes, effectiveness, payback, and tradeoffs.

- o Dissemination of results. The results of this EPA-sponsored project will be fully available. If the approach is successful, it is hoped that private industry (truck and scale companies) will work to further develop and enhance the technology on a larger-scale basis.

HOW FAR ALONG IS THE PROJECT?

At this point, the project has selected one technology and is doing preliminary field testing.
Scale: The scale technology being evaluated is a small industrial crane scale. A crane scale is primarily a hook and load cell suspended at the back of the truck. The barrels are hung on the hook manually by their handles. The system is based on available technology, can be installed so that it minimizes the external attachments that could be damaged by ground or alley clearance problems, weighs consistently on grades and inclines, and fits easily into the current collection system. During later stages of the project, we are examining the feasibility of retrofitting the cart dumper to weigh the barrels during semi-automated dumping. This technology would be less labor intensive and may be more applicable to systems in other jurisdictions.

Scanner: It has proved infeasible to have a truck-mounted automatic scanning system because no rugged technology is currently available. Instead, the project is using a bar code system that uses a 'rugged-ized' hand-held module (that is mounted in a bracket on the truck) and requires the use of a manually-activated "gun" to read the bar code. This two-step process (hanging the can plus activating the "gun") is still simple, but may not be efficient from a labor point of view. The project will be evaluating whether the "gun" bar code reader can be mounted in a holster and the programming modified so that the system can automatically read the bar codes on the cans. Although radio frequency may provide a quicker data collection method, installation and purchase cost have been prohibitive for the field test. This technology may show promise for full scale implementation.

Logger: Data storage during collection is in the portable data collection unit. Data from both the bar code scanner and the scale are stored here, and uploaded and downloaded to a PC for updating the customer file and preparing the biweekly customer reports.

The field test is expected to continue throughout the summer, with a report due in early fall. Information on the project will be available at its conclusion. Preliminary information certainly demonstrates the equity benefits of the project in that there was considerable variation in the amount of waste currently being disposed in similar-sized containers -- one test run showed variations between 10 and 63 pounds of waste in identical 32-gallon cans!

Although this is an experimental project, it is hoped that in the long run, a system can be developed that is practical and flexible for use in the variety of solid waste collection services. Such an approach has the capability to be more equitable than current approaches and to provide significantly improved waste reduction and recycling incentives.

SUMMARY

Many solid waste jurisdictions are facing tough challenges. Landfill space is becoming a problem, and jurisdictions need ways to reduce the amount of waste going to increasingly expensive disposal facilities. Expensive recycling programs are being under-utilized. Variable rates give an economic incentive for customers to reduce the waste they dispose of, and provide incentives for recycling and waste reduction.

Variable rate systems are fair and effective, and provide a number of other advantages, including:

- they can be implemented in a variety of situations
- the rates can be implemented relatively quickly
- variable rates can lead to system savings, and
- they integrate well with other programs, increase participation in recycling programs, and reinforce waste-reducing behavior.

There is no doubt that, from a variety of perspectives, many jurisdictions could benefit from replacing their current fixed-rate systems with volume-based rates.

Variable rate systems work, and make a great deal of sense from a system perspective. A variable can rate structure has proven to be one of Seattle's most effective recycling programs, and bag systems have proven to be very effective in a variety of smaller communities. The rates are a vital part of the Seattle's integrated solid waste system, and have allowed that Utility to set an aggressive, but achievable, 60% recycling goal. Seattle's customers have responded well to a rate structure that gives them alternatives and control, and they have responded with high levels of private recycling, very high participation levels in City-sponsored programs, significant reductions in service levels, and significant decreases in the waste brought to landfills. Customers have become an integral part of the solid waste system.

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ZONING FOR RECYCLING

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

ZONING FOR RECYCLING

INTRODUCTION

Solid waste disposal is becoming an increasing problem throughout North America. As a result of rising costs for waste disposal, there has been an increase in the number of waste reduction and recycling facilities. Increasingly, these facilities are running into barriers to their development in the form of local zoning ordinances which often do not address recycling facilities or, when they do address them, it is in very narrow terms.

HISTORY OF ZONING

The U.S. Supreme Court approved the concept of zoning in 1926 with Euclid v. Ambler Realty Co. (272 U.S. 365), and has since upheld zoning unless it was arbitrary or denied the owners all reasonable use of their property. According to Alexandra Dawson, in Landuse and The Law, "Every state now has a zoning act or a zoning enabling act authorizing cities, towns or counties to adopt zoning codes". Zoning was originally used as a tool to protect the "highest and best use," normally single family homes, from less desirable uses (multi-family dwellings or industry), which might lower property values. Thus, from its inception zoning was not used to create a comprehensive land-use pattern which could make the best use of natural, economic and social resources, but to protect the aesthetics and property values of neighborhoods.

Concern about the denial of all reasonable use of property, known as "the taking issue" has led to the institutionalization of a variety of options for property owners who want to pursue a use for which their property is not zoned. The most common option is the variance which allows a local board to vary the zoning when it would create a hardship to the owner, thus denying the owner use of his or her property. The variance has come under considerable criticism because of its misuse. It is often used when better solutions, such as reclassifying the use, may prove to be a lengthy process or cause political difficulties.

RECYCLING CENTERS AND ZONING

Recycling is quickly becoming an integral part of solid waste management. As a rapidly expanding industry its relationship to land-use is still unclear. Public officials, planners and politicians are becoming aware that there is an increasing need for recycling facilities and that there are many sizes and types of recycling operations. Yet most local governments still do not have provisions in their zoning ordinances for the proper siting of the various types of recycling facilities. In many cases all recycling centers are classified as salvage yards which are traditionally zoned as light industry. While this may be appropriate for large processing centers, which have little contact with the general public, it is highly undesirable for a buy-back center which is set-up to provide the public a convenient location to bring such recyclable materials as aluminum cans, glass bottles, newspaper and plastic bottles. In addition, as waste processing becomes more sophisticated, there is growing concern over the definition of a recycling center versus a solid waste facility.

CAN PAK RECYCLING INC.

Can Pak Recycing, Inc. is an example of a business which encountered a zoning problem. Can Pak Recycling, Inc. tried to set up a buy-back center in an old two bay gas station/convenience store, in Del City, OK. Del City is a middle-class bedroom community near Oklahoma City with a population of around 30,000. The local zoning ordinance, voted into effect in March, 1987 after a three year study, considers all permanent recycling operations as salvage yards classified as light industry.

Can Pak, Inc. operates buy back centers nationwide, though it primarily operates in the west, midwest and southeast. It is a subsidiary of IMS Recycling Services of San Diego CA. Oklahoma City area manager Jim Jenkins, oversees two successful buy-back centers currently operating in nearby Norman and Nicoma, OK, as well as a central processing facility in Oklahoma City. He hopes to open several more satellite facilities (buy-back centers) which will be serviced by the Oklahoma City processing facility.

The proposed site, in Del City was located in a C1 zone (commercial zone), in a residential neighborhood on a corner lot of a major east/west thoroughfare, East Reno Street, a section line road[1]. Mr. Jenkins expected about 25 to 30 cars per day would bring material to the center, with the busiest days being Mondays and

[1] The term "section line" refers to the division of the area into 640 acre parcels when the territory was first homesteaded. The borders of these sections have naturally become major travel routes.

Saturdays. Can Pak's goal was for the facility to bring in 4000 lbs./week of aluminum cans. According to Mr. Jenkins, there was plenty of parking to accommodate the expected flow of traffic.

A successful buy-back center needs to be convenient and attractive. Consumers generally don't want to go out of their way or to traditional areas (industrial zones), to recycle their bottles, cans and paper. Participation is much higher if the public can recycle materials as easily as they buy goods at their local convenience store. It is important for the facility to be neat, clean and attractive to the general public. Mr. Jenkins explained that as well as being concerned about the esthetics of their facilities, Can Pak uses low noise aluminum can densifiers to avoid disturbing the neighbors.

Mr. Pat Salvator, Regional Director of Can Pak Recycling Inc., explained that the facility was given both the electrical permit and building permit but when they tried to get an occupancy permit they were denied due to the zoning discrepancy.

Mr. Jenkins questioned the City Planner about why two buy-back operations, run by Reynolds Aluminum, consisting of tractor trailers parked in privately owned parking lots in a commercial zone, had no trouble getting permits. The City Planner knew nothing about the Reynolds trailers, which were operating with the permission of the parking lot owners but without any City permits. The City Planner felt this brought up some "question of the legality" of the Reynolds operations and an "investigation" was launched. According to the Chief Inspector of Code Enforcement for Del City, the decision was to grant 90-day outdoor use permits, as they would for a parking lot tent sale, though the matter has not been settled.

Mr. Jenkins, after he "tried everything else", determined that Can Pak's only option was to try to have the lot rezoned as light industrial. Because of the wording of the zoning ordinance there were no grounds for a variance and no "permit by right" exists in the ordinance, so reclassifying the use or rezoning became the only possible solutions if Can Pak wanted to keep the buy-back center at the proposed location. Reclassifying is a much lengthier procedure than rezoning. As a result, Can Pak filed to have the lot rezoned to light industrial.

To rezone, all abutting property owners have to be notified and a public hearing must take place. Although there were no objections from the public at the meeting, Can Pak had to withdraw their request for rezoning because the light industrial zone requires a minimum one acre lot size. The lot in question was .29 acres. Frustrated, Mr. Jenkins noted "we are trying to get the public and public officials to understand that we're not a junkyard", though he admits it will be a "long drawn-out process" because "nobody has figured out what procedures to use to get away from the junkyard image."

Ironically, everyone involved, including Del City officials and Can Pak employees, understands the value of having the recycling facility in Del City. It is simply that the zoning code has not allowed for a buy-back recycling center in the use classifications.

CALIFORNIA'S SOLUTION (AND THE SOLUTION'S PROBLEMS)

In recognition of the zoning barriers for commercial recycling centers and in response to the enactment of the 1986 California Beverage Container Recycling and Litter Reduction Act (AB 2020), the State of California has developed a model local zoning ordinance for beverage container recycling.

AB 2020 states that there must be a certified recycling facility in every convenience zone defined as: within 1/2 mile of a supermarket with $2 million or more in annual sales. According to Tania Lipshutz of the California Department of Conservation, Division of Recycling, this resulted in the establishment and permitting of approximately 2,000 new recycling centers within one year, as well as processing facilities to support them.

The Act permits local governments to adopt rules and regulations governing the operation of mobile recycling units or reverse vending machines. AB-2020 prohibits any agency from denying permits for the operation of mobile recycling units or reverse vending machines which have the permission of the property owner and are located on property zoned for commercial or industrial use within a convenience zone, unless the agency specifically finds that the individual facility would be detrimental to the public health, safety and well being. AB-2020 does not address the permitting of other larger recycling facilities or facilities outside of the convenience zones though the model zoning ordinance does.

Ms. Lipshutz notes in her paper Zoning and Planning for Recycling, presented to the 1988 National Recycling Congress; "the Division [of Recycling] found that elements of existing zoning ordinances hampered the permitting of even these small recycling centers, zoning ordinance amendments were often necessary, since the ordinances often included:

- Treatment of any type of recycling center as a junkyard, and therefore, restricting them to heavy industrial zones;
- Prohibition of outdoor activities or outdoor storage in commercial or manufacturing zones;
- Limited procedural options, requiring extensive and expensive use permits and architectural review for large permanent recycling centers and small donation centers alike; and,
- Prohibition of any activity not specifically allowed in the zoning ordinance."

The model ordinance divides recycling centers into five categories: 1) Reverse Vending Machines, 2) Small Collection Facilities, 3) Large Collection Facilities, 4) Small Processing Facilities and 5) Large Processing Facilities. The ordinance defines the recycling terms used, determines the permits needed (see figure 1), and sets criteria and standards for each of the categories of recycling facilities.

Figure 1

Type of Facility	Zones Permitted	Permit Required	Alternative Permit
Reverse Vending Machine(s)	All Commercial All Industrial	Administrative (or by right)	Minor Use
Small Collection	All Commercial All Industrial	Administrative	Minor Use
Large Collection	C-1	Minor Use	
	Other Commercial	Site Development	Minor Use
	Industrial	Site Development	Minor Use
Light Processing	Heavy Commercial	Conditional Use	
	All Industrial	Minor Use	Conditional Use
Heavy Processing	Light Industrial	Conditional Use	
	Heavy Industrial	Site Development	Conditional Use

Source: California Beverage Container Recycling - Local Government Guide

In reviewing the ordinance there are two potential problems that could arise if it is adopted. The first is the definition of a processing facility versus a collection facility. The distinction made in the model ordinance is the use of power driven equipment. The ordinance fails to recognize that the use of volume reduction equipment is necessary for most collection facilities to ship material cost effectively. This is especially true for materials that have a high volume to weight ratio such as plastic bottles and aluminum cans, which are costly to ship without some densification.

One possible solution would be to include performance specifications in the zoning law to protect neighbors from unwanted noise and (as mentioned in the model ordinance) unsightly operations.

The second potential problem is the definition of recyclable material: "Recyclable material is reusable material including but not limited to metals, glass, plastic and paper, which are *intended for reuse* [emphasis mine], remanufacture, or reconstitution for the purpose of using the altered form. Recyclable material does not include refuse or hazardous materials." This definition may be a problem because, as landfill tipping fees rise, the recovery of materials is becoming more sophisticated and the distinction between recyclables and refuse is becoming less obvious. Without a clear definition of what constitutes "recyclable" material there is the potential for the permitting of recycling centers which in reality are waste transfer stations or facilities which are stockpiling materials "intended for reuse" but for which there is no market.[3]

One solution could be to specify designated materials as being "recyclable" but this may have the unwanted effect of discouraging the development of new recycling technologies.

NEW JERSEY'S SOLUTION (AND THE SOLUTION'S PROBLEMS)

The New Jersey Department of Environmental Protection (NJDEP) is currently struggling with the problem of defining a recycling center. Under New Jersey's law, solid waste facilities are exempt from local zoning laws and recycling centers are considered solid waste facilities. However, recycling centers do not have to go through the rigorous Environmental Impact Statement (EIS) process and are not regulated by the State. The only requirement is that recycling facilities must

[3] Many state and local statutes cover this problem by specifying a time limit for storage.

be in the County Solid Waste Plan. This has led to a few facilities taking advantage of the system and calling themselves recycling centers when they are actually waste transfer stations as well as recycling centers.

As per N.J.S.A. 13:1E-99.34 " no recycling center shall receive, store, process or transfer any waste material other than source separated nonputrescible or source separated commingled nonputrescible metal, glass, paper, or plastic containers, and corrugated and other cardboard without the prior approval of the Department." With the increasing profits to be made handling solid waste it is a difficult law to enforce.

The problem became headline news in New Jersey when on August 7, 1989, a fire at Hub Recycling & Scrap Co. buckled a portion of Interstate 78 in Newark. Hub, which had declared bankruptcy in 1987, built up 30-foot piles of debris, most of it on neighboring property, using the recycling center as a front for an illegal landfill.

Prior to the Hub fire, Senators Contillo, Costa, and Ambrosio introduced an act amending the New Jersey Statewide Mandatory Source Separation and Recycling Act to "facilitate the growth and development of commercial recycling activities in this State." The bill, which has been accelerated through the legislative process since the Hub fire, attempts to set definitions to distinguish between regulated solid waste facilities which also engage in recycling activities (termed by the bill as "recycling facilities") and unregulated facilities which are strictly commercial recycling operations (termed by the bill as "recycling centers"). In addition, the bill requires the, newly defined recycling centers to be licensed by the DEP. The revenues from the fees collected are to be used by the DEP to support enforcement, including the periodic inspection of licensed recycling centers to ensure that they are not accepting solid waste.

The definitions for recycling operations are very clear:

> "Recycling center" means any facility, including a scrap processing facility, and designed and operated solely for receiving, storing, processing and transferring source separated, nonputrescible or source separated commingled nonputrescible metal, glass, paper, wood, rubber, plastic and plastic containers, and corrugated and other cardboard, or other recyclable materials approved by the department, and licensed under the provisions of section 5 of P.L. 1988, c. (now before the Legislature as this bill);

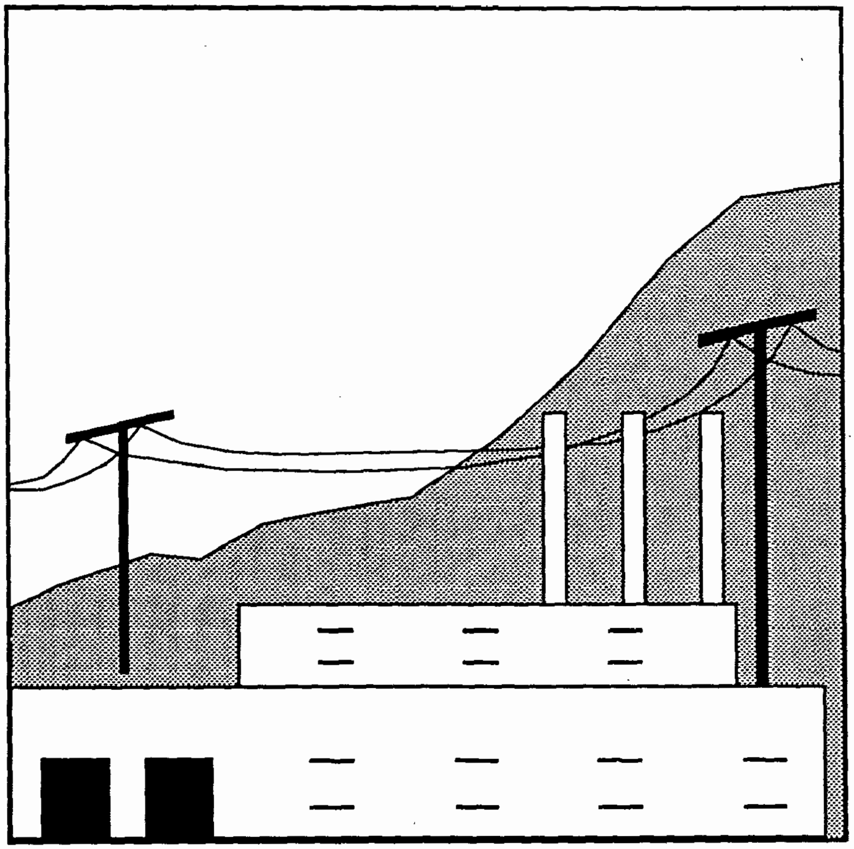
> "Recycling facility" means any transfer station or other solid waste facility at which putrescible or nonputrescible solid waste is accepted for disposal or transfer and at which recyclable materials are separated or processed from solid waste onsite for the purposes of recycling:

Originally, the bill was not well received because it placed an additional burden on the operators of legitimate recycling centers but, due to the Hub fire, it became clear that such legislation was needed.

SUMMARY

As the volume of waste and cost of solid waste management increases the viability of more extensive recycling and waste reduction activities will also increase and decisions to determine the best land-use options will become more complicated.

It is important for all public officials, like those in California and New Jersey, to recognize that these issues exist. We must begin to address them by using the available tools. One of these tools, zoning, will be extremely useful for attracting the kind of private sector initiatives necessary to help solve our growing solid waste problem. With zoning which encourages recycling operations of all types, a city, town or region can expect to see an increase in commercial recycling activities which will mean an increase in jobs, a boost for the local economy and a reduction in the amount of solid waste needing disposal



COMBUSTION

CHALLENGE OF COMPLIANCE WITH EPA'S NEW MUNICIPAL WASTE COMBUSTION REGULATION - MODULAR FACILITY PASCAGOULA, MISSISSIPPI

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

I. ABSTRACT

The Pascagoula Energy Recovery Facility is a typical european style mass-burn excess air facility. It houses two (2) solid waste 75 ton/day modular units capable of producing an average of 151 million pounds of steam per year. The steam generated is sold to Morton International, a nearby chemical plant. Although the facility is owned by the City of Pascagoula, it is considered a regional plant. The plant is located in the adjoining City of Moss Point and receives solid waste from Pascagoula and Moss Point as well as over 50% of Jackson County.

The plant, the first and only facility of its kind in Mississippi, has been in operation since 1985, has since incinerated over 180,000 tons of solid waste and generated over 800 million pounds of steam. Attachments to this paper are furnished containing additional information on this system.

This paper is presented to discuss the impact of the USEPA Proposed Environmental Guidelines, particularly their effects on small scale modular facilities.

II. INTRODUCTION

The topics discussed in this paper are in response to the proposed rules of Emission Guidelines for municipal waste combustors including: controlling emissions from existing municipal waste combustions (MWC) and recent USEPA notices relative to pending ash disposal legislation. The overall goal of these guidelines is to reduce air emission pollutants by 90%.

We have attempted to discuss each of the proposed regulations and compare them with existing performance based on current test data. We have also estimated the cost of the improvements required to meet the new standards.

In generally, the following topics are discussed:

MWC Emissions
Materials Separation
MWC Ash Disposal

III. MWC EMISSIONS

Based on the proposed guidelines, the emission requirements are divided into several categories:

Best Demonstrated Technology
MWC Organics
MWC Metals
MCW Acid Gases
Combustion Control
Certification and Operation Training

1. Best Demonstrated Technology

According to the guidelines for small scale facilities, the best demonstrated technology requires (1) good combustion and (2) an electrostatic precipitator. We believe the Pascagoula plant basically fits these guidelines, therefore, capital or operation cost increases are not expected.

2. MWC Organics - Dioxin/furan Emission Limit 200 grams/billion dscf

The Pascagoula facility maintains the primary combustion chamber temperature at 1900 degrees F. The post combustion chamber is approximately 1800 degrees F, and the flue gas at the boiler exit is above 400 degrees F. The plant is an excess air technology (approximately 100-150%). The carbon monoxide in the flue gases has been tested below 100 ppm, and the oxygen in the flue gas is 15%. The resonance time in the combustion chamber is over 2 seconds. This ensures adequate time for removing dioxin/furans. Tests conducted in 1988 measured total TCDB and TCDF at .001 grains/year. PCB and chlorophenol were tested at .504 grains/year and chlorobenzene at .225 grains/year. These rates are well below the required 200 gr/billion dscf.

The cost for conducting annual tests required by the proposed regulations to measure these contaminants is approximately $ 30,000/year.

3. MWC Metals - 69 mg/dscm at 7% O2

Based on tests in mid-1989, the combined heavy metals were less than 10 mg/dscm corrected to 12% CO2. The total particulate was .0415 grains/dscf compared with the permit requirement of .08 grains/dscf.

The above values are adjusted to 12% CO2 in the flue gases. The proposed regulations require the emissions to be corrected to 7% O2. This is roughly equivalent to a correction of 11 to 12% CO2, therefore, no impact on the facility is anticipated based on MWC metals. We do, however, expect annual testing will increase the operation cost by approximately $ 10,000/year.

4. MCW Acid Gases

Based on the proposed regulations, acid gas control will not be required on small MWC's with a total plant capacity of less than 250 tons/day.

5. Combustion Control

The CO emissions at the facility have been tested at less than 100 ppmv. The exact CO content of the flue gas has not been accurately determined. However, since the unit operates on excess air with a flue gas O2 content of 15%, the proposed CO limit should be easy to achieve.

The proposed flue gas temperature limit of 450 degrees F or less is consistent with present operations at the facility. The temperature is measured upstream of the PM control device.

We object to the proposed continuous monitoring locations. The guidelines require testing for the flue gas CO level at the inlet to the electrostatic precipitator. We feel the location should be downstream of the device since upstream measurements result in increased maintenance. Additionally, a continuous load weight measuring device at the MWC was installed as part of the original design. We found this equipment impossible to maintain as well as inaccurate in measurement.

We believe daily monitoring of the waste via mass balances (total in minus bypass and oversized bulky waste) will provide sufficient records.

Regarding continuous temperature monitoring, the facility maintains adequate temperature records since this information is imperative for proper operation of a steam plant.

We estimate the cost for installing the added monitoring system (including the opacity meter) at $ 100,000. The annual operating cost is approximately $ 5,000/year.

6. Certification and Operator Training

We support the requirement for certification by the American Society of Mechanical Engineers (ASME) for the Chief Facility Operator and Shift Supervisor. The facility presently is under contract to a private operating firm which monitors their own certification program. Standardization to the ASME regulations would assure the City that operators possess adequate knowledge of combustion and power generation. It is possible that operation certification will cost the City an initial cost of $ 10,000 and an annual labor cost of $ 30,000/year.

IV. MATERIAL SEPARATION

The proposed 25% reduction will have an adverse effect on the facility. This will result in a tonnage reduction from 36,000 to

27,000 tons/year. For the purpose of evaluation, we have assumed that 50% of the glass, metals and plastics are recycled, 10% of the garden wastes are composted and 25% of the paper waste is recycled. The BTU loss plus the reduction of disposal fees result in a 25% revenue loss. This would increase the tipping fee from $ 17.40/ton to over $ 26.00/ton (over $ 240,000 annual increase). Since two private landfills will charge approximately $ 18.00 per ton for hauling and disposal, the increased cost will more than likely make the facility non-competitive.

We have reviewed two material separation methods (1) curbside or source separation and (2) separation at the plant. There are potential financial benefits for the facility for separation at the plant on site separation will maintain waste volume at current levels and provide income from material sales. These benefits, however, do not offset the added cost of plant modification and operation and maintenance. In our opinion, therefore, curbside separation is the only viable option.

Unless consistent markets can provide sufficient income to offset costs, it is doubtful that communities around Pascagoula will continue to support the facility. These communities will more than likely elect to utilize the less expensive option of landfilling.

We support the material separation and recycling options, they are viable in larger populated areas with limited disposal alternatives. In Mississippi, however, the markets for recycled materials are scarce, and the County may not produce a sufficient volume to entice long-term agreements.

We believe that incineration is a form of solid waste reduction and at least the reduction programs be site specific in areas where (1) the costs are not prohibited, (2) the waste volume is significant to entice markets, and (3) the reduction requirements are applied only to landfills or incineration which are not producing an energy by-product. An energy recovery system is a form of recycling by reducing fossil fuel requirements and conserving energy for future generations. We feel the requirements should at least be delayed until sufficient markets for recycled materials have been established to offset the cost of material separation and handling.

V. MWC ASH DISPOSAL

Presently, the Pascagoula Facility deposits the ash from the facility in a monofill. The site was constructed in 1988, specifically for ash, by a private contractor. The facility includes groundwater monitoring wells and leachate collection. The monofill is located in an area having over 40 feet of clay liner and so far has been successfully operating. Tests have been performed to quantify the dioxin/furan content. The results indicate the dioxin and furan levels are 0.107 ppb, well below the maximum allowable concentration of 1.0

ppb.

Additionally, the ash is tested for heavy metals (EP toxicity) both at the plant and at the ash disposal site. Based on over 100 samples, no metals above the maximum concentration have been encountered. The tests performed are based on composite ash samples from the following locations in the facility:

Bottom Ash	93.5%
Undergrate	5.28%
Post Combustion Units	0.03%
ESP Fly Ash	1.06%

Future legislation may impose additional requirements on ash from the facility. We feel that only the fly ash should be regulated. The remaining should be approved for use as road fill, cinder block manufacturing, etc. We recommend test programs be widely initiated to demonstrate the uses of ash. Based on our experience at the ash landfill, we have found that ash is an excellent road base material and may have a high market potential in South Mississippi due to the lack of conventional fill materials.

Although regulations have not been completely developed, we understand that the EP toxicity test will be modified with additional testing required. If annual tests are required to measure the dioxin/furan contents, we estimate an added cost of $ 30,000/year.

VI. SUMMARY AND CONCLUSION

Overall, small scale facilities such as the Pascagoula Plant should have no major problems meeting the majority of the proposed emission regulations. The additional testing and monitoring requirements, however, will add substantially to the operation and maintenance costs at the facility. If a material separation program is mandated, the cost increase will be even more significant.

Summarizing, the added costs at the facility are:

Estimated Cost Increase
Based on Proposed Regulations

Item	Capital	Annual	$/Ton (1)
Demonstrated Technology	-0-	-0-	-0-
Organic Emissions	-0-	$ 30,000	1.11
Metal Emissions	-0-	10,000	0.37
Acid Control	-0-	-0-	-0-
Combustion Control	$ 100,000	5,000	0.18
Certification	10,000	30,000	1.11
Material Separation	-0-	240,000	8.88

Subtotal	$ 110,000	$ 315,000	11.66
Annual Cost of Capital (2)		16,000	0.59
Total Annual Increase		$ 331,000	12.26
Existing Fee			17.43
Adjusted		$ 29.69/Ton	29.69
% Increase		70%	

(1) Based on 27,000 tons/day from existing 36,000 tons/day.

(2) 8% interest - 10 year payout.

In comparison, landfill costs also have had changes in regulations resulting in increased disposal costs. To control these added costs, regionalized landfills have been developed charging from $ 12 - $ 15/ton. As recycling or material separation becomes mandatory, landfill costs will also increase.

Material separation and recycling must be cost effective based on the sale of recyclables. This requires market development (presently in progress) and regionalized recycling centers. Until such time as consistent markets for recycled materials are developed, it is my opinion that material separation will increase disposal cost at all facilities and compound the communities economic problems.

The challenges that that each public official must meet are:

1. Finding the most cost effective method of meeting the environmental regulations of solid waste disposal.

and 2. Determining the most acceptable method to the public.

Most decisions regarding solid waste are based solely on economics and public opinion. If the public is willing to increase their taxes and/or user fees, the waste streams will be dramatically reduced. If not, this problem will continue and all waste in our region will be landfilled.

To assist the communities in these decisions, the USEPA and the State Environment Quality Departments must work with site specific requirements based on each community's environmental problems. In areas like Mississippi, the most abundant resource is land. In counties directly north of the Coast, land is available for $ 300.00 per acre. Since these regions are sparsely populated, landfills in most cases can be easily sited. A dramatic increase in environmental regulations may force future disposal in Mississippi to be landfills at the expense of resource recovery.

Additionally, air pollution limits should be considered based on location and existing conditions, not blanket requirements for all. A 2000 ton per day facility in downtown New York City should be required to meet more stringent regulations than a 250 ton per day plant in Moss Point, Mississippi (population 19,000).

Finally, we must combat environmentalists who express their opinion without the basis of fact. The general public responds to issues emotionally and tend to sway political decisions. As a point in fact, our facility was recently attacked by a major Washington based Environmental Coalition as generating a "cloud of death" due to dioxin/furans. Since we had already conducted tests to demonstrate compliance, we contacted the individuals to determine their source of information. Their source was data on ten "similar" facilities, with less than one half of these showing problems. The Pascagoula Facility was included without basis of fact.

Environmental protection is an issue facing all the population. We feel it would be in everyones best interest for our community leaders, environmental leaders, local and state government officials, and technical experts to work together to help solve the problems we face. Through their combined cooperation, they can find solutions based on fact and community concern.

CHARACTERIZATION OF MUNICIPAL WASTE COMBUSTION ASHES AND LEACHATES

RESULTS OF TWO FIELD STUDIES

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ABSTRACT

Incineration of MSW has become an important alternative to the land disposal of MSW. Incineration is an effective means of reducing the volume of MSW and can provide an important source of energy. Ash from the combustion of household waste has been excluded from regulations under Subtitle C of RCRA, which regulated disposal of hazardous wastes. However, in some instances testing the residues from municipal waste incinerators by the Extraction Procedure (EP) Toxicity test is being required to determine if these residues would be classified as hazardous waste and, therefore, subjected to disposal regulations under Subtitle C. Ashes from MWC facilities, on occasion, have exhibited hazardous waste characteristics as determined by the EP Toxicity test. The debate regarding the representativeness and the validity of this test and the relation of these results to actual leachates from ash disposal facilities has not been settled.

For this reason, EPA and CORRE have cosponsored a study designed to enhance the data base on the characteristics of MWC ashes, laboratory extracts of MWC ashes, and leachates from MWC ash disposal facilities. Ash samples were collected from 5 MWC facilities and leachate samples were collected from the companion ash disposal sites. These ash and leachate samples were analyzed for the Appendix IX semivolatile compounds, polychlorinated dibenzo-p-dioxins/polychlorinated dibenzofurans (PCDDs/PCDFs), metals for which Federal primary and secondary drinking water standards exist, and several miscellaneous conventional compounds. The ash samples were also subjected to six laboratory extraction procedures and the extracts were then analyzed for the same compounds as the ash samples. All sampling, laboratory preparation, and laboratory analysis followed stringent quality assurance/quality control (QA/QC) procedures.

A major environmental concern regarding the effects of ash-monofill leachates is the long-term changes in the composition of such leachates. To address this concern, EPA has committed to study such effects at the Woodburn Ash-Monofill located in Marion County, Oregon. To date, the EPA selected monofill was visited three times during the past two years. Ash, leachate, and soil samples were collected and subjected to the same testing and QA/QC procedures as the CORRE/EPA study samples.

The major findings of these two studies are described in this paper.

INTRODUCTION

This paper provides a summary of the findings provided in a recent report which has been prepared for the United States Environmental Protection Agency (EPA) and the Coalition on Resource Recovery and the Environment (CORRE). EPA and CORRE have cosponsored this study to enhance the data base on the characteristics of MWC ashes, laboratory extracts of MWC ashes, and leachates from MWC ash disposal facilities.

The Coalition on Resource Recovery and the Environment (CORRE) was established to provide credible information about resource recovery and associated environmental issues to the public and to public officials. In providing information, CORRE takes no position as to the appropriateness of one technology compared to others. CORRE recognizes that successful waste management is an integrated utilization of many technologies which taken as a whole, are best selected by an informed public and informed public officials.

Incineration of municipal solid waste (MSW) has become an important waste disposal alternative because it provides an effective means of reducing the volume of MSW as well as an important source of energy recovery. Currently, 10 percent of the United States MSW is incinerated. Based on the number of municipal waste combustion (MWC) facilities being planned across the country, this percentage is expected to increase to 16-25 percent by the year 2000.

As incineration of MSW has increased in recent years, so has concern over its management. To resolve the many legal and technical issues surrounding ash, Congress is considering several legislative initiatives that would classify municipal waste combustion (MWC) ash as a special waste under Subtitle D of the Resource Conservation and Recovery Act (RCRA) and require the Environmental Protection Agency (EPA) to develop special management standards for the full life cycle of ash. In anticipation of Congressional action, EPA and the Coalition on Resource Recovery and the Environment (CORRE) cosponsored this study to characterize ash and to gain a better understanding of how it behaves in the environment.

To provide long term ash, leachate, and soil characterization data, EPA committed to a long-term (several years) study at an EPA selected ash-monofill. EPA selected the Woodburn Ash-Monofill located in Marion County, Oregon. To date, this disposal facility was sampled three times.

DESCRIPTION OF THE CORRE/EPA STUDY

Combined bottom and fly ash samples were collected from five mass-burn MWC facilities and leachate samples were collected from the companion ash disposal sites.

The facilities sampled were selected by CORRE to meet the following criteria:

- o The facilities were to be state-of-the-art facilities equipped with a variety of pollution control equipment.
- o The facilities were to be located in different regions of the United States.
- o The companion ash disposal facilities were to be equipped with leachate collection systems or some means of collecting leachate samples.

The identities of the facilities are being held in confidence.

The ash and leachate samples collected were analyzed for the Appendix IX semivolatile compounds, polychlorinated dibenzo-p-dioxins/polychlorinated dibenzofurans (PCDDs/PCDFs), metals for which Federal primary and secondary drinking water standards exist, and several miscellaneous conventional compounds. In addition, the ash samples were analyzed for major components in the form of oxides.

The ash samples were also subjected to six laboratory extraction procedures and the extracts were then analyzed for the same compounds as the original ash samples. The following six extraction procedures were used during this study:

- Acid Number 1 (EP-TOX)
- Acid Number 2 (TCLP Fluid No. 1)
- Acid Number 3 (TCLP Fluid No. 2)
- Deionized Water (Method SW-924), also known as the Monofill Waste Extraction Procedure (MWEP)
- CO_2 saturated deionized water
- Simulated acid rain (SAR)

These extraction procedures have been used separately by a variety of researchers on MWC ashes but never have all six procedures been used on the same MWC ashes. This was intended to compare the analytical results of the extracts from all six procedures with each other and with leachate collected from the ash disposal sites used by the MWC facilities.

All sampling, laboratory preparation, and laboratory analysis followed stringent EPA quality assurance/quality control (QA/QC) procedures. The detection limits of the analytical methods used were well below present levels of human, environmental, or regulatory concerns.

The EPA publication "Interim Procedures for Estimating Risk Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-Dioxins and Dibenzofurans (CDDs and CDFs)" was used to evaluate the dioxin data. These procedures use Toxicity Equivalency Factors (TEFs) to express the concentrations of the different isomers and homologs as an equivalent amount of 2,3,7,8-Tetrachloro Dibenzo-p-Dioxin (2,3,7,8-TCDD). The Toxicity Equivalents, as calculated by using the TEFs, are then totaled and compared to the Centers for Disease Control (CDC) recommended upper level of 2,3,7,8-TCDD Toxicity Equivalency of 1 part per billion in residential soil.

The major features of the five MWC facilities and ash sites sampled are provided in Table 1, and Table 2 respectively. Pertinent information on the operating conditions of the MWC facilities, as well as information about the air pollution control equipment used is also provided in Table 1.

CORRE/EPA STUDY RESULTS AND CONCLUSIONS

Major findings of and conclusions drawn from the results obtained from the sampled ash, natural leachates, and laboratory extracts are summarized in the paragraphs which follow.

Ash Analysis Results

Of the five ash samples (one from each facility) analyzed for the Appendix IX semivolatile compounds, four samples contained bis(2-ethylhexyl)phthalate, three contained di-n-butyl phthalate, and one contained di-n-octyl phthalate. Two PAHs, phenanthrene and fluoranthene, were detected in only one of the five ash samples. These semi-volatile compounds were detected in the parts per billion (ppb) range.

The results for the ash samples analyzed for PCDDs/PCDFs are presented in Table 3. This table also includes the calculated Toxicity Equivalents (TE) for each homolog of PCDD/PCDF. The data indicate that PCDDs/PCDFs were found at extremely low levels in each of the ash samples. The Total TE for each ash sample was well below the Centers for Disease Control (CDC) recommended Toxicity Equivalency limit of 1 part per billion 2,3,7,8-TCDD in residential soil.

All 25 of the ash samples (five daily composites from each facility) were analyzed for the metals listed on the primary and secondary drinking water standards as well as for the oxides of five major ash components. Although, the results from these analyses indicate that the ash is heterogeneous, this heterogenicity appears to have been reduced by the care taken when compositing the ash samples during this study. Data from this study showed less variability than comparable data in the literature.

Metals showing the widest range of concentrations among samples collected at each facility included barium (ZB); cadmium (ZB); chromium (ZD, ZE); copper (ZA, ZB, ZC); lead (ZD); manganese (ZA, ZC); mercury (ZE); zinc (ZB, ZD, ZE); and silicon dioxide (ZA).

Metals showing the widest variation of concentrations between the facilities included barium (results for Facility ZC are lower than the results for the other facilities); iron (results for each facility vary from all of the other facilities); lead (results for Facility ZD are higher than the results for the other facilities); mercury (results for

Facilities ZC and ZD are lower than the results for the other facilities); sodium (results for Facilities ZD and ZE are lower than the results for the other facilities); calcium oxide (the results for Facilities ZA and ZB are higher than the results for the other facilities); and silicon dioxide (the results for Facility ZC are higher than the results for the other facilities).

Some additional findings of the ash sampling and analyses are as follows:

- o The ashes are alkaline with the pH ranging from 10.36 to 11.85.
- o The ashes are rich in chlorides and sulfates. The total soluble solids in the ashes varied from 6,440 to 65,800 ppm.
- o The ashes contained unburnt total organic carbon (TOC) ranging from 4,060 ppm (0.4 percent) to 53,200 ppm (5.32 percent).

Leachate Analysis Results

Only four Appendix IX semivolatile compounds were found in the leachates. Benzoic acid was found in two leachate samples collected at one site. Phenol, 3-methylphenol, and 4-methylphenol were found in the leachate samples from another site. All of these compounds were detected at very low levels (2-73 ppb).

PCDDs/PCDFs of the higher chlorinated homologs were found in the leachate from one site only. This indicates that PCDDs/PCDFs do not readily leach out of the ash. The low levels found in the leachates of the one site probably originated from the solids found within the leachate samples because these samples were not filtered nor centrifuged prior to analysis.

The metal content in the leachate samples did not exceed the EP Toxicity Maximum Allowable Limits established for the eight metals in Section 261.24 of 40 CFR 261. Indeed, the data indicate that although the leachates are not used as a source of potable water, they are close to being acceptable as such as far as the metals are concerned.

The major constituents in the leachate samples was salt. The main salt constituents in these leachates were chloride, sulfate, and sodium. Additional observations on the leachate analyses were:

- Sulfate values ranged from 14.4 mg/L to 5,080 mg/L, while Total Dissolved Solids (TDS) ranged from 924 mg/L to 41,000 mg/L.
- The field pH values ranged from 5.2 to 7.4.
- Ammonia (4.18-77.4 mg/L) and nitrate (0.01-0.45 mg/L) were present in almost all leachate samples.
- Total Organic Carbon values ranged from 10.6 to 420 ppm.

Ash Extracts Analysis Results

The data obtained during the metals analyses of the ash extracts indicate, in general, that the extracts from the EP Toxicity, the TCLP 1, and the TCLP 2 extraction procedures have higher metals content than the extracts from the deionized water (SW-924), the saturated CO_2 solution, and the Simulated Acid Rain (SAR) extraction procedures.

The EP Toxicity Maximum Allowable Limits for lead and cadmium were frequently exceeded by the extracts from the EP Toxicity, TCLP 1, and TCLP 2 extraction procedures. One of the extracts from the EP Toxicity extraction procedure also exceeded the EP Toxicity Maximum Allowable Limit for mercury.

None of the extracts from the deionized water (SW-924), the saturated CO_2 solution, and the Simulated Acid Rain (SAR) extraction procedures exceeded the EP Toxicity Maximum Allowable Limits. In addition, all of the extracts from these three extraction procedures also met the Primary and Secondary Drinking Water Standards for metals.

Table 4 compares the range of concentrations of the metals analyses of the ash extracts with the range of concentrations for leachate as reported in the literature and the range of concentrations for the leachates as determined in this study. For the facilities sampled during this study, the data in Table 4 indicate that the extracts from the deionized water (SW-924), the saturated CO_2 solution, and the SAR extraction procedures simulated the concentrations for lead and cadmium in the field leachates better than the extracts from the other three extraction procedures.

Additional observations are:

- Of the five composite samples of the deionized water (SW-924) extracts analyzed for the Appendix IX semivolatile compounds (one from each facility), only one sample contained low levels of benzoic acid (0.130 ppm).

- None of the extracts contained PCDDs/PCDFs. These data confirm the findings of the actual field leachate samples that PCDDs/PCDFs are not leached from the ash.

DESCRIPTION OF THE LONG TERM STUDY

The Woodburn Ash-Monofill, located in Marion County, Oregon, was selected by EPA as suitable to provide the needed long-term characterization data of leachates generated from the monofill, of the ashes aging in the monofill and of the surrounding soils potentially affected by airborne dust from the ash-monofill.

As part of the EPA commitment to study these long term effects, EPA sponsored the first year study (1988) during which two sampling trips were conducted and the results were summarized in the report entitled: Municipal Waste Combustion Ash and Leachate Characterization, Monofill-Baseline Year, which was published in August of 1989. EPA also sponsored the second year study, which took place in 1989 and which resulted in a report entitled: Municipal Waste Combustion Ash and Leachate, Monofill - Second Year Study and was published in January of 1990.

The soil, ash, and leachate samples collected during the past two years were subjected to the same chemical analytical testing as outlined previously for the CORRE/EPA study. All sampling and analytical procedures were subjected to the same EPA required QA/QC protocols as the CORRE/EPA study.

LONG-TERM STUDY RESULTS AND CONCLUSIONS

Major findings of and conclusion drawn from the results obtained from the samples collected during the past two years (three trips) from the Woodburn Ash-Monofill are summarized in the paragraphs which follow.

Ash Analysis Results

As expected, the ash samples contained metals and low levels of phenolic and phthalate compounds.

The ash samples also contained low levels of dioxins. However, the 2,3,7,8-TCDD toxicity equivalency of these samples, calculated following EPA prescribed procedures, did not reach the center for Disease Control (CDC) recommended limit for residential soils of 1 ppb.

Leachate Analysis Results

The major constituent in the leachate samples, collected from this site, is salt. This agrees with data available from other sites. The total dissolved solids (TDS) levels ranged from approximately one-third to somewhat higher than the levels found in sea water. The main salt constituents in these leachates were chloride, sulfate, and sodium.

The leachate samples contained elevated concentrations of total organic carbon (TOC) and ammonia-nitrogen. The presence of these constituents indicates that uncombusted organic matter remains in the ash and anaerobic biodegradation may be occurring.

As expected, the leachate samples also contained metals. However, all metal concentrations in all leachate samples were below the EP-toxicity maximum allowable limits.

The leachate samples were essentially free of dioxins and the leachates contained essentially no semivolatile compounds on the Appendix IX list.

Soil Analysis Results

To date, the soils in the vicinity of the Woodburn Ash-Monofill have not been affected by the airblown ash dust from the monofill. The soil samples were essentially free of dioxins and semivolatile compounds on the Appendix IX list.

The soil samples did not contain metal levels beyond the levels found in the site background sample. Those soil samples collected from locations close to roads, which are subject to vehicular emission effects, contained somewhat higher lead levels than the site background sample and the rest of the soil samples.

The soil samples collected from locations close to roads also contained somewhat higher levels of dioxins. The levels of 2,3,7,8-TCDD toxicity equivalency in all soil samples were below one part per billion, which is the level recommended by the CDC for residential soils.

FUTURE LONG TERM STUDY OBJECTIVES

Studies to be conducted in years to come at this site will provide data on time trends for the ash, the leachates, and the soils. Some data gaps may be closed, and answers to important questions regarding the heterogenicity of the ashes, the varying levels of TDS in the leachates, and the verification of the existence of anaerobic conditions in ash monofills may be obtained.

ENVIRONMENTAL AUDITING OF RESOURCE RECOVERY FACILITY

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13 - 16, 1990

INTRODUCTION:

Modern society today is the product of constantly advancing technology. Technological progress is responsible for our overall living standard and also for pollution and waste. The production of waste material is an inherent part of natural processes, but nature, in its wisdom, reuses whatever it produces, from fallen leaves to manures and carcases, all things which live, and all the substances which their body exceret, are subject to decay, a process which transforms organic waste in to nourishment for new life. Mankind has disrupted this natural cycle through the sheer volume of its waste production and introduction of new substances which do not breakdown and may poison the environment.

Concerns for the environment are not limited to deterimental effects of pollution, but also include recovery and utilization of resources now reconized as finite. It was determined that energy contents of all the municipal waste generated in U.S. is equivalent to 50 million tons of coal. Number of resource recovery facilities continues to increases rapidly in response to growing shortage of landfill space. Resource recovery facility (Waste to Energy) reduces the amount of material to be disposed of by 75 to 80% and hense increases the landfill lifespan; and steam generated by recovering heat of combution can be utilized to generate electricity.

The resource recovery facility must not only meet the solid waste needs of local community, but must also comply with applicable environmental regulations, be acceptable to public and be compatible with the environment. Failure to recognize these four aspects of facility development can result into a filed project. Facility owner or operator has a responsibility to inspect such facility at regular interval to make sure that the facility continue to meet all air, water and solid waste regulations. In order to perform an effective compliance inspection of resource recovery facility the inspector must be famililar with all aspects of facility operation and the regulations which applys to it. This protocol is designed to provide sufficient information to carry out compliance inspection of Resource Recovery Facility.

What is Resource Recovery Facility?

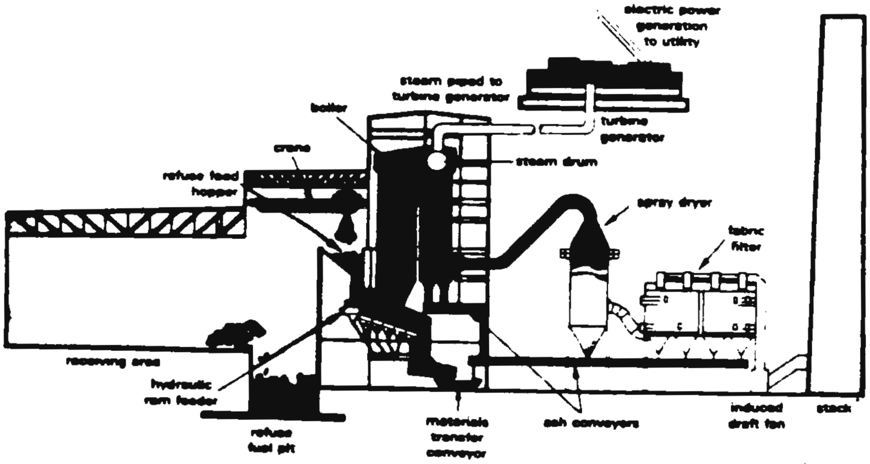
The primary objective of the resource recovery facility is to capture the energy released by combustion of solid waste and to reduce the volume of solid waste to be landfilled. The figure shows schematic of resource recovery facility:

Trucks enter in the receiving area and unload directly in to refuse pit. The refuse pit is sized to hold 4 to 7 days worth of trash. Crane operator working from the overhead cabin control the grapple to move waste from refuse pit to the feeding hopper. From the feeding hopper waste is pushed by a ram feeder in to combustion chamber. Here, temperature greater than 2000 F turn garbage in to ash. Primary and secondary combustion air from the pit is blown in, below and above the grates respectively to fuel the combution process in a furnance and to maintain negative pressure over the pit to prevent dust escape and to reduce the odor. Excess combustion of all volatiles while still in the combution chamber. Heat of combustion will be recovered in a boiler thereby producing superheated steam, which will be used to drive a turbine to generate electricity. The flue gases from the boiler will preheat the boiler feed water and then passes through the spray/wetscrubber and baghouse to control acid gases and to separate fly ash and then discharged to atmosphere through a stack. Ash remaining in a combustion chamber and boiler will be removed by a ram discharger and then conveyed to a storage area. After determining characteristics of ash it will be dumped in a appropriate landfill.

ENVIRONMENTAL AUDITING:

All facility should establish self auditing procedure to assure that compliance with all applicable environmental laws and regulations is maintained. Advanced preparation should remove nearly all of the potential surprises, and assure that your facility is not exposed to serious legal risk because of non-compliance with environmental rules and regulations.

An environmental auditing of an operating resource recovery facility should be a thorough examination of a facility's operating records and environmental practices, gather informations about its compliance with federal state and local regulations and to identify non-compliance with environmental regulations for follow-up corrective action. Following comprehensive checklist may vary for each facility depending upon specific permit conditions for respective facility.



ENVIRONMENTAL COMPLIANCE INSPECTION REPORT

A. General Information:

****

Name of the facililty: ____________________

Facility I.D. number : ____________________

Facility Address : ____________________

Facility Manager & : ____________________
Phone Number

Date of Inspection : ____________

Inspected By : ________________

****

B. Incoming and outgoing wastes:

Conditions

Conditions	Y	N
1. Are only permitted waste being accepted at this facility? (Permitted waste ID # 10, 13, 23, 25)	___	___
2. Are all wastes being accepted according to the approved delivery schedule	___	___
3. Are all traffice control signs and/or measures implemented to provide orderly vehicle movement?	___	___
4. Are only registered vehicles being permitted to off load their wastes at this facility	___	___
5. Are all incoming vehicles equipped with functional exhaust silencer system?	___	___
6. Is all waste being delivered to this facility at a rate that will not exceed the facility's capacity to store and/or process the wastes? (Processing Rate 12 Tone/hr, Storage 800 Tone)	___	___
7. Is there a continuous visual monitoring of all incoming wastes for unauthorized waste material?	___	___

	Y	N
8. Are all unauthorized wastes pulled out from the waste stream, and segragate and stored in a secured manner?	___	___
9. Are spot checks being performed by facility personnel in accordance with the approved operation and maintenance manual?	___	___
10. Have all noise control conditions been implemented?	___	___
a. All ash haulage vehicles and ferrous metal transfer trailer, parking, connecting and disconnecting are to be conducted within the ash storage building.		
b. All ash and ferrous metal revocery being performed within the ash loading building with doors closed during loading operation.		
c. All vehicles should equipped with functional exhaust silencer system.		
11. Is the operation of the facility in accordance with following conditions?	___	___

Y N

a. Odor associated with solid waste should not be dectected off site.

b. The tipping floor entrance and exit doors should remain closed at all times other than normal operation hours.

c. Air drawn off from the refuse bunker and tipping area should be used in combustion process.

12. Are non-processible waste materials, process residues and recovered ferrous metals handled and stored according to the following: ___ ___

a. Non-processible waste, process residues and recovered ferrous metals are to be stored within the confines of an enclosed facility at all times.

b. All ash residue and recovered ferrous metals from the ash are to be stored within the ash load-out building and ash storage building.

Y N

13. Are all trailer/roll offs containers being loaded solely within the ash loadout building in a controlled manner to prevent dusting, leakage, and spillage? ___ ___

14. Are all trailer/roll offs containers for ash labeled properly for tracking outside of the ash load-out building? ___ ___

C. Operational and Maintenance Requirements:

1. Is the operation of the facility meeting the approved processing rates? (12 tons/hr or 108 million BTU/hr) ___ ___

2. Are all systems and related equipments kept in proper operating order at all times? ___ ___

3. Are all Emission conditions of Air pollution control permit being maintained? ___ ___

a. So2 (Sulfur Dioxide)

The 3 hour average concentration of So2 in the stack gas from a unit must be less than 20% of the average concentration

Y N

of SO_2 at the inlet to the acid gas control equipment for that unit. However the concentration of SO_2 can never exceed 100 ppmv on a dry basis corrected to 7% oxygen.

b. HCL (Hydrogen Chloride)

For any one hour period the average conce. of HCL in the stack gas of each unit shall not exceed 50 ppmv on a dry basis corrected to 7% oxygen or 10% of the HCL concentration at the inlet to the acid gas control equipment.

c. CO (Carbon Monoxide)

For any one hour period the average concen. of CO in the stack gas of each unit shall not exceed 400 ppmv on a dry basis corrected to 7% oxygen. However, the 4 day moving average concen. of CO in the stack gas should not exceed 100 ppmv on a dry basis corrected to 7% oxygen.

d. NO_2 (Nitrogen Dioxide)

For any 3 hour period the average concen. of NO_2 in the stack gas of each unit shall not exceed 350 ppmv on a dry basis corrected to 7% oxygen.

Y N

e. Oxygen:

The concen. of oxygen in the flue gas at the boiler exit of each unit must be no less than 6% by volume measured on a dry basis.

f. Non Methane Hydrocarbon's as Methane

For any 3 hour period the average concen. of non-methane hydrocarbon in the stack gas shall not exceed 43 ppmv on a dry basis corrected to 7% oxygen.

g. Opacity:

The opacity of the emission from each unit must not exceed 20%. Note: an exception to the 20% limit is if opacity did not exceed 20% for more then 3 minutes, during a period of 30 consecutive minutes. However, it never exceeded 40%.

4. Boiler operating parameters are in accordance with following Air Pollution control permit conditions? ___ ___

Y N

a. Within one hour after the waste has been introduced in the boiler the temp. one second downstream of the secondary air injection area may not be less than 1500 degree Farenheit.

b. No waste being introduced into a boiler unless the temp. 0.3 seconds downstream of the secondary air injection area is greater than 1500 degrees.

c. The temp. one second downstream of the secondary air injection area may not be less than 1600 degree at least 90% of the time waste is being incinerated.

d. Permanent temp. sensors located in the combustion chamber and at the inlet of the boiler convection section will be correlated to read the required temp. 0.3 and 1 second downstream, of the secondary air injection area.

e. Auxiliary burners must be able to operate automatically if the temp. one second downstream of the secondary air injection area drops below 1550 degree while waste is being incinerated.

5. All emission control equipments are in line while waste is being incinerated? ___ ___

Y N

a. At no time baghouse be bypassed while waste is being incinerated unless the temp. of the flue gas entering the baghouse exceeds 475 degrees or falls below 130 degrees in which case the waste charging to the affected unit will cease.

b. If the temp. of 1500 degree is not maintained one second downstream of the secondary air injection area, waste should not be charged to the affected unit.

c. If 6% oxygen by volume can not be maintained at the boiler exit, waste should not be charged to the affected unit.

d. During periods the scrubber is down because of a malfunction, and if for any 3 hour period the average concen. of So2 in the stack gas for the unit exceeds 250 ppmv on a dry basis corrected to 7% oxygen, cessation of waste to the affected unit is required.

6. Are provisions being implemented according to the approved NJPDES - DWW/DSW section of the permit? ___ ___

a. Whenever any activities result in a discharge of toxic pollutants, into the surface or ground waters, the incidents are to be reported when occure or believed to occur.

Y N

b. All effluent limitations and monitoring requirements should be implemented.

c. All general requirements of DGW and DSW should be implemented. (Physical inspection on weekly basis)

7. Are provisions being implemented according to the water allocation diversion? ___ ___

8. Are following conditions of the approved O & M manual being implemented? ___ ___

a. Inspections of all major aspects of the facility in which adverse environmental or health consequences are possible, should be performed on daily basis.

b. Preventive maintenance are to be performed according to potential equipment deterioration or malfunction.

c. In the case of any emergency all the facility personnel should follow the contigency plan contained in the O & M manual.

Y N

9. Are routine housekeeping and maintenance procedures being implemented within the facility to prevent accumulation of dust and debris? ___ ___

a. Tipping floor is to be cleaned at least once a day.

b. All facility floors, traps, sumps or catchment basins maintained free of obstruction to facilitate effluent drainage.

c. Facility grounds are to be maintained in a manner free of litter and debris.

d. All incoming wastes, facility processed wastes and effluents stored in a bunker, basin, pitss, sumps or other containment vessels are to be kept at a level that prevent spillage or overflow.

10. Is all facility exterior facing maintained in a manner keeping with the original design? ___ ___

11. Is a qualified applicator of pesticides directing an effective vermint control program? ___ ___

Y N

12. Is all fly ash that has been processed through the fly ash conditioning units being properly wetted so it remains in the wetted state throughout the rest of the residue processing and or transportation of the ash? ___ ___

13. Is all water discharge to the river at a temp. not more than 20 degree greater when it was withrawn from the river? (If facility's process water is supplied by a river) ___ ___

14. Are the approved sampling and analysis requirements being implemented? ___ ___

    a. All samples are to bollected from the approved location.

    b. All daily samples are to be composited into a monthly sample and to be analyzed using EPA Toxicity Test.

15. Are all operational records being recorded on a daily and monthly basis and have the required monthly summaries and/or tallies been submitted to the proper agencies ___ ___

D. **Safety and Emergency Procedure:**

	Y	N
1. Are all security equipment and systems in proper operating conditions?	___	___
2. If there is a turbine/generator trip condition was waste processing operations reduced accordingly to reflect the reduction in the boiler thermal load?	___	___
3. Are fire detection and protection systems kept operable at all times?	___	___
4. Are all occupational safety and health (OSHA) standards being implemented in the operation of the facility?	___	___
5. Are only facility personnel and authorized visitors allowed on site?	___	___

E. Files and Records:

1. Are following documents and records are maintained all the times at the facility? __ __

   a. Operating Permits and supporting documents

   b. Process Flowsheets

   c. Emergency Action Plan and Notification procedure

   d. Operating Log

   e. Maintenance Records

   f. Periodic reports filed with regulatory agencies

   g. Permit exceedences reports

   h. Storage and disposal records

   i. Emissions inventories

   j. Sampling records and description of analytical method

Y = In Compliance

N = Not in Compliance

F. Inspection Comments:

____

____

____

____

____

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Inspector's Signature	Facility Representative's Signature

THE FINANCIAL IMPACT OF THE EMISSIONS GUIDELINES ON AKRON, OHIO'S RECYCLE ENERGY SYSTEM

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

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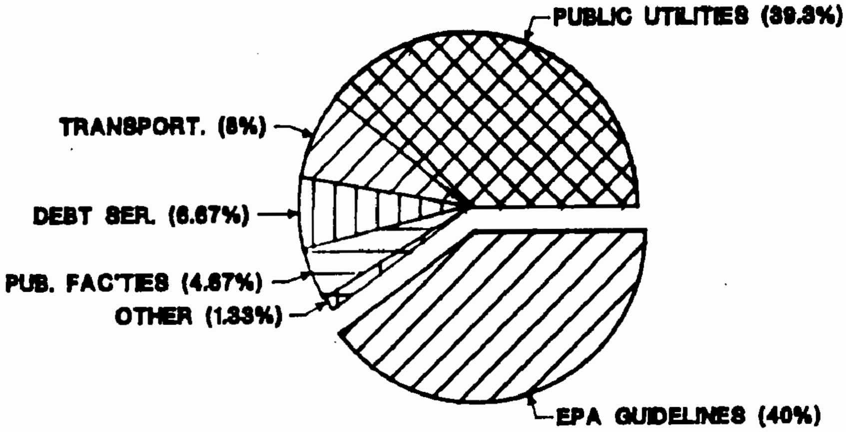
LOCAL CAPITAL COMPARISON



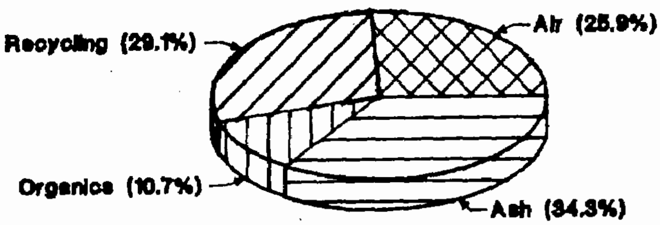
The Recycle Energy System is located in downtown Akron, Ohio. The facility serves the residents of the City of Akron as well as several surrounding communities. The R.E.S. is owned by the City of Akron and is currently, and has been for the last three years, operated under contract by wTe Corporation of Ohio.

The facility, completed in 1979 at a cost of 65 Million Dollars, currently receives and combusts 1,000 tons per day of residential and commercial solid waste. It has taken 10 years for the facility to achieve its design capacities. After struggling with low production rates caused primarily by the fuel delivery system, the City was forced to invest 2.5 Million Dollars to replace the pneumatic conveyor system with a more conventional belt conveyor system. Safety problems also developed and numerous fires and explosions caused damage which required additional capital investment and expensive repairs. In addition, operating revenues did not cover operating costs requiring heavy City subsidies and the diversion of limited funds from other much needed municipal improvements.

Only within the last three years has the facility begun to operate safely and continuously providing steam, hot and chilled water, as well as tipping services, on a continuous basis to its customers. Just as the facility has begun to provide the services for which it was originally designed, the City finds itself facing another new challenge as has been posed by the recent Source Emissions Guidelines and the pending Draft Ash Management Guidance (U.S. EPA March 1988).

For the purpose of this paper, we have included a brief discussion on incinerator ash management. The U.S. EPA Draft Ash Management Guidance, if enacted, will also have a significant cost impact on municipal solid waste combustors. We believe it is important for communities to consider the aggregate effect of recent EPA activities.

TOTAL COST
$60,914,139



The City of Akron, along with many other mid-western cities, struggles with a declining industry base and increasing costs. Akron locally funds approximately 90 Million Dollars in capital improvement projects per year.

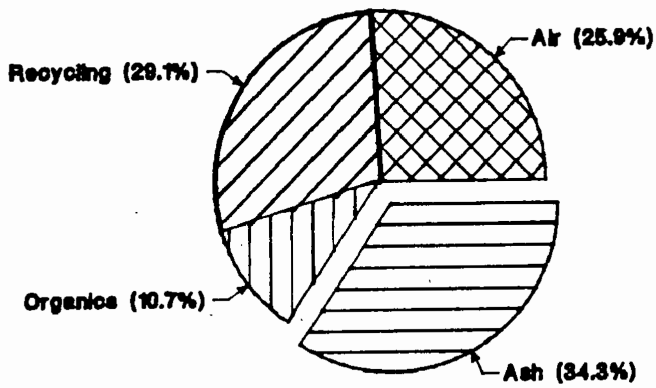
With the new Source Emissions Guidelines, initial estimates are that Akron will be required to fund a 40 Million Dollar capital investment. Our initial estimate for incinerator ash disposal is 20 Million Dollars which suggests that Akron will face a total capital investment of 60 Million Dollars. This would represent approximately 40% of a total 150 Million Dollar capital program. This new potential financial burden is selective in that it only affects those communities who have been progressive and forward thinking and have already funded municipal waste combustion facilities to address growing solid waste problems.

Most citizens support a clean environment. We all understand the importance of preserving the environment in which we live for ourselves and future generations. The challenge is how to accomplish these goals in a logical and equitable manner and provide the best use of funds for long-term solutions.

To the layman, the Emissions Guidelines only requires new equipment which is intended to better clean smoke from the combustion of municipal solid waste, but this is only one part of the Guidelines. There is also a section which deals with recycling. It is the combination of these elements that makes the Guidelines costly; not only in terms of capital expense, but also in annual operating expenses. When Ash Management is included, the total cost is devastating.

For the Akron Recycle Energy System, of the 60 Million Dollar total capital investment estimated for the new Emissions Guidelines and Draft Ash Management Guidance, the largest single cost would be new ash management requirements, followed by the

INCINERATOR ASH
$20,884,148



requirement to remove recyclables.

It is unclear to what extent the recycling requirement will affect clean air, but without discussion as to whether or not recycling actually impacts clean air, even the remaining components carry a heavy financial burden for existing facilities in consideration of the relatively small number of such facilities and their significant importance to solid waste management.

Before we discuss the impact of the EPA's new Source Emissions Guidelines, we must pause to consider current thinking regarding incinerator ash.

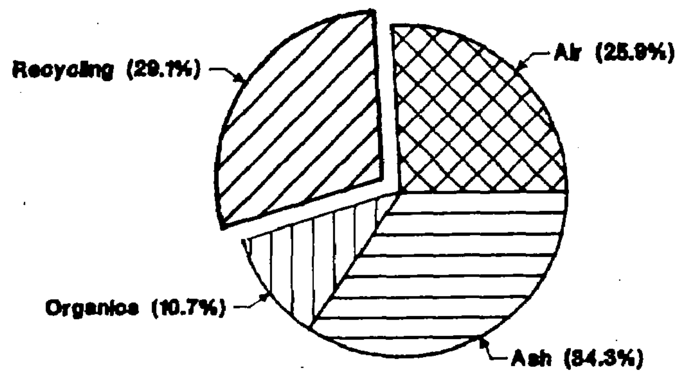
One of the most hotly contested issues of recent years has been the method of disposal of incinerator ash. The two extreme view points are:

1) incinerator ash is a hazardous waste and should be disposed of in hazardous waste landfills, and

2) incinerator ash is not a waste at all, but can be reused as road bases and other types of soil stabilizers.

The question is whether or not ash will leach heavy metals under landfill conditions. Under current regulations, the test which is used to determine the leachability of heavy metals from incinerator ash is the **extraction procedure toxicity test**. Several studies suggest that this particular test unfairly represents the actual leachability of heavy metals from incinerator ash. A recent study, prepared jointly by the EPA and CORRE (Coalition On Resource Recovery And The Environment), suggests that in actual landfill conditions, leachate from incinerator ash is very close to primary drinking water standards. If these findings are true, rules requiring special treatment and handling are unnecessary. Despite the fact that a growing amount of data indicates that incinerator ash should be considered a useful material, the EPA continues to suggest that ash be landfilled in a monofill constructed to

RECYCLING
$17,727,854



current landfill standards. At present, very few such landfills exist.

It will be difficult for communities which had the foresight to build incinerators to comply with the more stringent Source Emissions Guidelines, but at the same time to require these incinerators to either locate or construct a specialized landfill for the disposal of ash in light of current knowledge seems excessive.

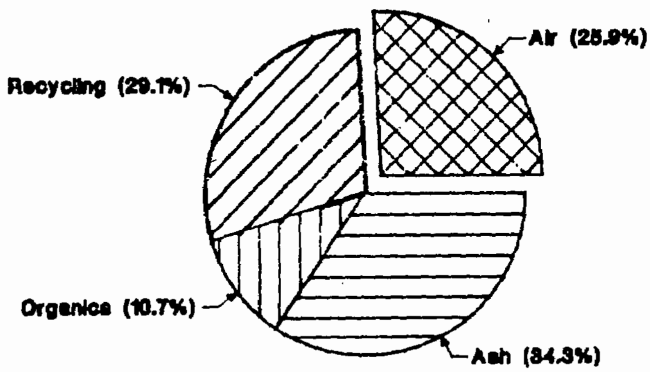
For a City the size of Akron, estimates indicate that the capital investment required for the construction of a incinerator ash landfill alone will represent 34.4%, or approximately 21 Million Dollars of the total 60 Million Dollar investment.

Ash Management and recycling together represent over 60% of the total capital cost. The requirement to recycle 25% of the input to the Akron facility represents approximately 18 Million Dollars of the 60 Million Dollar total capital investment.

Recycling is a very popular issue and it appears that the requirement of recycling is being written into all new legislation. In Ohio, Akron, along with most other communities, is already struggling with the development of effective City-wide recycling programs. Ohio has been required to do this as a result of State House Bill 592 which was signed into law in June of 1988. The State of Ohio has elected to include recycling as one component of a comprehensive solid waste management plan.

The new Emissions Guidelines assumes that the removal of recyclables will remove pollutants from the air. Although in some cases this may be true, there is little comprehensive and conclusive data to support this approach. Recycling is a solid waste management issue and communities all across the United States will eventually recycle a significant percentage of their solid waste stream. Front-end processing at municipal waste combustors is only one option and communities should be free

PARTICULATE & ACID GAS
$15,773,737



to elect or develop those options which work best and provide the best cost benefit.

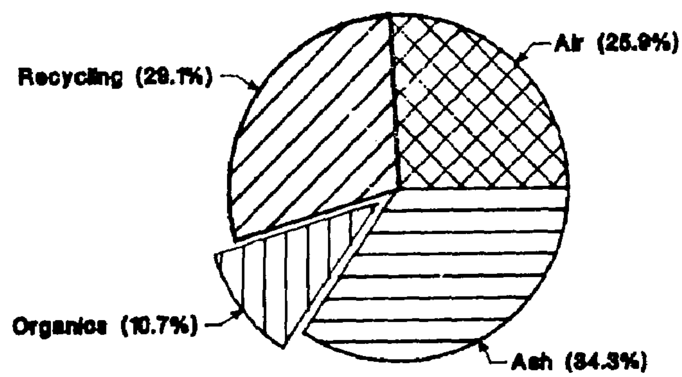
In Akron, the Recycle Energy System is a waste-to-energy facility, thus those recyclables which are combusted and provide an energy contribution are being recycled. During the next few years, as markets develop for recycled materials, combustion may be the most economical alternative.

Another major component of emissions regulations requiring extensive capital investment is particulate and acid gas control. Particulate emissions are being regulated to approximately one half of the allowance that existed at the time of construction of the Akron Recycle Energy System. Acid gases, such as hydrochloric acid and sulfur dioxide, were not considered and thus not regulated at that time. The result is that Akron will be required to replace all existing air emissions control equipment. It is estimated that this requirement will cost approximately 15.8 Million Dollars and will require the installation of lime injection equipment and new fabric filters to replace the existing precipitators. This represents 26% of the total investment.

Because Akron has its own landfill, the City will also experience a significant side effect of the proposed Best Available Control Technology. The current strategy to control acid gases proposes the injection of lime into the gas stream, thus transferring an air pollution problem into a solid waste problem. For every 22 pounds of sulfur dioxide that is removed from the flue gas stream, the facility will generate an additional 2,000 pounds of solid waste which must be landfilled. Aside from the economic impact of the installation of new equipment, a community such as Akron will also suffer serious landfill life depletion whether speaking in terms of existing landfills or new landfills specifically designed to accept incinerator ash.

Organic toxin control represents

ORGANICS
$6,528,400



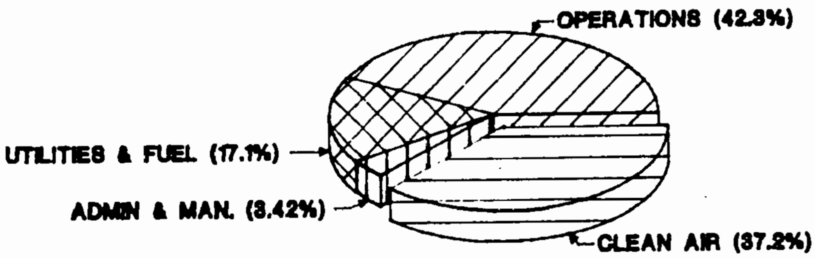
another element of the capital investment at approximately 6.5 Million Dollars. The new Guidelines propose that dioxins and furans can be controlled in the combustion process. The assumption is that improved mixing of the RDF with combustion air will create higher combustion temperatures and destroy dioxins and furans within the furnace. These are newly discovered elements in the exhaust gas stream, and existing facilities, in many cases, were not designed or constructed with this type of control in mind. For the City of Akron, this involves the entire fuel feed system as well as the overfire air system. Major changes, including the replacement of fans and fuel feeders, will be required in order to comply.

The level which is being proposed for a large facility is 250 nanograms per standard cubic meter. In consideration of the fact that these are newly discovered elements, control technologies have not been fully proven, and the EPA has not fully developed a cost benefit for such a stringent level of control, this requirement, at this time, may not represent the best use for scarce resources. To retrofit a 10-year old facility such as the Akron Recycle Energy System to a level of technology commonly known as "Best Available Control Technology" will require significant investment in new controls, fuel delivery equipment, fabric filters, lime handling equipment and front-end separation equipment.

After the initial capital investment, the financial burden does not end. The estimated annual operating cost for all of the new equipment, as well as a new landfill, is approximately 8 Million Dollars a year. This will represent an increase of approximately 60% over current operating costs.

Akron, not unlike other communities across the United States that have invested in incinerators and waste-to-energy facilities, has found it necessary to subsidize the facility since its start-up in 1979. This substantial increase in operating cost could lead to

COST IMPACT



additional local subsidies throughout the remaining life of the facility.

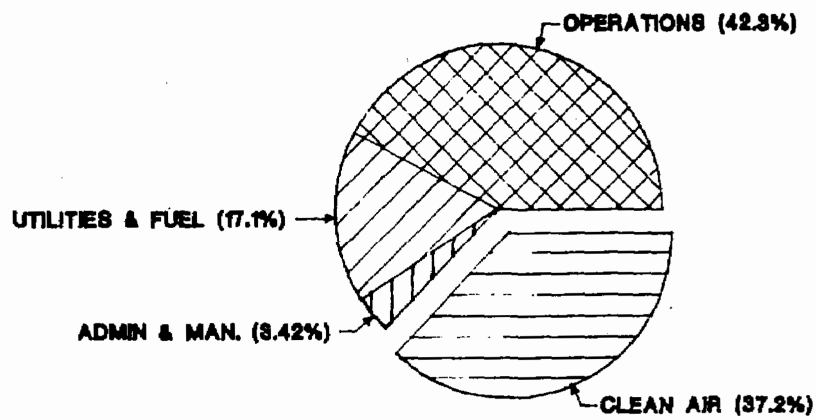
The current solid waste management crisis has only come to light as a result of the dwindling number of landfills. Aside from the accelerated rate of landfill closures, more stringent rules for siting and permitting has rendered this process time consuming and expensive resulting in few new landfills being opened. The new Emissions Guidelines place a heavy burden on those few communities which have already constructed incinerators and could result in a similar scenario for municipal solid waste combustors. With landfills and incinerators being legislated out of existence, the entire effort towards integrated solid waste management could be defeated at great expense to the economic welfare of the nation.

Just how significant is a 8 Million Dollar increase in the operating cost of a facility such as the Akron Recycle Energy System. The current annual operating budget for the facility is approximately 14 Million Dollars. If the estimated 8 Million Dollars required to comply with the new Emissions Guidelines and possible new Ash Management Guidance is included, the new operating budget will be approximately 22 Million Dollars per year. When compared with the other major components of the cost of operation, the additional cost represents approximately 37% of the total cost, second only to the total cost of all labor and material consumed at the facility on an annual basis.

With a 14 Million Dollar annual operating cost, the facility is required to set its tipping fee at $42 per ton in order to approach break even. This is substantially above tipping fees charged by surrounding landfills, and thus it is difficult to acquire the amounts of waste necessary to meet steam demand.

The Akron plant operates as a utility providing steam "on demand" to critical businesses and hospitals in the

TIPPING FEE DISTRIBUTION
@ $72.00 PER TON



downtown Akron area and is forced to burn expensive natural gas when MSW is not available which defeats the purpose of the facility and unnecessarily consumes precious, non-renewal natural resources. Of the $42/ton tipping fee, 67% of the fee dollar goes to labor and materials required to operate the facility.

On an annual basis, the Akron Recycle Energy System requires approximately 250,000 tons of municipal solid waste in order to meet its steam requirement. The City of Akron provides only 50% of this requirement. Once the operating cost has been increased by 8 Million Dollars, a tipping fee of $72 per ton will be required in order to break even.

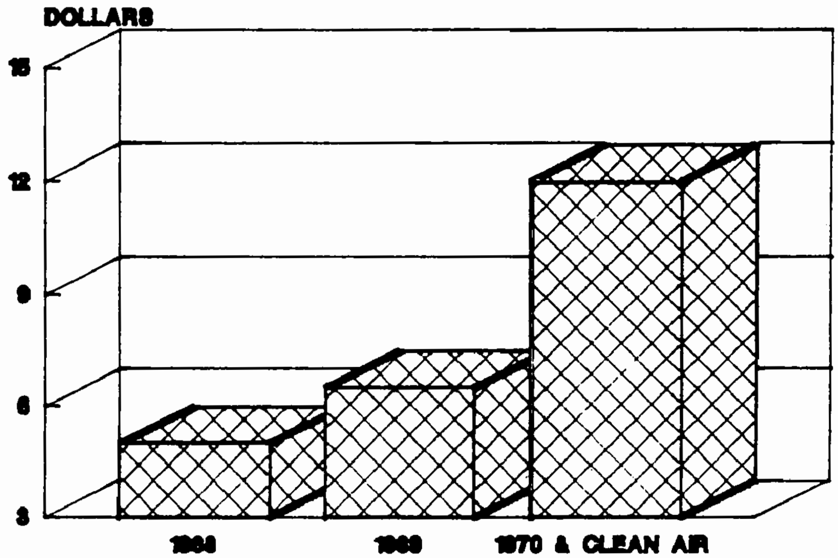
At $72 per ton, waste haulers who are not required to use the facility will have a strong incentive to take their waste to local landfills, thus more quickly using up an already rapidly dwindling waste management resource and leaving Akron with a shortage of the required fuel to meet its steam demand.

The new requirements represent approximately 37% of the $72 tipping fee provided that the Guidelines are enacted as proposed.

Finally, we must consider the impact upon the citizens of the City of Akron. The Akron Recycle Energy System processes 1,000 tons per day of municipal solid waste. Approximately 500 tons is collected from the City of Akron's residents. If we distribute a $72 per ton disposal cost to those households in Akron which are required to use the facility, it will increase their curb service fee by approximately 70%.

This represents an increase of $5 per household per month, or $60 per year. This agrees with the EPA's projections of an average increase of $58 per year per household. This is a local increase which will affect communities currently incinerating their solid waste much more than others not currently incinerating.

CURB SERVICE FEE
DOLLARS PER MONTH



The purpose of the Emissions Guidelines is to reduce airborne pollutants which is to the benefit of all of the citizens of the United States, but it appears that during the initial years the heaviest burden of cost will fall upon those communities which already operate municipal waste combustors.

Ohio's House Bill 592 required the establishment of solid waste management districts and charged those districts with the responsibility of establishing a ten-year waste management plan. The key component missing from the Emissions Guidelines is an analysis of its impact upon comprehensive solid waste management.

FLEXIBLE AND ENFORCEABLE
RESOURCE RECOVERY
PERFORMANCE GUARANTEES FOR MASS BURN PROJECTS

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First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

ABSTRACT

Resource Recovery Service Agreements typically contain performance guarantees that require the vendor/operator to process a guaranteed quantity of waste over a given period of time and to produce a guaranteed quantity of energy from that waste, based on a specified energy content. The community/owner, on the other hand, typically guarantees to deliver, within set time frames, a minimum quantity of municipal solid waste. The vendor's processing and energy guarantees are conditioned upon the community meeting its delivery commitment.

In order to establish both parties' guarantees, certain assumptions normally have to be made about the weekly, monthly and yearly amounts of waste available to be delivered and its average composition, and therefore, energy value. The accuracy of these agreed upon assumptions has a direct effect on the validity and enforceability of these long-term guarantees. However, communities frequently do not have accurate databases for establishing these assumption. In addition, the resource recovery industry recognizes that waste composition, energy value and waste quantity will change over time. To protect both the vendor and the community during the typical twenty-year term of a Service Agreement, flexible yet accurate guarantees are essential.

This paper describes a guarantee structure that gives the community flexibility when establishing its waste delivery schedule and waste

composition by permitting greater variations in waste stream quantity and energy value without relieving the vendor of its waste processing and energy production guarantees.

Introduction

A major problem facing most drafters of Resource Recovery Service Agreements is how to structure a set of performance guarantees that provide the community/owner with the maximum benefits of high unit availability and performance while protecting the vendor/operator from wide variations in waste stream quantity or energy value. Typically, the weekly quantity of waste in a community will vary by 20% over the course of the year and the energy value can range from 3800 Btu/lb to 6000 Btu/lb. Communities are, therefore, faced with the difficult decision of whether to design for average conditions or peak conditions.

While resulting in some bypassing of waste, a design based on average daily waste flow and energy value results in the facility operating at maximum efficiency during the most frequent operating conditions. A facility design based on peak conditions results in frequent operations at partial load and inefficient energy generation. If the community decides to design for peak conditions, it then faces the problem of insuring that the facility operates as efficiently as possible during periods of low waste flow or low energy value. If annual performance guarantees are used, what typically results is either very conservative performance guarantees which do not adequately protect the community against inefficient operation, or guarantees which are very difficult for the community to enforce.

Most Resource Recovery Service Agreements attempt to avoid this problem by assuming that over an extended period of time, such as an operating year, conditions will average out. In addition, the contracts generally provide for retesting the facility if the community or the vendor suspects that these "average conditions" assumptions are no longer valid. In reality, any failure by the vendor to meet its annual guarantees of waste throughput and energy, which could possibly result in damages to the community, may well be unenforceable not only because the community cannot establish what the energy value of the waste was, but also because the community may not have consistently met its weekly or monthly delivery guarantees.

Guarantee interpretation and enforcement problems are particularly difficult when a community sizes a project to its existing or future waste processing needs in addition to allowing for the seasonal variation of waste quantities. For such communities, there is little possibility of averaging out waste flow and energy value or making up for lost capacity during peak waste flow periods.

This paper proposes a solution for communities to assure flexible yet enforceable performance guarantees. To accomplish this, both processing and energy guarantees are developed and monitored separately in such a way that the community is assured of efficient operations even during periods of considerable deviation from the facility design condition.

Processing Guarantee

As stated earlier, many Resource Recovery facilities are designed to process the daily tonnage at some specified heating value. However, the amount of waste generated in a community, as well as its heating value, will vary from day to day and from month to month. In addition, allowances have to be made for scheduled and unscheduled plant maintenance during the year. There is also a problem in determining the exact amount of waste that is being processed. It is a simple process to accurately measure the amount of waste received by a facility, but it is very difficult to instantaneously measure on a continuous basis how much material is actually being loaded into the boilers. In most communities the waste profile cannot be exactly matched by the facility's processing profile, which leads to either bypassing of waste or under-utilization of the facility. In a situation where the facility will be under-utilized during portions of the year, a monthly processing guarantee protects the community better than an annual guarantee.

It is suggested that the following processing guarantee structure be used. First, a monthly processing target is established based on the facility's daily throughput rating and the number of days in the month. For example, the target for a 1000 ton per day (TPD) plant for the month of June, would be 30,000 tons. Secondly, using this target, allowances are made for scheduled and unscheduled maintenance during the month. For example, for a two boiler plant with an 85% availability guarantee, there would be 2628 boiler-hours (8760 hr/yr x 0.15 x 2) allowed for maintenance during the year. It is suggested that 30% to 50% (depending on the operator's normal maintenance procedures) of these hours be allocated to scheduled maintenance to be agreed upon by the vendor and the community at the beginning of each operating year to coincide with the expected low waste flow periods. Once set, the vendor must use scheduled maintenance hours in a given month or lose them. The remaining maintenance hours are then available to the operator for use as he deems necessary for unscheduled maintenance during the year. For a 1000 TPD plant with two boilers this would result in a maintenance allowance of 20.83 tons for each hour of boiler downtime.

$$\frac{1000\ \text{TPD}}{2} \div 24\ \text{hrs.} = 20.83\ \text{TPH/boiler}$$

For our example, assume that there were five days of scheduled maintenance for one boiler during the month and there were three days used for one boiler for unscheduled maintenance. The monthly processing guarantee for June would then become:

$$30{,}000 - (5 \times 24 \times 20.83) - (3 \times 24 \times 20.83) = 26{,}000\ \text{tons}$$

Once the vendor uses his allotment for scheduled and unscheduled maintenance during the year, any outages beyond this do not result in a reduction in his monthly processing guarantee.

To determine if the vendor has met his guarantee, it is recommended that the plant's truck scales be used to determine the amount of waste delivered to the plant during the month and how much nonprocessible waste such as white goods, or unacceptable waste, etc., is bypassed around the boilers. The quantity of waste in the pit or on the tipping floor is then estimated at the beginning and the end of each month to determine any change in pit inventory. Assuming a six day pit storage capacity and a $\pm$ 10% measurement accuracy on the quantity of waste in the pit, the amount of waste actually processed during the month can be determined to within + 2%.

Monthly penalties or bonuses can then be assessed based on whether the vendor has met or exceeded the monthly processing guarantee. Using the June examples above, if the vendor exceeded its processing commitment of 26,000 tons, it may be entitled to a fee for processing excess waste. In contrast, by failing to process 26,000 tons, the vendor may be liable for costs of landfilling waste it should have processed as well as lost energy revenues or other damages. However, it is recommended, that there be a yearly reconciliation of these penalties and bonuses based on the yearly throughput guarantee, i.e., at year end if the vendor has met his yearly throughput guarantee, then the monthly penalties are rescinded. If the vendor has not met its yearly throughput guarantee, then any monthly bonuses would be refunded.

Developing a processing guarantee similar to the one outlined above solves only half of the community's concern, that of processing a guaranteed amount of waste and decreasing the community's dependence on limited landfill space. Just as critical to the community is efficient facility operations, which assures energy revenues at a guaranteed level to offset the facility's costs.

ENERGY GUARANTEE

Most Resource Recovery operating contracts require the vendor to guarantee the net energy production capability of the facility. Usually, both a short-term (acceptance test) guarantee and an annual guarantee are required. Actual energy production is dependent upon many variables including waste heating value, boiler load, and operating efficiency. Energy guarantees are normally made based on a reference waste composition and heating value; a factor which neither the vendor nor the community can control. During acceptance testing, the facility can be operated at full load and careful calculations can be made of the quantity and heating value of waste processed. Therefore, an accurate comparison of guaranteed and actual energy production can be made.

An annual energy guarantee based on a reference waste composition is difficult to enforce because there is no realistic method of measuring heating value over long periods of time. In addition, the boilers and turbine will not always operate at full load and therefore, design efficiency. These variations make any annual energy guarantee very difficult to monitor and enforce.

The primary concern of the community should be that the facility is operated efficiently at all times, under all conditions of waste flow and energy value. Efficient operation provides comfort to communities relying heavily on energy revenues when setting service fees and guaranteeing debt service payments. If efficient operation can be demonstrated on an ongoing basis, then the community is assured that the maximum amount of energy is being extracted from the waste, and the maximum energy revenue is being generated by the facility.

The best way to determine if the vendor is operating the facility efficiently is to continuously measure key operating parameters. To verify energy guarantees, these operating parameters must be equated to energy production. Before outlining the proposed guarantee structure, a brief electrical energy production primer is helpful.

When waste is burned in the boilers, heat is absorbed by boiler water which is then converted into steam. For a specific facility design, the amount of steam produced is primarily dependent on the heating value of the waste, the waste feed rate, and boiler cleanliness. The steam is piped to a turbine-generator where its energy is used to generate electricity. The amount of electricity produced by the turbine-generator is primarily dependent on the steam flow and ambient air conditions.

The best measure of whether a boiler is operating efficiently is the temperature of the flue gas leaving the boiler. If this temperature is higher than the design point, energy is being wasted. If this temperature is lower than the design point, the boiler is being operated more efficiently than predicted. The guarantee structure presented uses the boiler economizer exit gas temperature to determine if the boiler is being operated efficiently. The net electricity generated per pound of steam is used to determine if the turbine-generator and auxiliaries are being operated efficiently.

The proposed performance guarantee structure uses three performance curves and the monitoring of five operational parameters. The first curve shows boiler economizer exit gas temperatures as a function of boiler steam flow. The second curve shows the impact of differential boiler exit gas temperature on boiler efficiency. The third curve shows net electrical generation as a function of steam flow and ambient air temperature. To protect the community, these curves should be made a part of the vendor's bid proposal and compared to other vendor's curves to insure that they fairly represent the facility's guaranteed operating performance. The five parameters which are continuously measured are boiler steam flow, boiler economizer exit gas temperature, turbine steam flow, ambient air temperature, and net electrical generation. If the facility uses a wet cooling tower, humidity must also be measured and incorporated into the net electrical generation curve.

In order to determine if the facility is producing the guaranteed electrical output, the following calculation is made hourly by the facility's computer.

Step 1 - For each of the boilers, use Curve 1 to determine the theoretical boiler exit gas temperature.

Step 2 - Calculate the boiler exit gas temperature differential by subtracting theoretical boiler exit gas temperature from the actual measured boiler exit gas temperature.

Step 3 - Using Curve 2, determine the boiler efficiency adjustment factor for each boiler.

Step 4 - Calculate an adjusted boiler steam flow by multiplying the actual boiler steam flows by the associated boiler efficiency adjustment factors. Sum the adjusted boiler steam flows to calculate an adjusted turbine steam flow.

Step 5 - Using Curve 3, determine a guaranteed net electrical production using the adjusted turbine steam flow and the measured ambient air temperature.

Step 6 - Calculate an electrical production deviation by subtracting the actual measured electrical production from the adjusted net electrical production (Step 5).

If the vendor has produced more energy than guaranteed, the deviation will be positive. If less energy than guaranteed is produced, the deviation will be negative. For every hour in the month that energy is produced. the deviations can be summed to calculate a monthly net electrical production deviation, which represents, in kilowatt-hours, the excess or shortfall in energy generation.

The following example illustrates how this procedure would work in practice. As stated earlier, the five operating parameters that are measured continuously are boiler steam flow, boiler economizer exit gas temperature, turbine steam flow, ambient air temperature, and net electrical production.

For our example, assume that there are two boilers and the measured parameters are as follows:

Boiler 1:

- steam flow : 95,000 lbs/hr
- exit gas temp. : 452°F

Boiler 2:

- steam flow : 75,000 lbs/hr
- exit gas temp. : 434°F

Turbine steam flow	:	170,000 lbs/hr
Ambient air temp.	:	70°F
Net electrical production	:	14,200 KW

Step 1:

From Curve 1, the theoretical boiler economizer exit gas temperatures are:

Boiler 1	:	442°F
Boiler 2	:	414°F

Step 2:

The boiler exit gas temperature differentials are then:

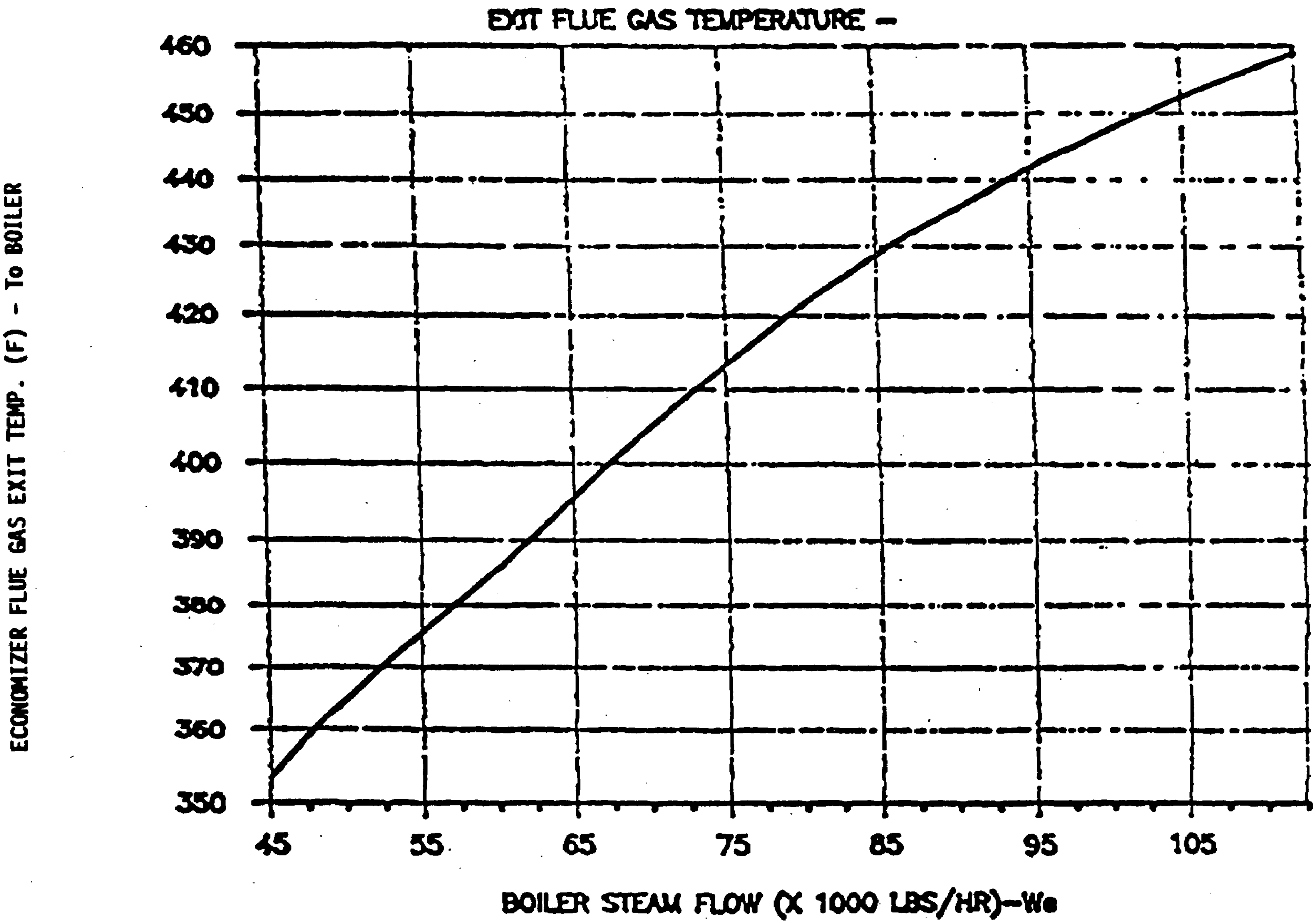
Boiler 1	:	+ 10°F
Boiler 2	:	+ 20°F

Step 3:

Using Curve 2 the boiler efficiency adjustment factors are:

Boiler 1	:	1.005
Boiler 2	:	1.011

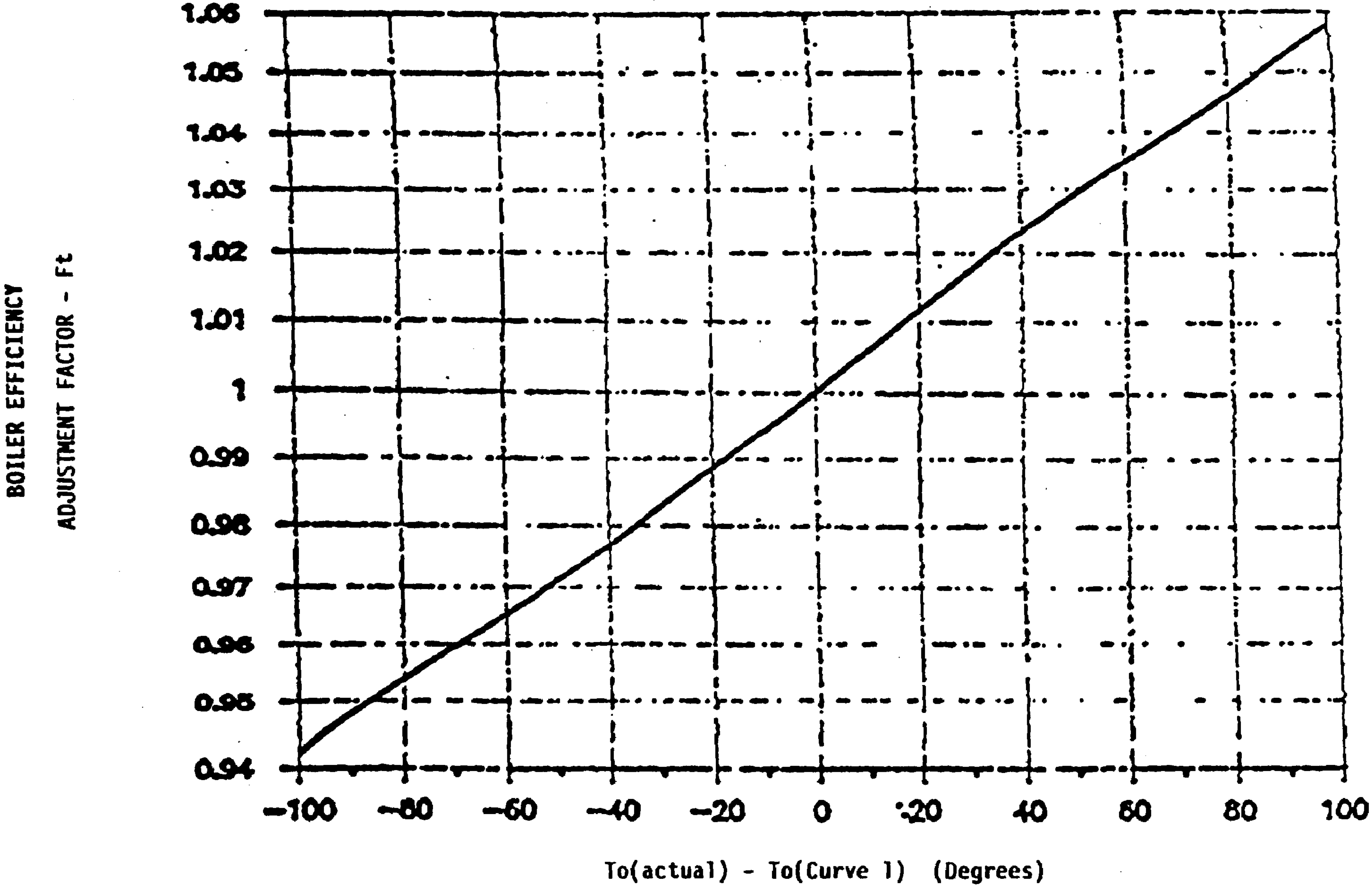
CURVE 1


EXIT FLUE GAS TEMPERATURE –
460
450
440
430
420
410
400
390
380
370
360
350
ECONOMIZER FLUE GAS EXIT TEMP. (F) - To BOILER
45
55
65
75
85
95
105
BOILER STEAM FLOW (X 1000 LBS/HR)—We

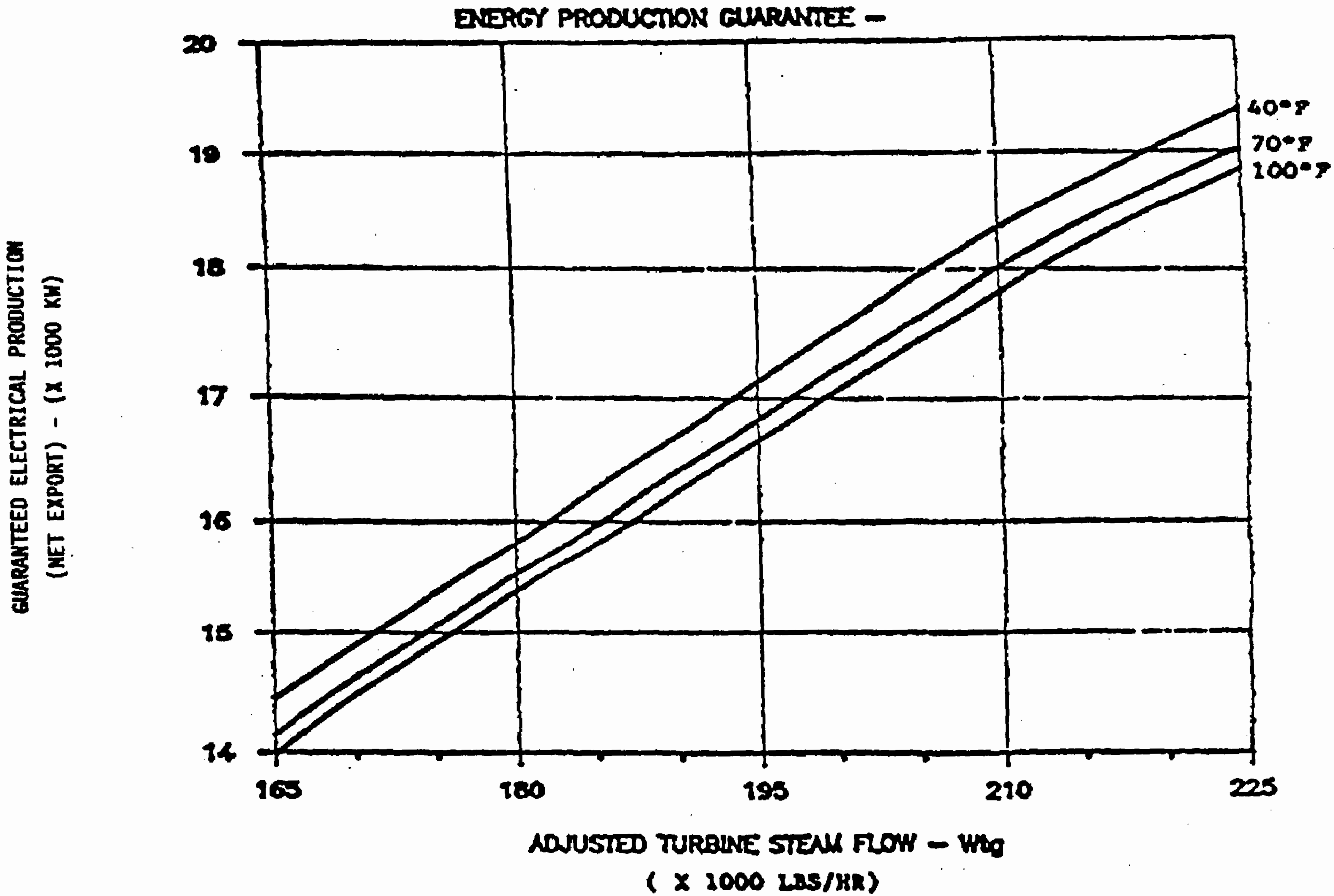
832

CURVE 2

TEMP. DIFFERENTIAL ADJUSTMENT FACTOR



CURVE 3


ENERGY PRODUCTION GUARANTEE —
GUARANTEED ELECTRICAL PRODUCTION
(NET EXPORT) - (X 1000 KW)
20
19
18
17
16
15
14
165
180
195
210
225
40°F
70°F
100°F
ADJUSTED TURBINE STEAM FLOW — Wtg
(X 1000 LBS/HR)

834

Step 4:

The adjusted boiler steam flows and the adjusted turbine steam flow is then:

Boiler 1	:	95,000 x 1.005 = 95,475 lbs/hr
Boiler 2	:	75,000 x 1.011 = 75,825 lbs/hr
Turbine	:	171,300 lbs/hr

Step 5:

Using Curve 3 with an ambient air temperature of 70°F the guarantee net electrical production at the adjusted turbine steam flow of 171,300 lbs/hr is:

Net electrical production: 14,700 KW

Step 6:

The electrical production deviation for the hour is then:

Net electrical production deviation = 14,200 - 14,700 = - 500 KW

The vendor then would be penalized 500 KWH in its energy guarantee for this hour.

This process is repeated automatically every hour by the facility's computer and the differentials between the guaranteed net electrical production and the measured electrical output are summed to compute monthly and/or yearly bonuses or damages.

Summary

The above set of performance guarantees can be used to provide a guarantee structure that meets the primary needs of the community of a contracted quantity of waste being processed efficiently. These guarantees are clear and easy to administer and enforce. Although no set of guarantees can be completely rigorous and cover all eventualities, the approach presented allows for a wide range of plant operations, waste flow, and energy value while maintaining an acceptable level of validity and enforceability.

IMPLEMENTATION OF GUIDELINES FOR AIR EMISSIONS FROM EXISTING MUNICIPAL WASTE COMBUSTORS

David F. Painter

U.S. EPA

Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

Implementation of Guidelines for Air Emissions
from Existing Municipal Waste Combustors

Summary

This presentation provides an overview of proposed guidelines for air emission limits for existing municipal waste combustors as they were proposed in the Federal Register (54 FR 52209). The overview is followed by a summary of public comments on the proposal. The remainder of the presentation covers the practical aspects of implementing the guidelines. Topics covered include timetables and assignment of responsibilities during the implementation process. Also legislative proposals under consideration at the time of the presentation will be reviewed in the context of how they might impact the current implementation procedures.

MINIMIZATION OF TRACE METAL LEACHINGS IN SEAWATER FROM STABILIZED MSW INCINERATION ASH

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ABSTRACT

Municipal solid waste (MSW) incineration ash has been stabilized into a non-friable solid block form which can be used as construction material in marine environment. Studies were conducted on full-size (5 cm x 15 cm) blocks and also on ground samples of stabilized ash blocks to demonstrate that trace metals are retained inside the stabilized MSW ash block and that leaching of trace metals from MSW ash is minimized by the stabilization process. Results show that release of Cu and Cd from the stabilized ash block is insignificant, occurring only in the initial three days after the submersion in seawater. Lead was found to not be released from the stabilized ash block in seawater. Leaching of Cu, Cd, and Pb from loose MSW ash was significantly reduced by stabilization process. Retention of Cu, Cd, and Pb inside the stabilized MSW ash blocks is due to the combination of physical enclosement and chemical binding.

INTRODUCTION

Incineration of municipal solid waste (MSW) is currently the main alternative to landfill disposal of the bulk solid waste. Incineration of the wastes may generate toxic substances both in gaseous and solid forms [1-2]. MSW incineration ash is the solid residue that remains when the wastes is burned in an incinerator. The ash is enriched in trace metals and contaminants of environmental concern [3-6]. The physical and chemical properties of incineration ash vary with source of MSW being burned and operational procedures used at individual incinerator facilities [7-8]. Incineration results in a reduction in volume of MSW by about 90 percent and a reduction in weight by 75 percent. Production of MSW incineration ash will continue to increase because more MSW incinerator will be built to solve the problem of managing the increasing quantities of MSW due to rapid growth. It is estimated that 19 million tons of ash will be generated in the U.S. by the year 2000 [9]. Methodologies for ash management have to be developed, including ash utilization. The methodologies must be environmentally acceptable to reduce the burden on an already shrinking land space for landfills.

Reuse of the ashes should be considered. Ash recycling, if demonstrated environmentally acceptable, represents an alternative to ash disposal with potential economic and social benefits. For its safe and beneficial use, ash must be physically and chemically characterized and the treated ash products must not create damage to the environment and pose no problem to human health.

Stabilization of the friable ash materials into non-friable solid forms is one of the potential methods for ash reuse. For over a decade, studies have been conducted to demonstrate that the stabilized ash products can be used as artificial reef materials in the ocean [10]. Wastes applied using the methodology include coal ash, flue-gas desulfurization (FGD) sludge [11], oil ash [12], dewatered sewage sludge [13], and metal processing waste [14]. To demonstrate the suitability of using the stabilized ash materials for reef application at sea, studies conducted have included comprehensive engineering, chemical, and biological investigations. Generally, laboratory evaluations are first conducted, followed by a field demonstration and monitoring before the methodology is adopted for managing ashes.

In this paper, the laboratory evaluation of metal leaching from both loose and stabilized MSW ash is presented. The goal of the study was to demonstrate the effectiveness of stabilization in reducing metal leachings from MSW ash in seawater. The results are useful for the assessment of the fate of trace metal in MSW ash after the stabilized ash block becomes debris at sea.

METHODOLOGY

Ash Stabilization

The methodology of ash stabilization has been described elsewhere [10]. In brief, the process begins with the mixing of the ashes with water and chemical additives, such as lime and cement. The mixture is then fabricated into block forms using conventional concrete block technology. The blocks are then cured at a constant temperature for a period of time so that a solid product is produced. From a series of mix designs, an optimum mix is selected based on the development of compressive strength and its chemical characteristics. Factors in determining the effectiveness of stabilization are ash-additives ratio, particle size distribution of the ashes, water content of the mix, and curing condition. The production of an optimum mix is the result of a unique combination of these factors.

MSW incineration ash used in this study are fly ash, scrubber ash, and bottom ash. Three types of stabilized ash blocks were produced, i.e., 100% bottom ash (block B), 70% bottom ash + 30% scrubber ash (block BS), and 60% bottom ash + 40% fly ash (block BF). Desirable amounts of cement and water were added to each type of mix. Lime was only used in the formation of block BF.

Elemental analysis

Analysis of elemental composition in MSW ash samples was conducted by analyzing hydrofluoric/boric acid digests of the ashes using the method reported by Silberman and Fisher [15]. Approximately, 500 g of the starting materials were dried and ground to fine powder using a porcelain mortar and pestle, and then oven dried again at 105°C. About 0.5 g samples of the dried materials were placed into 125-ml Nalgene plastic bottles followed by the addition of 10 ml of distilled-deionized water and 10 ml of concentrated hydrofluoric acid. The samples were shaken mechanically for 24 hr and then 80 ml of saturated boric acid solution were added. The samples were again agitated for 24 hours, followed by ultrasonication for one hour. The digests were filtered through a 0.45 μm Millipore[R] filter paper and then analyzed for major and trace elements using atomic absorption spectrophotometer (AAS) equipped with Zeeman background correction.

Seawater Tank Leaching Study

Metal leachings from the stabilized ash blocks into surrounding seawater was examined following the method used by Duedall et al. [16]. A solid cylinder of stabilized ash sample was suspended with monofilament line inside polyethylene tanks containing 2 liters of filtered seawater. Each tank was placed on a magnetic stirrer to generate a constant motion to the seawater. A 0.45 μm membrane filter was placed over an opening in the cover of the tank to ensure aeration. The tank water was replaced with fresh seawater after the initial 3-day period, and then was replaced at two-week intervals for the remainder of the leaching period. The water samples were taken at the interval of 1, 2, 3, 6, 9 and 12 days in the initial 12-day period, then weekly sampled for 6 weeks and biweekly sampled for 8 weeks. Collected water samples were filtered through a 0.45 μm Millipore[R] filter, acidified to pH 2 using Ultrex[R] nitric acid, and stored for later analysis by AAS.

Ash-Seawater Leaching Study

To evaluate the effectiveness of stabilization on reducing element release from MSW ash exposed to seawater, a series of leaching experiments were conducted on the loose ash and ground stabilized ash blocks. The powdered stabilized ash samples were dried at 105°C and then were passed through a series of sieves to form different size fractions ranging from < 250 μm to > 1000 μm. Samples of each size fraction were placed in plastic (LPE) bottles containing seawater to form 1:1000 (wt/vol) mixtures; the mixture was placed on the shaker to allow the reaction to occur at an interval of 0.5, 2, 8, 24, and 48 hrs, respectively. At the end of the leaching period, the aqueous phase was collected by filtering the mixture through a 0.45 μm Millipore[R] filter. The filtered solution was then analyzed for selected elements.

Three replicate samples of the study materials were analyzed. Matrix modifiers, i.e., NH_4NO_3 and $(NH_4)_2HPO_4$, were used for the analysis of Cu, Cd, and Pb in seawater samples. National Institute of Standard and Technology (NIST) Standard Reference Material (SRM) 1633a fly ash and NIST SRM

Multielement Mix Solutions (3171 and 3172) were analyzed in order to determine the completeness of digestion of the ashes, the accuracy of the analytical methods, and to provide quality assurance of the analysis.

RESULTS AND DISCUSSION

Results of elemental analysis on the ash samples prior to stabilization are shown in Table 1. These data are considered average value of the ash used in the study. In general, the range for elemental variation in MSW incineration ash is very large due to the nature of the waste stream and operational conditions in the incinerator. The batch of ash samples collected is assumed to be well-mixed as a result of sample collection and of transportation. Data shown in Table 1 indicate that Ca, Si, and Al are enriched in all ash samples, including fly, scrubber, and bottom ash. These ashes may thus have pozzolanic characteristics which is a preferred property for stabilization.

Cadmium, Pb, and Zn were found to be enriched in fly ash indicating fly ash is the ash of concern environmentally. Enrichment of Cd in fly ash is expected because Cd is vaporized by incineration and is recondensed on the fly ash particles during the cooling of the off-gases [17]. The distribution of Zn is different from that predicted [17] and may be due to the operation condition at the incinerator.

Table 1. Elemental concentrations in MSW incineration ash (N = 6).

Element	Fly Ash	Scrubber Ash	Bottom Ash
Al (%)	4.6	6.5	2.8
Si (%)	15	19	22
Ca (%)	6.8	8.6	7.7
Mg (%)	1.1	1.8	0.9
Fe (%)	1.1	3.4	6.8
Zn (%)	4.2	0.4	0.4
Pb ($\mu g\ g^{-1}$)	5500	1200	1700
Cu ($\mu g\ g^{-1}$)	810	1100	2100
Ni ($\mu g\ g^{-1}$)	120	250	160
Cd ($\mu g\ g^{-1}$)	380	30	24
Cr ($\mu g\ g^{-1}$)	155	403	201

Table 2 shows the results of tank leaching studies on stabilized MSW ash blocks. The detected concentrations in test solution were less than 5 $\mu g\ L^{-1}$ for Cu and less than 1 $\mu g\ L^{-1}$ for Cd. Lead was not detected in the solution. The results indicate that leaching of Cu, Cd, and Pb from stabilized MSW ash blocks in seawater is insignificant. The initial leaching for Cu and Cd occurs at the surface of the block which is in direct contact with seawater. Previous studies on stabilized energy waste blocks [18] also showed that interaction of the stabilized blocks with seawater after the emplacement at sea occurred mainly at the surface of the block.

Table 2. Leaching of Cu, Cd, and Pb ($\mu g\ L^{-1}$) from stabilized MSW ash blocks in seawater.

	Stabilized MSW Ash Block								
Time	B[1]			BF[1]			BS[1]		
(day)	Cu	Cd	Pb	Cu	Cd	Pb	Cu	Cd	Pb
1	3.58	0.24	n.d.	2.35	0.15	n.d.	1.21	n.d.	n.d.
2	4.08	0.16	n.d.	1.56	0.42	n.d.	3.23	n.d.	n.d.
3	2.81	n.d.	n.d.	n.d.	n.d.	n.d.	1.91	n.d.	n.d.
6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
9	n.d.[2]	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
19	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

1. Block B represents 100% bottom ash; BF represents 60% bottom ash and 40% fly ash; BS represents 70% bottom ash and 40% scrubber ash.
2. n.d. represents not detectable. Detection limit for Cd is 0.1 $\mu g\ L^{-1}$; for Cu is 1 $\mu g\ L^{-1}$; for Pb is 1 $\mu g\ L^{-1}$.

As mentioned above, application of the stabilized ash block in marine environment requires a demonstration that the materials are environmentally acceptable. Data shown in Table 2 indicate that trace metals, such as Cu, Cd, and Pb, are retained inside the block which has a good physical integrity.

One question may be raised dealing with the fate of these metals if the block is cracked or turned into debris after placement into the ocean. Investigation of this concern can be achieved by examining the release of metals from ground ash blocks. Table 3 shows the percent leaching of Cu, Cd, and Pb from both the powdered stabilized MSW ash blocks and loose ash. Without stabilization, Cd was nearly depleted from fly ash after placement into seawater, while only about 10% of Cd was released from loose bottom ash after it was in contact with seawater for 48 hours. Stabilization of the ash by mixing 60% of bottom ash with 40% of fly ash results in a very significant reduction in Cd leaching.

Table 3. Percent leaching (%) of Cu, Cd, and Pb from loose MSW ash and powdered stabilized ash block.

Time	Fly Ash			Bottom Ash			Block BF		
(hr)	Cd	Cu	Pb	Cd	Cu	Pb	Cd	Cu	Pb
0.5	97	2.9	0.39	2	0.34	0.49	1.0	0.13	n.s.
2	98	1.8	0.32	5	0.54	0.29	1.6	n.s.	n.s.
8	83	2.1	0.30	11	1.06	0.34	-	n.s.	n.s.
24	94	1.6	0.25	13	1.42	0.63	2.6	n.s.	n.s.
48	91	1.6	0.23	14	1.64	0.30	2.7	n.s.	n.s.

1. Block BF represents the mix containing 60% bottom ash and 40% fly ash.
2. n.s. represents not significant; the value is less than 0.01%.

For Pb and Cu, only small percentage was released from the ashes into seawater. This is still of concern because high concentration of Pb and Cu are found in most of MSW ashes. Stabilization process also significantly minimizes the leaching of Pb and Cu in seawater.

Research conducted is for a worst case, i.e., assuming the stabilized MSW ash blocks become cracked leading to debris soon after the emplacement at sea. However cracking is improbable based on previous engineering investigations which have shown that stabilized ash blocks made from coal fly ash and FGD sludge residue have maintained their physical integrity in the ocean at least 10 years [19].

To understand the mechanism of the stabilization process on retaining trace metals in the stabilized blocks, studies were conducted on ground block samples of varying sizes fraction. The results are shown in Table 4; leaching of Cd increased as the particle size decreased indicating that physical enclosement may be the major mechanism for retaining Cd within the block matrix. Leaching of Cu showed little influence from particle size indicating that retention of Cu is mainly by chemical bindings.

Table 4. Leaching of Cu and Cd from ground stabilized ash block (BS) in seawater.

Particle Size (μm)	Cu ($\mu g\ L^{-1}$)	Cd ($\mu g\ L^{-1}$)
< 250	6.80±0.14	0.47±0.07
250-500	3.80±1.10	0.26±0.12
500-1000	7.87±0.25	0.12±0.05
> 1000	9.50±2.70	0.14±0.02

CONCLUSIONS

Stabilization has significantly minimized leaching of Cu, Cd, and Pb from MSW incineration ash. Copper, Cd, and Pb are retained inside the stabilized MSW ash block. Retention of Cd is mainly due to physical enclosement while Cu is retained by chemical bindings. The study indicates that the stabilized MSW ash block is chemical stable in seawater. Application of this material in marine environment should be further considered and investigated.

ACKNOWLEDGMENTS

We thank Dr. Iver W. Duedall for reviewing the paper and valuable suggestions. We also thank H. Emma Yoo for preparing digest samples for elemental analysis. This work was funded by HDR Engineering, Inc.

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PROPOSED AIR POLLUTION EMISSION RULES FOR MUNICIPAL WASTE COMBUSTION FACILITIES

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INTRODUCTION

The EPA proposed regulations for municipal waste combustors (MWC's) on December 20, 1989. The regulations include (1) performance standards under Section 111(b) of the Clean Air Act (CAA) for new, modified, or reconstructed MWC's and (2) emission guidelines for the States to use to develop control requirements for existing MWC's under Section 111(d).

This paper will summarize the proposed air emission standards and guidelines, as well as the bases for the prescribed emission limits. The schedule for the remainder of the regulations development will also be discussed.

REGULATORY APPROACH

The EPA has chosen to regulate MWC's under Section 111 of the CAA (52 FR 25339). The Administrator determined that MWC's would be regulated under Section 111 because the range of health and welfare effects and the range and uncertainties of estimated cancer risks did not warrant listing of MWC emissions as a hazardous air pollutant under Section 112. Section 112 also could not be used to address particular constituents of MWC emissions including lead and hydrogen chloride (HCl). Finally, the development of emission guidelines under Section 111(d) would permit a more thorough evaluation of existing MWC's at the State level than would be possible with a general rulemaking at the Federal level under Section 112.

The implementation of Section 111 involves several steps commencing with the selection and characterization of the source category to be regulated. The source category is characterized in terms of types, numbers, and sizes of facilities and an emissions evaluation. The applicability of the standards is established by defining affected facilities. Under Section 111, the Agency must then identify the best demonstrated technology (BDT), which is defined as the best system of continuous emission reduction that has been adequately demonstrated taking into account costs and other environmental and energy impacts. Regulations development under Section 111 also requires the selection of the pollutants to be regulated from the particular source category. Finally, the EPA must select the format for the standard and establish the numerical emission limits for the pollutants which will be regulated.

The proposed MWC standards address air emissions from new and existing sources. Air emission limits for new sources are proposed under Section 111(b) for the criteria pollutant nitrogen oxides (NO_x), and a designated pollutant. A designated pollutant is a pollutant which is not listed as a hazardous air pollutant under Section 112 of the CAA or is not a criteria pollutant under Sections 108-110.

The designated pollutant selected for regulation under this standard is the collection of compounds emitted by MWC's referred to as "MWC emissions." "MWC emissions" are categorized into three general subclasses of pollutants: MWC organics, in particular dioxins and furans; MWC metals, the condensible metals associated with particulate matter (PM) emissions from MWC's; and MWC acid gases, specifically sulfur dioxide (SO_2) and hydrogen chloride (HCl).

By setting emission limits for a designated pollutant for new sources under Section 111(b), the Agency invokes Section 111(d) for the regulation of designated pollutants from existing sources. Thus, by selecting "MWC emissions" as the designated pollutant, the EPA is empowered to set emission guidelines for that pollutant from existing MWC sources under Section 111(d). States will then have the duty to develop State regulations to implement the emission guidelines for their existing MWC source population. A State plan would be submitted to the EPA that includes the emission standards for their existing MWC facilities and establishes compliance schedules for retrofit.

The current proposal also includes combustion standards and materials separation requirements which are applicable to both new and existing MWC's. These elements of the proposal, as well as the stack emission limits, are discussed below in detail.

NEW SOURCE PERFORMANCE STANDARDS (NSPS)

The proposed standards for new MWC's pursuant to Section 111(b) apply to those facilities commencing construction after December 20, 1989. The EPA has estimated that this standard will apply to approximately 50,000 tons per day (tpd) of MWC capacity by 1994.

The emission limits for new facilities are outlined in Table 1. The applicability of the standards is subdivided into two categories based on plant capacity: large facilities, greater than 250 tpd, and small facilities, less than or equal to 250 tpd. The purpose for the size categorization is due to the greater emissions potential from larger MWC facilities, the fact that over 90 percent of new capacity will be attributed to large facilities, and the dramatic increase in costs associated with emissions control for new, small facilities.

The proposed NSPS for large, new MWC facilities would require an emission limit of 5 to 30 ng/dscm for total tetra- through octa-chlorinated dibenzo-p-dioxins and dibenzofurans for the control of MWC organics. MWC metals would be controlled by an emission limit on PM of 0.015 gr/dscf. This level of PM control would result in greater than 97 percent control of all MWC metals with the exception of mercury. The level of PM emissions would be monitored continuously by the use of an opacity monitor at the stack and a 10 percent opacity limit, based on a 6-minute average, would apply. MWC acid gases would be reduced through emission limits for both HCl and SO_2. Emission limits of 95 percent reduction or 25 ppmv for HCl, and 85 percent reduction or 30 ppmv for SO_2 are proposed. Compliance with the HCl emission limit would be demonstrated using proposed EPA Method 26 (54 FR 52190). The SO_2 emissions would be continuously monitored.

The emission limits for large facilities are based on the application of good combustion practices (GCP) and a spray dryer/fabric filter (SD/FF). In addition to "MWC emissions" control, large, new combustors would also be limited to 120 to 200 ppm of NO_x based on the application of selective non-catalytic reduction technology. Continuous monitoring of NO_x would also be required.

For small, new MWC facilities, the proposed maximum emission level of dioxin/furan emissions is 75 ng/dscm. The PM emission limit is identical to that for large facilities. The level of acid gas reductions required is 80 percent or 25 ppm for HCl and 50 percent or 30 ppm for SO_2. These proposed emission limits are based on the application of GCP and duct sorbent injection (DSI) followed by an electrostatic precipitator (ESP) or FF.

Annual emissions testing would be required for all new MWC's. However, if a small, new MWC is in compliance with the standards for three consecutive annual tests, the facility may skip the next two annual tests. If the next test demonstrates compliance, the facility may again skip the next two years. Therefore, at a minimum, a small MWC must conduct emissions testing at least once every three years.

EMISSION GUIDELINES (EG) FOR EXISTING SOURCES

The emission guidelines for "MWC emissions" from existing MWC sources are proposed pursuant to Section 111(d). Emission guidelines and compliance times are described in the proposal and are to be used by States in developing State regulations for the control of existing MWC facilities. The intent of the proposed guideline is to compel State regulation of MWC's through the application of the best demonstrated technology.

The proposed emission guidelines for existing facilities are outlined in Table 2. The guidelines are subdivided into three subcategories of facilities based on plant capacity: small facilities, up to 250 tpd; large facilities, between 250 and 2200 tpd; and regional facilities with capacities greater than 2200 tpd.

The proposed guidelines for existing, small facilities would require the application of good combustion control for the control of MWC organic emissions and an ESP upgrade for particulate control for the reduction of MWC metals. Total tetra- through octa-chlorinated dibenzo-p-dioxin and dibenzo-furan emissions would be limited to 500 ng/dscm. Particulate emissions would be limited to 0.03 gr/dscf.

The emission guidelines for existing, large MWC facilities would require additional control of organic emissions as well as the control of acid gas emissions. The proposed guidelines would require the application of GCP and dry sorbent injection into the furnace or the duct for the control of MWC acid gases followed by an ESP or FF. Dioxin and furan emissions would be limited to 125 ng/dscm while PM would be limited to 0.03 gr/dscf. MWC acid gases would be controlled through a 50 percent reduction of both HCl and SO_2 or an emission limit of 25 ppmv and 30 ppmv, respectively.

The proposed guidelines for regional MWC facilities are based on the application of GCP and a SD/FF. The emission limits are identical to those discussed above for large, new MWC facilities except that NO_x control would not be required for existing MWC's.

The proposed emission guidelines in most cases would be expected to result in compliance with State standards within 3 years of adoption. However, longer compliance times may be required for those facilities requiring extensive retrofit and schedule adjustment would be considered.

Annual testing would be required for all existing MWC facilities. However, if a facility shows compliance with the emission guidelines for three consecutive annual tests, they will be permitted to skip the next two annual tests. If they again demonstrate compliance in the third year following their last test, they may skip another two years. In any circumstance, each existing facility will be tested a minimum of once every 3 years.

MATERIALS SEPARATION

The proposed MWC standards would require that all municipal solid waste (MSW) to undergo preprocessing prior to combustion. This preprocessing is defined as the removal of 25 percent or more by weight from the MSW of the following components: paper and paperboard; ferrous metals; nonferrous metals; glass; plastics; household batteries; and yard wastes.However, no more than 10 percent of the total 25 percent can be attributed to the yard waste component. This materials separation requirement would apply to all MWC facilities, existing and new. The proposed standards would also preclude the combustion of lead acid vehicle batteries and require the removal of household batteries.

The materials separation requirement may be met by an on-site mechanical or manual separation program or an off-site community separation program, or a combination thereof. If an off-site or community program is implemented to comply with the requirements, a plan describing the separation program and the compliance demonstration methods would be submitted to the EPA or the State agency for approval. Compliance with the proposed materials separation requirements would be demonstrated based on the calendar year average of measurements of the total weight of MSW received, the weight of MSW combusted, and the weight of materials separated.

Demonstration of compliance with the materials separation requirement would not be required until the end of the second full calendar year after initiation of the materials separation program. A report of the percent materials separation achieved would be submitted after the first full calendar year of operation to determine the progress toward meeting the requirement. However, this report would not be used to determine compliance. The second and subsequent annual report would be used to determine compliance.

A new MWC facility must have a separation program in place at the initial start-up of the facility. However, for new facilities which commence construction between proposal and promulgation, a materials separation program would not have to be implemented until December 31, 1992, or at initial start-up, whichever is later. Demonstration of compliance with the materials separation requirement would not be required until December 1994, or at the end of the second full calendar year after start-up.

The proposed emission guidelines for existing MWC facilities would require the implementation of a materials separation program by December 31, 1992. Recordkeeping and reporting requirements would be identical to those for new facilities. Therefore, the first annual report would be due December 31,

1993. However, this interim report would not be used for compliance purposes. The initial demonstration of compliance would occur the following year with the submittal of the December 31, 1994 report.

Removal of lead-acid vehicle batteries would result in a reduction of lead emissions from MWC's. Household battery separation is proposed to effect reductions in mercury emissions from MWC's. Add-on control systems have proven to be ineffective in achieving consistently high removals of mercury from MWC flue gas. Since much of the mercury in MSW is in the form of batteries, EPA is proposing separation of batteries from the waste stream as a means of reducing MWC mercury emissions. The EPA continues to study this issue.

Finally, the proposed materials separation requirements include a provision whereby the EPA would grant a facility a permit to combust separated, combustible materials if no markets exist for the material. A recycling market would be considered to be unavailable if, after separating the material and searching for a market for 120 days, the MWC operator could demonstrate to EPA that either no recycler will take the material or that the cost of recycling is equal to or exceeds the cost of landfilling. However, the materials separation requirement would remain in place even where a combustion permit has been granted. This will assure stability in the materials separation program. The combustion permit would be effective for one year, but is renewable on an annual basis.

COMBUSTION CONTROL REQUIREMENT

The proposed MWC standards would establish combustor operating practices for both existing and new sources. Good combustion practices (GCP) involve the proper design, construction, operation, and maintenance of an MWC. The implementation of GCP would result in a reduction of MWC organic emissions by promoting their destruction. These practices would include limits on carbon monoxide (CO), combustor load, and the flue gas temperature at the control device outlet as outlined in Table 3.

Techniques employed to minimize CO are similar to those required for the effective destruction of organics. Therefore, a CO emission limit is proposed for the various combustor types. For modular starved air and modular excess air types of MWC's, the CO emission limit would be 50 ppmv (at 7 percent O_2 on a block 4-hour average basis). For mass burn waterwall, mass burn refractory, and fluidized-bed types of MWC's, the CO emission limit would be 100 ppmv (at 7 percent O_2 on a block 4-hour average basis). For mass burn rotary waterwall, refuse-dervied fuel (RDF), and coal/RDF co-fired MWC's, the CO emission limit would be 150 ppmv (at 7 percent O_2 on a block 4-hour average basis).

Combustor load also affects MWC organic emissions. At combustor loads exceeding maximum capacity, the potential for PM carryover increases and residence times decrease leading to an increase in organic emissions. Municipal waste combustors would not be allowed to operate above 100 percent of their maximum capacity as demonstrated during compliance testing (1-hour average basis). Municipal waste combustors that do not generate steam would be exempt from maximum load level requirements because these types of MWC's cannot feasibly measure load level.

The proposed standards would require all MWC's to maintain a flue gas temperature of 230°C (450°F) or less (4-hour block average) at the PM control device inlet. The purpose of this requirement is to prevent post-combustion formation of dioxins and furans.

Operator training is considered by EPA to be an integral part of the implementation of GCP. The proposed GCP would therefore require American Society of Mechanical Engineers (ASME) certification of the chief facility operator and shift supervisors. In addition, a training manual must be developed for the remaining MWC personnel who occupy positions associated with the combustion process. The training manual should focus on the various components of the combustion process and how they impact performance and emissions. The manual should also specify remedial measures that are effective during process upsets and startups and shutdowns.

SCHEDULE

The remaining schedule calls for promulgation of the new source performance standards and emission guidelines in December 1990. The States will then be required to develop and submit a plan implementing the guidelines. Approximately 9 months is expected to be necessary for State plan submittals. The EPA must prescribe a plan for a particular State if that State fails to meet the deadline or submits an unsatisfactory plan. The EPA will approve State emission standards which meet the emission guidelines through the application of the best systems of continuous emission reduction which are reasonable available. For health-related pollutants, as is the case for "MWC emissions", State emission standards must ordinarily be at least as stringent as the emission guidelines. However, where justified due to the unreasonableness of application, relief may be granted on a case-by-case basis.

TABLE 1. MWC EMISSION LIMITS FOR NEW FACILITIES[a]

	NEW FACILITIES	
Plant Capacity, tpd	$\leq$250	>250
MWC Metals, gr/dscf (as PM)	0.015	0.015
MWC Organics, ng/Nm^3 (as CDD/CDF)	75 (250)[b]	5-30
MWC Acid Gases		
HCl, % Reduction[c]	80	95
SO_2, % Reduction[d]	50	85
NO_x, ppmv	none	120-200

[a] Corrected to 7% O_2

[b] Value indicated for RDF facilities

[c] Indicated percent reduction or less than 25 ppmv.

[d] Indicated percent reduction or less than 30 ppmv.

TABLE 2. MWC EMISSION GUIDELINES FOR EXISTING FACILITIES[a]

	EXISTING FACILITIES		
Plant Capacity, tpd	≤250	>250 to 2200	>2200
MWC Metals, gr/dscf (as PM)	0.030	0.030	0.015
MWC Organics, ng/Nm^3 (as CDD/CDF)	500 (1000)[b]	125 (250)[b]	5-30
MWC Acid Gases			
HCl, % Red.[c]	none	50	95
SO_2, % Red.[d]	none	50	85
NO_x, ppmv	none	none	none

[a] Corrected to 7% O_2.
[b] Value indicated for RDF facilities.
[c] Indicated percent reduction or less than 25ppmv.
[d] Indicated percent reduction or less than 30 ppmv.

TABLE 3. GOOD COMBUSTION PRACTICES LIMITS

POLLUTANT OR PARAMETER	LIMIT
MAXIMUM LOAD LEVEL	100% OF DEMONSTRATED CAPACITY
MAXIMUM TEMPERATURE AT PM CONTROL DEVICE INLET	230°C (450°F)
<u>CO Emissions:</u>	
Modular MWCs	50 ppmv
Mass burn waterwall	100 ppmv
Mass burn refractory	100 ppmv
Fluidized bed combustor	100 ppmv
Mass burn rotary water wall	150 ppmv
RDF spreader stoker	150 ppmv
Coal/RDF co-fired	150 ppmv
OPERATOR CERTIFICATION AND TRAINING	ALL OPERATORS CERTIFIED BY ASME; TRAINING MANUAL AND TRAINING FOR OTHER PERSONNEL

SALES OF ELECTRIC POWER USING MUNICIPAL SOLID WASTE

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13 - 16, 1990

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SALES OF ELECTRIC POWER USING MUNICIPAL SOLID WASTE

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Introduction

My topic today is "Sales of Electric Power Using Municipal Solid Waste." I have divided the topic into four parts. First, I will discuss the current state of non-utility generation in the United States. Then I will turn to state and federal regulatory issues which you should be aware of in connection with electric generating projects. Third, I'll mention some of the more important contract issues you will see in your negotiations with utilities. I'll close with a couple of practical suggestions to keep in mind when you are developing a project. I will use the term municipal solid waste, or "MSW", to refer to both landfill gas and municipal solid waste.

Overview of Power Sales Opportunities

Let's begin by looking at where we are today compared to where we were five or ten years ago. One of the most important changes in the electric utility industry during the last ten years has been the development of an active and growing independent power industry. A primary reason for this change is that Congress passed the Public Utility Regulatory Policies Act or ("PURPA") in 1978. PURPA requires utilities to purchase electricity from non-utility generating facilities using certain technologies. These include facilities fueled by MSW and are known as "qualifying facilities" or "QF's".

During the early and middle 1980's most utilities purchased power from qualifying facilities and other non-utility generators with great reluctance. This was because utilities preferred to build their own generating plants so those plants would be included in rate base. Utilities also questioned the reliability of non-utility generation.

Today many utilities are actively seeking bids for generating capacity -- from qualifying facilities and from non-utility generators which do not qualify under PURPA and which cannot force utilities to buy their power. This is because, in recent years, many utilities have had difficulty including the cost of their own generating plants in rate base. They may have had cost overruns or they may have found that they did not need all of their new capacity once it was built. In these cases, utility shareholders, rather than ratepayers, have had to bear all or part of the cost of a new plant. As a result, utilities are more reluctant than before to bear the risks of building new capacity.

At the same time, non-utility generation has been around for a while and has been proven to be reliable. Utilities who have dealt with these generators have acknowledged their reliability in situations such as last year's San Francisco earthquake. For these reasons, I think you will find that utilities which need new generating capacity are increasingly willing to buy your power. In addition, many economists suggest that electric utilities in the United States have underforecast load growth during the '90's, so opportunities to sell capacity to utilities may increase during the next several years.

There is another side to this story which you should also be aware of. Regulatory and economic barriers which discouraged non-utility generation which did not qualify under PURPA have been reduced. As a result, there is interest in this area by large developers, including non-regulated utility subsidiaries. Generally the projects are increasing in size, with capacities as high as several hundred megawatts.

As I mentioned, utilities are turning to competitive bidding when they need new capacity. What this means to you is that there will be more competition when you try to sell capacity to a utility and that your larger competitors may have a price advantage due to the economies of scale. In spite of this competition, I am optimistic about the future of generating projects fueled by MSW for three reasons.

First, a project like yours may be ideal where a utility is of the old school and has not wanted to deal with qualifying facilities, despite the legal obligation to do so. Your projects typically will be small enough so they will not be viewed as threats to the utility's rate base. The utility may be happy to sign a contract with you, so it can point to your contract when larger developers complain that the utility is discouraging the development of QF's.

Second, the national concern about the environment and waste disposal has led some states to pass laws which encourage non-utility generation fueled by landfill gas and MSW. Two of those states are Illinois and Michigan. In Illinois the standard rate available to a qualifying facility is less than 2 cents/kwh. Where the qualifying facility is fueled by MSW, Illinois law requires that the utility purchase power at a rate equal to the rate paid to that utility by the city or county where the facility is located. (Such facilities must be qualifying facilities under PURPA and must be certified by the Illinois Commerce Commission.) This can be as high as 6 or 7 cents a kilowatt hour. The utility receives a tax credit for the difference between the two rates. The generating facility must repay the difference between the two rates to the state after it has been in operation for ten or twenty years, depending upon the type of project. The end result is an interest-free loan which enhances the project's cash flow in the early years.

Michigan has taken a slightly different approach. Under the Michigan law, utilities must pay the highest legal rate for energy and capacity purchased from MSW facilities even if the utility goes out for bids and is able to purchase capacity from other sources at a lower rate. In both states, purchases from MSW facilities are not counted in determining whether a utility has exceeded its permitted capacity reserve margins.

The third reason I am optimistic about MSW fueled generation is that utilities do not want to be overly dependent on generation which burns a single type of fuel. They seek fuel diversity in order to limit the impact of outages due to interruptions in fuel supply. Landfill gas and MSW enhance utility fuel diversity. For example, if a utility is heavily dependent on natural gas, your projects will be attractive because, unlike natural gas, your fuel supply will not be affected by outages or curtailments of transporting pipelines. This advantage is significant because, if you bid to sell capacity to a utility, most of your competitors will be projects fueled by natural gas.

In evaluating a seller's fuel supply when it buys generating capacity, a utility also will want to see a firm fuel contract for the term of the power sale contract. Here again, your projects have the edge over natural gas in the current gas market. This is because, at the present time, it is almost impossible to sign a contract for a firm, long term supply of natural gas at a reasonable price. In contrast, it is generally possible to line up a supply of MSW on a firm basis. Your ability to present a strong fuel supply contract will help sell your project to a utility.

Federal Regulatory Issues

Now that I have given you a look at where we are today, I want to turn to some of the state and federal regulatory issues you will face in connection with your generating facility. As

I mentioned earlier, PURPA requires that utilities purchase electricity generated by qualifying facilities which burn MSW. Under PURPA, a qualifying facility is entitled to received a rate equal to the purchasing utility's avoided cost. The avoided cost is the cost to the utility if it had generated the same amount of power itself instead of buying it from the qualifying facility. If the utility needs additional generating capacity, the avoided cost must include a component to compensate the qualifying facility for the fact that the power purchase has allowed the utility to avoid or to defer building new capacity. The actual method of calculating avoided cost is determined at the state level and will vary from one utility to another.

Besides a guaranteed market for their power, there are three other important benefits available to facilities which qualify under PURPA. First, qualifying facilities and their parent companies are exempt from regulation by the Securities and Exchange Commission under the Public Utility Holding Companies Act. Second, utilities are required to provide backup power to qualifying facilities at cost-based, non-discriminatory rates. Backup power is the catch-all term for any power the qualifying facility is unable to supply for its own use. With an MSW project, you are most likely to need utility service for startup after an outage. Third, PURPA exempts most qualifying facilities from regulation as utilities at the state and federal levels. Facilities larger than 30 megawatts are subject to regulation by the Federal Energy Regulatory Commission (FERC) and must make certain filings before commencing operation.

The benefits of PURPA are available to MSW fueled facilities which meet the following three criteria:

1. First, the generating facility must have a generating capacity no greater than 80 megawatts. This should include most MSW fueled facilities.
2. Second, a utility may not own more than a 50 percent equity interest in the facility; and
3. Third, the facility must be fueled primarily by MSW.

This means that use of natural gas or other fossil fuels cannot exceed 25 percent of the total energy input in a calendar year. More importantly, fossil fuels can be used only for certain purposes specified in PURPA or otherwise permitted by the FERC, the federal agency which administers PURPA. You cannot simply oversize your facility in relation to your projected supply of fuel and burn fossil fuel 25 percent of the time, unless your usage falls within the permitted uses.

Once you know that your facility meets these criteria, the next step is to qualify the facility with the FERC. This can be done in one of two ways. First, the owner or operator of the facility can self-certify by filing a Notice of Qualifying Status with the FERC. The second alternative is to ask the FERC to issue an order certifying that the facility qualifies under PURPA. From a legal standpoint, both approaches achieve the same result, although there may be practical reasons to seek an FERC order instead of self-certifying.

Besides defining qualifying facilities, the FERC rules address various other aspects of PURPA. For example, the rules define those times when, for operational reasons, a utility is not required to purchase power from a qualifying facility. I will not discuss those rules here other than to say that you should become familiar with them.

Non-utility generating facilities which do not qualify under PURPA are commonly known as independent power producers or "IPPs". If your facility is an IPP, you will have opportunities to respond to bids for capacity by some utilities, although utilities are not required to buy your power. You will have to seek certain authorizations and waivers from the FERC, and the Public Utility Holding Companies Act may affect the ownership structure of your project. The regulatory climate is becoming increasingly favorable to IPPs, so inability to qualify under PURPA should not necessarily deter you from developing a project.

State Regulatory Issues

Now I'm going to turn to the state regulatory scene. Because the FERC regulations are implemented at the state level, you will have to look to your state public utility commission after you qualify your facility with the FERC, if you plan to sell power to an investor-owned utility. For municipal utilities, the situation varies by state. Often there is no state regulation, so you will have to look to the FERC if you want to enforce your rights under PURPA.

As you have seen, the basic issues of who qualifies under PURPA and the benefits available under PURPA are federal questions. State public utility commissions administer PURPA insofar as rates paid to qualifying facilities, rates utilities may charge for backup power, utility interconnection charges, and most other aspects of the relationship between the utility and the qualifying facility. All of these items must meet the standards set out in the federal rules, but you will find that each state has its own interpretation of those rules. For that reason, it is essential that you become familiar with the PURPA rules of your state commission before you approach a utility about buying your power.

As you know, a utility is required to pay a rate for your power which is equal to its avoided cost. That rate will either be set or approved by the state commission. Typically, the rate will include an energy payment for each kilowatt hour of electricity delivered. The energy payment generally reflects the utility's costs for fuel and for operating and maintenance expenses. The capacity component also may be paid on a kilowatt hour basis. More commonly, however, the capacity component is a monthly payment per kilowatt of capacity.

During the last several years, utility avoided costs have decreased in most areas of the country. One major exception is the northeast, where utilities need generating capacity. Where we saw avoided costs as high as eight or ten cents/kilowatt hour six or eight years ago, many people consider four cents an attractive rate today. Where utilities do not need capacity, avoided costs may be 2 cents or less, which can make it very difficult to support a project, unless the state has passed legislation similar to the Illinois law I mentioned earlier.

You will find that many utilities have a tariff in place which includes a standard rate to be paid for purchases of energy (and sometimes capacity) from qualifying facilities. However, you should keep in mind that you are not limited to the tariff rate. Instead of the tariff, you may negotiate a rate with the utility for the purchase of your power. This rate must reflect the utility's avoided cost over the life of your contract, as it exists when the power is sold, or as projected when the contract is signed. There are many ways to design such a rate. For this reason, you may want to use the services of a rate consultant to be sure that any non-tariff rate you propose is designed in a way which is acceptable to the state commission.

Besides setting the power purchase rate, the state commission sets the rate which you pay to buy backup power from the utility. This rate can be significant because it can include a demand component which you must pay every month whether or not you use backup power that month. The demand component may be based on your maximum usage of power during the year. Here as with avoided cost, you may be able to propose a negotiated rate, subject to approval of the state commission.

There are also several indirect ways in which the state commission will affect your project. The commission's determinations of utility need for generating capacity, type of new capacity, and timing of capacity additions all impact your ability to sell power to utilities regulated by the Commission. In addition, the state public utility commission may prescribe standard contracts for power purchases by utilities. State commissions also may adopt generic rules which will affect your project.

In each of these situations you can intervene before the commission, individually or as part of a group with similar interests. Whether or not you decide to invest the time and money to fully participate in a commission proceeding, your very presence as an intervenor will remind the commission, and its staff, that there are interests to consider other than utility interests.

Your state commission also can be helpful if you reach an impasse in negotiating with the utility, either before or after a contract is signed. In most states you can request that the commission resolve your dispute with the utility. Sometimes commission staff will mediate a dispute and you can reach a reasonable settlement without filing a formal complaint.

As I mentioned, many utilities are turning to competitive bidding if they need capacity. This is because they generally have offers to buy more capacity than they need. At the present time, there is a trend toward greater consideration of non-price factors in selecting a winning bid. Here, fuel diversity and environmental concerns may favor MSW projects. Some bidding schemes may include a set-aside which provides that a certain block of capacity must be purchased from generating facilities burning fuels such as MSW.

Bidding schemes are generally approved by the state commission. A bidding scheme may be proposed by a utility or may grow out of a generic rulemaking. As a participant in this process, you will have yet another opportunity to develop a climate in your state which is favorable to MSW projects.

Contract Issues

Now I am going to turn from the regulatory arena to your power sale contract with the utility. I want to mention some of the major contract terms which you should be aware of in your negotiations.

I have already discussed avoided cost and backup power rates so I won't mention them again here. Some other contract provisions which will have a strong impact on the economics of your project include these five:

1. "Regulatory out" clauses,
2. Dispatchability requirements,
3. Cost of interconnection facilities,
4. Cost of upgrades on the utility's system, and
5. Performance standards.

First, a "regulatory out" clause is a contract provision which allows the utility to reduce its payments to you or to seek a refund of past payments if it cannot pass those payments on to its customers. Utilities often want the right to use this "regulatory out" at any time during the contract term. The risk of having this provision in a contract can be reduced if you request that your state commission approve the utility's passthrough of its payments to you for the life of the contract, before the contract term begins. Whether or not you achieve this goal, you may want the right to terminate the contract rather than receive a lower rate for the remainder of the contract term.

Second, a utility may require the ability to dispatch your plant. That means the utility can tell you to shut your plant down in certain situations. Sometimes the utility will want the ability to automatically back off your generation by computer. In negotiating this provision, you will want to specify those times when you will be required to shut down, including a maximum number of hours each year. You should not be required to back off your generation where the utility would not back off its own plant of equivalent size and type. Even if you are asked to back off your generation, you should continue to receive capacity payments. You will probably end up losing the energy payments in such cases.

The third and fourth contract terms are at issue because PURPA requires that you pay for additional equipment and facilities required by the utility to enable the utility to receive your power. This includes interconnection facilities which are required so that you may begin delivering power to the utility. You may also be asked to bear the cost of upgrades required by the utility at the interconnection or on its transmission system during the term of your contract.

In both cases, it is important that your contract specify your maximum financial obligation for each of these items. Otherwise you will have signed a blank check for the utility to cash. With regard to upgrades, you may also want the right to terminate the contract rather than incur substantial cost toward the end of the contract term. You should also require that the utility provide a detailed explanation of its actual costs for interconnection facilities and subsequent upgrades.

Fifth and last, if you are selling capacity to a utility, the utility will specify a level at which you must generate. For example, you may be required to generate at 75 percent of nameplate capacity on an annual basis. This is called a capacity factor. If you do not meet this level of performance, your capacity payments will be reduced. In setting the capacity factor, you must be realistic as to how well your plant can perform. You should also be sure that your plant is not expected to perform any better than an equivalent utility-owned plant.

Conclusion

In the remaining few minutes, I want to offer a couple of practical suggestions which may be of help to you. First, I want to stress the opportunities for input into actions by your state legislature and your state public utility commission. They have to be educated about the value of MSW fueled generation. Many experts believe that one half of the generating capacity needed in this country by the year 2000 will be supplied by non-utility operators. This will create a window of opportunity for you, particularly if your industry joins together to market MSW fueled generating projects.

Second, it is important that you keep up on regulatory developments in this area. These developments may suggest a new approach which you had not considered in connection with your project. For example, the FERC has recently issued several orders which permit qualifying facilities to own electric transmission and interconnection facilities. There are two situations where you may want to own these facilities. The first is where a utility quotes a prohibitive charge for interconnection facilities. You may be able to construct some of those facilities at a lower cost. In the second situation, you may find that a neighboring utility will pay more for your power than your local utility. Your local utility may not agree to wheel or transmit your power to the second utility. In that situation, you should consider building a line to deliver your own power to the second utility.

If utility rates won't support your project, consider selling your power directly to a large consumer. You may risk becoming subject to regulation at the state level, but there may be ways to minimize that risk. In this situation, consider involving the purchaser in your facility's ownership or seeking an order exempting your project from state regulation. The key is to be aware of all your options as the environment changes and to think creatively.

That concludes my prepared remarks. Thank you for your attention. I will be happy to answer any questions you may have.

THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY MUNICIPAL WASTE COMBUSTION RESIDUE SOLIDIFICATION/STABILIZATION EVALUATION PROGRAM

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Presented at the

First United States Conference on Municipal Solid Waste Management

June 13-16, 1990

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MUNICIPAL WASTE COMBUSTION RESIDUE
SOLIDIFICATION/STABILIZATION PROGRAM

ABSTRACT

Vendors of solidification/stabilization (S/S) and other technologies are cooperating with the U.S. Environmental Protection Agency's (U.S. EPA's) Office of Research and Development (ORD), Risk Reduction Engineering Laboratory to demonstrate and evaluate the performance of the technologies to treat residues from the combustion of municipal solid waste (MSW). Solidification/stabilization is being emphasized in the current program. This technology may enhance the environmental performance of the residues when disposed in the land, when used as road bed aggregate, as building blocks, and in the marine environment as reefs or shore erosion control barriers.

The program includes four S/S process types: cement, silicate, cement kiln dust and a phosphate based process. Residue types being evaluated are fly ash, bottom ash and combined residues. An array of chemical leaching tests and physical tests are being conducted to characterize the untreated and treated residues.

The S/S evaluation program is the first part of ORD's Municipal Solid Waste Innovative Technology Evaluation (MITE) program.

INTRODUCTION

During the past two years there has been a significant concern expressed about the management of the residues from the combustion of municipal solid waste. Much of this concern has centered on the fact that when the residues are subjected to the Extraction Procedure for Toxicity (EP tox) and the Toxicity Characteristics Leaching Procedure (TCLP) they will fail for lead and cadmium a significant portion of the time. This occurs more often for the fly ash, less for the combined fly ash and bottom ash, and least often for the bottom ash alone. Because of this, a controversy exists as to whether or not the residues should be considered and regulated as a hazardous waste or exempted because they originated from burning municipal solid waste. Several states are requiring that these residues be disposed into landfills with designs and operating procedures as, or more, stringent than those for hazardous waste. Municipal Waste Combustion (MWC) ash characteristics are extremely variable as is the leachate from these ashes. Ranges of metal concentrations observed in bottom and fly ashes from many sources are presented in Table 1[1]. Detailed descriptions of the chemical and physical characteristics of MWC residues are available[2,3,4,5].

Because of the growing concern about the residues and anticipating the need for appropriate treatment techniques, the Office of Research and Development designed and implemented a program to evaluate the use of solidification/stabilization technologies for treating the residues. The program was formally announced on September 19, 1989. Originally known as the U.S. EPA MWC Ash Solidification/Stabilization Evaluation Program, it is now the Municipal Innovative Technology Evaluation program (MITE). This paper presents the design and status of the current program.

THE MITE PROGRAM

The MITE program is an Office of Research and Development (ORD) program designed to conduct demonstrations of technologies for managing municipal solid waste. The objective is to encourage development and use of innovative technology for municipal solid waste management. The program is patterned after the Superfund Innovative Technology Evaluation program (SITE). It is, therefore, a cooperative program in which the technology developer and/or vendor pays the cost of conducting the demonstration. U.S. EPA pays the cost of testing and evaluation, including analytical cost. U.S. EPA will report the results of the evaluations in an unbiased manner, thus providing a means for assisting municipalities and others to better evaluate and select technologies more appropriate for their given situation.

The current program is demonstrating and evaluating alternatives for the treatment of residues from the combustion of municipal waste. While it is uncertain if treatment will be required prior to disposal, it is most likely that treatment will be necessary for any utilization option. Solidification/-Stabilization (S/S) technology was selected for initial evaluations based upon experience and knowledge of the technology for treating hazardous waste and experimental studies on solidifying municipal waste combustion (MWC) residues(6). Solidification/Stabilization (S/S), in general terms, is a technology where one uses additives or processes to transform a waste into a more manageable form or less toxic form by physically and/or chemically immobilizing the waste constituents. Most commonly used additives include combinations of hydraulic cements, lime, pozzalons, gypsum, silicates and similar materials. Other types of binders, such as epoxies, polyesters, asphalts, etc. have also been used, but not routinely. More detailed descriptions of S/S technology are available(7). The program objective is to provide a credible data base on the effectiveness of S/S technology for treating the residues.

Preliminary design of this program was completed by the U.S. EPA. Because U.S. EPA believed it important to have results completely unbiased and as scientifically credible as possible, a panel of international experts was assembled to provide oversight to the program. This Technical Advisory Panel (TAP) consists of experts from academia, industry, state and federal governments, and environmental groups.

PROGRAM ORGANIZATION AND DESIGN

Organization - The program involves the participation of several different organizations with separate roles. The Risk Reduction Engineering Laboratory (RREL) is managing and directing the program. The TAP is providing valuable peer review, oversight and technical design. This service is donated. Staff at the U.S. Army Corps of Engineers Waterways Experiment Station (WES) are coordinating and observing the demonstrations at WES facilities located in Vicksburgh, Mississippi. WES is also responsible for performing the physical testing and some of the extraction/leaching tests. A Versar laboratory experienced in MWC residue analysis is performing the majority of the analytical work. Specialized analyses, testing and modeling is being performed by the University of Illinois and the Netherlands Energy Research Center. Rutgers University in conjunction with the New Jersey Institute of Technology is assisting in the coordination of the various activities and participants. Vendors are participating by providing valuable time and money.

Tests and Analyses - The program was conceived by U.S. EPA and the basic design was based on the testing and evaluations performed on hazardous and other waste treated by solidification/stabilization technologies in various research and evaluation programs of U.S. EPA. At the request of U.S. EPA, the TAP reviewed and modified this preliminary design. The tests and analytical protocols included in the program are provided in Tables 2, 3, 4, 5, 6 and 7. The purpose for conducting the test and analysis listed is also included. Methods listed in the Tables are either approved U.S. EPA or ASTM methods.

Ash Types Tested - Residue selected for testing was limited to that collected from a modern state-of-art waste to energy facility (i.e., high burn out, lime scrubber with fabric filter, etc.). There were several reasons for limiting the number of residues included in the program. The prime objective is to evaluate solidification/stabilization for treating the residues, rather than determine how characteristics of different residues may affect the performance of the technology. In addition the apparent variability of MWC residues is becoming less of an issue, especially with the newer combustion facilities. Proper sampling and analysis, changes in air pollution controls and similar factors will play more important roles in the variability of residues. The program currently includes four different S/S process types plus one control. Because of the extensive list of tests being performed, the analytical cost for the program is the major U.S. EPA expense. For each additional source of residue added these costs must be duplicated. This would have reduced the number of processes which could be evaluated to an unacceptable number. The program is also developing and evaluating testing protocols that can be used to evaluate selected S/S processes on different residues if required in the future.

These considerations quickly led to the conclusion that the program would test the residue from only one facility. The residue types are the fly ash (including the scrubber residue), the bottom ash and the combined ash. The MWC facility samples has the following process sequence: (i) primary combustor with vibratory grates, (ii) secondary combustion chamber, (iii) boiler and economizer (iv) dry scrubber with lime, and (v) particulate recovery using baghouses (fabric filters). Bottom ash sampled was quenched after exiting from the combustion grates. Fly ash sampled was mixed residuals from the scrubber and baghouses. The fly ash was screened to pass a 0.5 inch square mesh. The bottom ash and combined ash were screened to pass a 2 inch square mesh at the MWC facility. Materials not passing through the 2 inch mesh were rejected. After shipment to the WES, each ash type was dried to less than 10% moisture, crushed and screened to pass a 0.5 inch mesh (nominally 3/8 inch after clogging), and homogenized.

Processes Selected - Process types selected in the program are cement based, silicate based, cement kiln dust and phosphate based. A non-vendor cement process is being performed by experienced staff of WES and U.S. EPA in Vicksburg, MS.

Process selection was competitive based upon evaluation of proposals submitted by parties interested in participating. A formal Request For Participation was issued by U.S. EPA which provided information required to respond. Under direction of U.S. EPA, the TAP developed evaluation criteria which was used to make final selections.

Twenty-one responses were received and evaluated. The responses were divided into 11 S/S processes, 6 vitrification processes and 4 other miscellaneous processes. Based upon the evaluation criteria, the S/S process proposals were judged to be superior. In order not to select similar S/S process types (e.g., two cement based) with the limited resources available, the decision was made to select the best proposal out of the different types available. The vitrification process proposals were generally incomplete and failed to address some major issues. This, in conjunction with the potential high quantities of residues required for most of these processes, resulted in the decision not to select one for evaluation. Alternatives for evaluating vitrification processes are being pursued. Proposals in the other miscellaneous category were not acceptable and were rejected.

During the request for participation, evaluation and selection process, provisions were made for maintaining confidentiality of information so marked by the responders.

Following is a brief description of each of the processes selected.

Cement Based Process - This process involves the addition of polymeric adsorbents to a slurry of MWC ash prior to the addition of portland cement. The final product is soil-like rather than monolithic.

Silicate based process - This is a patented process using soluble silicates as an additive with cement. The additives are used to promote several types of reactions with the polyvalent metal present to produce insoluble metal compounds, gel structures, and promote hydrolysis, hydration and neutralization reactions. The process immobilizes heavy metals through reactions involving complex silicates. The final product is clay-like material.

CKD process - This is a patented process involving mixing the MWC ashes with quality controlled waste pozzolans and water. Good quality control on the reagents is required because they are secondary materials derived from processing other materials. Therefore, the pozzolanic characteristics critical to the process are subject to change. The finished product is similar to moist soil, but hardens to a concrete-like mass within several days.

Phosphate process - A water soluble phosphate is used in this patented process to convert lead and cadmium to insoluble forms. The process is designed such that fly ash is mixed with lime, then this material can be mixed with the bottom ash and the mixture treated with a source of water soluble phosphate. The process does not alter the physical state of the ash.

DEMONSTRATIONS

Process - The procedures for conducting the demonstrations were established so that the process vendors could review data from characterizations of the various ash prior to the demonstration. Samples of the ashes were also furnished to the vendors so that they have the opportunity to pretest their process prior to the demonstration. This permitted them to make modifications if desired. Vendors were responsible for providing any specialized equipment or ingredients required. Each agreed to permit observation by U.S. EPA selected observers if it was necessary to conduct the demonstration at the vendor's facilities. Otherwise the demonstrations were to be conducted at a U.S. EPA selected facility and observed by U.S. EPA designated staff.

During the process demonstration, each vendor was requested to carry out three replicate batches for each ash type. A total of between 50 and 100 gallons of each ash type is being treated for each process. Numerous molds and samples are prepared from these batches. All molds and sample containers are provided by WES and U.S. EPA. Each vendor provides enough process additives for analysis and archiving. Most equipment and laboratory facilities required for the demonstrations are provided by WES.

Scale - The processes are being demonstrated at bench scale. Reasons for this include the technologies being tested, resources required for full scale demonstrations and the desire to include as many different processes as possible within available resources. The program plan was to conduct a full scale field demonstration of a selected process if deemed necessary. Because of the nature of S/S technologies, U.S. EPA and the TAP believed that bench scale demonstrations were adequate to prove if the technology is an effective treatment for MWC residues. Sufficient experience is available for conducting the engineering and design required for scaling to a specific situation. Furthermore, the bench scale permitted much more detailed testing to be completed and thus more exploration of the basic mechanisms involved in the process. This in turn will assist in the determination of expected long-term behavior. A drawback with this scale however, is the difficulty in sampling and variability associated with bottom ashes.

Schedule - At this writing three of the process demonstrations have been completed. Barring unexpected difficulty all will be completed by mid-May. Because of curing times (i.e., 28 days) and other test requirements the physical testing, chemical testing and analytical procedures will not be completed until mid-October. The final report is expected by the end of December 1990.

Future MITE Demonstrations - It is planned that future MITE demonstration candidates will be solicited by notice in the Commerce Business Daily, through appropriate MSW trade organizations, interested developers and similar means. At this time, emphasis for these demonstrations is expected to be on processes for recovering marketable products from the MSW stream. Resources of 1000K have currently been allocated in FY'91 for MITE.

RESULTS AND CONCLUSIONS

Results from the various physical and chemical tests are not available at this writing. Statements and conclusions concerning process performance are therefore not possible. The final report will provide the results from all the testing and will provide a sound basis for determining the effectiveness of S/S techniques to treat MWC residues. The results will also provide information on the most useful testing protocols for evaluating, selecting and designing the S/S process for treating MWC ash.

TABLE 1. Ranges of Total and Leachable Metals in United States MSW Combustor Ash as Determined by Researchers[1]

Compound	Bottom Ash mg/kg	Bottom Ash Leachate mg/l	Fly Ash mg/kg	Fly Ash Leachate mg/l
Pb	31 - 36,600	0.02 - 34	2.0 - 26,000	0.019 - 53.35
Cd	0.81 - 100	0.018 - 3.94	5 - 2,210	0.025 - 100
As	0.8 - 50	ND(0.001) - 0.122	4.8 - 750	ND(0.001 - 0.858)
Cr	13 - 1,500	ND(0.007) - 0.46	21 - 1,900	0.006 - 0.135
Ba	47 - 2000	0.27 - 6.3	88-9000	0.67 - 22.8
Ni	ND(1.5) - 12,910	0.241 - 2.03	ND(1.5) - 3,600	0.09 - 2.90
CU	40 - 10,700	0.039 - 1.19	187 - 2,300	0.033 - 10.6

ND = Not Detectable; () = Detection Limit

TABLE 2. Chemical Analysis Performed on Treated and Untreated Ash

Assay	Method	Purpose
Total Extractable Metals	3050, 6010	See Metals Analysis List (Table 6)
Dioxins/Furans	8280	Community Concern (Untreated Only)
pH, Anions, Total Available Dissolved Solids, and Ammonia	9045, 300.0, 160.1, 350.2	Salts and Ionic Species
Loss on Ignition	209D	Residual Organic Matter (typ. 2-5%) and Water of Hydration
Chemical Oxygen Demand	508A	Reduced Inorganic and Organic Matter
Total Organic Carbon		Residual Organic Matter

TABLE 3. Physical Tests Conducted on Treated and Untreated Ash

Physical Test	Purpose
Moisture Content	Useful general data
Loss on Ignition	Residual/Organic Matter and Hydrated Water
Modified Proctor Density	Compressibility
Bulk Density	Volume and Similar Physical Changes
Particle Size Distribution	Potential Use as Aggregate
Cone Penetrometer	Curing Rate and Hardness
Pozzolanic Activity*	Untreated S/S Potential
Porosity/Surface Area	Potential for Liquid-Solid Contact and Diffusion Effects
Permeability	Resistance to H_2O Transmission; Assist in determining contaminant Release Mechanisms
Unconfined Compressive Strength (UCS)	Load Bearing Capacity
UCS after Immersion	Hydration Effects and Swelling
Freeze/Thaw**	Physical Weathering Effects
Wet/Dry**	Physical Weathering Effects

* Untreated Ash Only
** Treated Ash Only

TABLE 4. Leaching Tests for Treated and Untreated Ash

Leach Test	Purpose
TCLP (1 extract)	Regulatory Leach Test
Distilled Water Leach Test (4 extracts)	Extended Extraction in a Well-Mixed System without Acid
Acid Neutralization Capacity (10 extracts)	Buffering Capacity of Solid and pH Dependence of Metals Release
Monolith Leach Test (7 extracts)	Estimate Potential Release Rates Through Diffusion
Static pH @ pH = 4.0 with HNO_3 Liquid:Solid Ratio is 100:1	Total Species Available for Release Under "Worst Case" Scenario

TABLE 5. Chemical Analysis Performed on Leach Test Extracts

Assay	Method	Purpose
Metals	3020	See Metals Analysis List (Table 6)
Chemical Oxygen Demand (COD)	508A	Surrogate for Leachable Organic Species
Total Suspended Solids	160.2*	Physical Erosion of Solid
Total Dissolved Solids	160.1	Leachable Total Salts
pH	150.1	

* Monolith leach test only (ANSI 16.1)

TABLE 6. List of Metals Subjected to Analysis

Metal	Untreated and Treated Ash (Solid)		Extracts
	ICP or AA	Neutron Activation	ICP or AA
Aluminum	X	X	X
Antimony	---	X	X
Arsenic	X	X	X
Barium	X	X	X
Beryllium	X	---	X
Boron	X	---	X
Cadmium	X	---	X
Calcium	---	X	X
Chromium	X	X	X
Cobalt	---	X	X
Copper	X	---	X
Iron	---	X	X
Lead	X	---	---
Lithium	X	---	X
Potassium	---	X	X
Magnesium	---	X	X
Manganese	---	X	X
Mercury	X	---	---
Molybdenum	---	X	X
Nickel	X	---	X
Selenium	X	X	---
Sodium	---	X	X
Silicon	---	X	X
Silver	X	X	X
Strontium	---	X	X
Thorium	---	X	---
Tin	X	---	X
Titanium	---	X	X
Vanadium	---	X	X
Zinc	X	X	X

TABLE 7. Additional Metals Analysis Using Neutron Activation

Untreated and Treated Ash (Solid)

Metal	Neutron Activation Only
Cesium	X
Dysprosium	X
Gallium	X
Hafnium	X
Indium	X
Rubidium	X
Scandium	X
Uranium	X

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"UTILIZATION APPLICATIONS OF RESOURCE RECOVERY RESIDUE"

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INTRODUCTION

In 1989 MSW ash will amount to between 2.8-5.5 million tons and its annual generation rate is expected to increase two to five depending on how many facilities are built (1). The manner in which these residues are regulated impact the Waste-to-Energy Industry. Such regulation, however, varies by state and with proposed federal legislation. Attempting to regulate and legislate MSW ashes without a technical appreciation may be one reason for such diversity. This paper provides an engineering perspective toward achieving environmentally acceptable and cost-effective ash disposal and utilization.

o In-Plant Ash Fundamentals

The ash generated from Mass Burn MSW systems is composed primarily of Bottom Ash [BA] (75-85 weight%) and FA (15-25 weight%). The ash generated from Refuse Derived Fuel [RDF] reflects a higher FA (40 weight%) to BA (60 weight%) distribution; due to RDF's suspension firing.

A typical Flue Gas Cleaning [FGC] system consists of reacting the incinerator flue gas with lime (usually in an absorption vessel) followed by particulate removal (bag house or electro-static precipitator). While these systems are designed to remove Acid Gases and particulate, they increase the waste generation rate due to the product of reaction products and unreacted lime. The AGC waste is composed of Fly Ash [FA] and Dry Flue Gas Cleaning (i.e. Scrubber Residue [SR]) Reaction Products. Equipped with a FGC system, the combination of BA, FA, and SR amounts to 1/4 to 1/3 of the weight of the MSW feedstock.

Depending upon the design of the Ash Handling system the FA/SR waste may be combined with the BA. Since the BA is quenched, the resultant blend will contain water. This mixture of ash and FGC wastes are conveyed to a disposal site. This Combined Ash [CA] may be thixotropic mud-like and contains considerable lime. Its solids content should be maintained to ensure optimal transportability characteristics i.e. (a) prevention of fugitive dusting; (b) elimination of spillage; (c) prevention of pre-mature set-up reaction. Typically, the transportation solids content could range from 80-90% to satisfy these criteria.

In view of the industry-wide trend toward installation of dry lime Air Pollution Control [APC] to remove such acid gases as SO2, HCl etc. and in light of the USEPA's proposed air emissions requirements of MSW incinerators (2), this paper's discussion of MSW ash emphasizes the presence of unreacted lime reagent. Engineering properties are discussed to provide a basis for utilizing the ash. Due to the controversy and previous misconceptions surrounding MSW ash, however, its environmental characteristics should be considered.

o Environmental Considerations of MSW Ash

Recent field studies of MSW ash landfills strongly supports the relatively benign characteristics of this ash.

NUS (3) states that "the leachates ... are close to being acceptable for drinking water use, as far as the metals are concerned". Both the public and regulatory community have focused on the results of laboratory tests (e.g. EP Tox, TCLP) to predict MSW ashes' leaching. These tests, however, do not reflect field leachates results; "leachate from the disposal sites tested out below the level that those two tests deem hazardous" (4).

Although EP Tox results have shown excessive levels of Pb and Cd, the presence of unreacted lime (from the APC system) could account for significant reductions of such constituents (5). The author has contended that such ash should be deemed pozzolanic and recognized by regulatory authorities (6). Recently some state regulatory agencies have recognized this behavior and incorporated it within their classification of MSW ash landfills. The California Dept. of Health Services concluded that MSW "... ash possesses intrinsic physical and chemical properties rendering it insignificant as a hazard to human health and safety, livestock, and wildlife". The "intrinsic property" is the formation of a "lime/pozzolan mixture" so that when "compacted (the) ash forms a hard, non-erodible surface" (7).

o Low Empirical Solubilities of MSW Ash

Rather than regarding the presence of lime inducing pozzolanic behavior as a benefit (to reduce the ashes' potential leachate), some regulators have postulated that the lime could deleteriously affect underlying clay liners (5). The following summarizes the leachate and raw pH data:

	Lime-based APC		ESP Only	
	ASH	LEACHATE	ASH	LEACHATE
pH	11.68 - 11.85	6.7 - 7.4	11.58 - 11.82	6.9
	10.91 - 11.67	6.5		

The significant pH drop from raw ash levels to leachate values are explained by considering the inherent pozzolanic behavior of lime-based MSW ash. As CaO enters into the pozzolanic reaction it is no longer available as a soluble component and is not detected in the leachate. The alkaline pH of the non-lime based ash and its similar reduction of leachate also may be explained by considering the pozzolanic chemistry. CaO reacts with Al_2O_3, Fe_2O_3, and SiO_2 to form pozzolanic end-products (8). MSW Ash inherently reflects an alkaline pH; Water Leach testing of Hennepin Energy Resource Company's Bottom Ash pH = 9.2 - 9.3 (9). The reduction of soluble alkalinity (water leach pH) in ashes from Resource Recovery Facilities with and without lime-based APC could be due to consumption of pozzolanic reactants.

TABLE 1: POZZOLANIC REACTANTS - LEACHATE pH

	W/ Lime APC	W/O Lime APC
% Al_2O_3 [A]	7.39 - 10.30	5.93 - 13.00
% Fe_2O_3 [F]	3.90 - 18.15	5.73 - 10.64
% SiO_2 [S]	19.00 - 43.80	32.00 - 62.90
% CaO [C]	15.10 - 25.70	9.70 - 12.00
% A + S + F	32.76 - 66.85	50.83 - 77.65
[A + S + F]/ C	1.27 - 3.63	4.24 - 8.01
pH - Ash	10.91 - 11.85	10.36 - 11.82
pH - Wat. Leach-Int.	11.78 - 12.48	9.97 - 10.70
pH - Wat. Leach-Fin.	11.12 - 12.48	10.28 - 10.60
pH - Field Leach	6.50 - 7.40	6.90 - N.A.

NOTE: N.A. = Not Available

Table 1 depicts that both types of ashes lie within the pozzolanic requirements (ASTM 618) and that the ratio of pozzolanic reactants lies within the range of analogous clean coal technology residues(10).

The lower field leach pH's (6.5 - 7.4) compared to raw pH (10.28 - 12.48) and initial water leach pH (9.97 - 12.48) suggest a reaction. This reaction, however, may not be a neutralization mechanism since the final water leach pH of 10.28 - 12.48 predicts soluble alkalinity. Realizing the final water leach pH is much higher than the field leach pH, infers the reduction of soluble alkalinity due to a dissipative reaction. This reaction could represent the CaO combining with the other pozzolanic constituents. Lacking geo-technical engineering data from the NUS study prevents a more definitive explanation. Nonetheless, all the data indicates that the actual field pH's of MSW do not reflect their initial basic alkalinities and that only slight solubilization of alkaline constituents occur in nature.

ASH UTILIZATION AS NATURAL LINER

The Waste-to-Energy facility's primary concern regarding MSW ash involves yielding a transportable material. This ash, however, upon exiting the mechanical conveying system, awaiting transport to a land-fill, may be subject to regulatory testing and should be subject to proper Disposal Site Management. This paper offers data demonstrating the concrete-like behavior of MSW ash and incorporates such results into Ash Management Principles to ensure set-up. Regulatory agencies should review this technical information and allow the application of basic Civil Engineering and Concrete Chemistry to be reflected within Sample Preparation Procedures and Testing.

Achieving the Inherent Concrete-like Behavior

Table 2 compares the author's derived mineralogical content of MSW ashes (Mass Burn and RDF) to Portland Cement. The comparative similaritics suggest that solubilization of MSW Combined Ash [CA] (i.e. BA, FA, and SR) should react in a concrete-like manner. The author's prior work has discussed this potential behavior of MSW ash (due to its favorable mineral composition) and of the relatively high lime content of MSW ash (due to higher stoichiometrics and no recycle) (9). RDF ash, also, reflects a higher lime content than Mass Burn Residues. This theoretical basis provides a framework for considering Heavy Metal Reduction and enhancement of geotechnical properties. Achieving such behavior depends upon solubilizing the free, available lime and attaining optimal compaction.

TABLE 2: CHEMICAL COMPARISON TO PORTLAND CEMENT

Composition of Portland Cement			MSW Ash	
Component	Cement	Clinker	Mass Burn	RDF
SiO_2	18-24	21.7-23.8	24	37
Al_2O_3	4-8	5.0-5.3	6	4
Fe_2O_3	1.5-4.5	0.2-2.6	3	5
CaO	62-67	67.7-70.8	37	43

Laboratory work has revealed an inverse trend relationship between (a) Percent Solids/Water of Solubilization and (b Mean and Particle Size Distribution. To achieve a Geotechnical Property (i.e. strength, permeability), reflecting set-up conditions, more water of solubilization was required for a recipe with finer Particle Size Distribution. A possible explanation for this relationship is that the smaller sized particles exhibit a greater surface area; thus requiring more water of solubilization within the voids to promote the pozzolanic or set-up behavior.

Effect of Water of Solubilization on Set-up Time

Not only does the introduction of additional water of solubilization facilitate attaining concrete-like behavior but optimizing the % Water of Solubilization reduces the set-up time. When highly reactive Combined Ash (i.e. Bottom and Fly Ash with Scrubber Residue) was tested at two different Percent Solids the following permeabilities and curing times were determined.

% Solids	Permeability (after 120 Hrs)	Permeability (after 28 days)
75	2.5 X 10 EXP-7 cm/sec	1.31 X 10 EXP-8 cm/sec
80	2.3 X 10 EXP-5 cm/sec	1.02 X 10 EXP-8 cm/sec

Achieving the significantly lower permeabilities (i.e. two orders of magnitude reduction) at the early cure time (120 Hours), when more water was present in the sample, suggests that adding water of solubilization accelerates the reaction. An aqueous phase is more quickly established for the chemical constituents to react. Since 28 day permeabilities were essentially the same for both Percent Solids samples, the reactions were completed for these ashes of equivalent composition. When more water is available for solubilization of reactive constituents, reaction time is reduced and a harder, less permeable material produced.

Field Demonstration of In-Situ Permeability

Such encouraging laboratory results justified a field demonstration. A field program, designed to demonstrate the viability of low-cost in-situ chemical treatment achieving liner-like permeabilities, was initiated at an older Mass Burn facility. Ash from this facility, not equipped with a FGC system, represented an opportunity to demonstrate the cost-effective methodology of in-situ addition of Portland Cement and of lime [CaO] to non-chemically reactive MSW ash. Field Curing occurred during worst-case winter conditions. A detailed description of this study has been reported by Forrester and Goodwin (11).

Test Patches were formed from non-reactive Combined Ash [CA]. Portland Cement [PC], 6-10 % by weight, and Lime [CaO], 6-7% by weight, were added in-situ to separate patches. Optimum waters of solubilization were attained to promote chemical reaction.

The permeabilities derived from the Field Demonstration Test Patches are compared to the results of a Laboratory Study. The Laboratory Study reflects PC dosages ranging from 6-9% and CaO dosages from 3-6% (by weight). Ashes used in the Laboratory Program were composite sampled from a newer Mass Burn facility, equipped with a FGC system contributing unreacted CaO to the Combined Ash [CA]. Permeability results of the field and laboratory programs are reported in Table 3. The variation of in-situ and laboratory permeabilities reflect typical field and lab testing differences (12).

Inherent Chemical (Concrete-like) Reactions

Bottom Ash [BA] should not contain free available CaO, since it is collected upstream of the FGC system. Combined Ash [CA] studied in the laboratory represents the combination of BA with the separately collected FA and SR. Since the CA studied in the field did not reflect lime contribution from a FGC system, the laboratory BA should represent a similar composition. Table 3 reports that older non-reactive CA + 0% exhibited a laboratory permeability of 1.9 X EXP-5 cm/sec; practically equivalent to raw laboratory studied BA permeability of 1.8 X EXP-5 cm/sec. Thus, the CaO Test Patch CA permeability results can be compared to Lab Program results for CA with and without CaO addition. These latter ashes were obtained from a newer facility reflecting significant inherent CaO due to high stoichiometry of the FGC system.

The Test Patch Program (Table 3) reports permeability results from 6.4 X EXP-6 cm/sec to 2.3 X EXP-8 cm/sec. The one to three orders of magnitude permeability reduction in the presence of free CaO suggests concrete-like behavior. The raw, but reactive, CA permeability of 5.5 X EXP-6 cm/sec could reflect the presence of excess lime contributed from the operating FGC system. Upon the addition of lime to reactive CA, permeabilities ranging from 4.2 X EXP-6 cm/sec to 8.1 X EXP-7 cm/sec were achieved. These permeabilities agree with field measurements. Both sets of results demonstrate at least an order of magnitude reduction of permeability; suggesting the presence of a lime-based concrete-like reaction.

Effect of Adding Portland Cement

Adding Portland Cement [PC] to non-reactive Test Patch CA reduced the permeability by two to four orders of magnitude. The field in-situ and cored permeabilities ranged from 7.5 X EXP-7 cm/sec to 2.8 X EXP-9 cm/sec. The permeabilities, obtained from the laboratory study of BA with similar PC dosages, ranged from 1.5 X EXP-7 cm/sec to 1.7 X EXP 10-8 cm/sec. Thus, the addition of 6-10% Portland Cement added to non-reactive MSW ash attained permeabilities varying from slightly greater to at least an order of magnitude less than the liner requirement of 1 X EXP-7 cm/sec.

TABLE 3: PERMEABILITY COMPARISON FIELD AND LABORATORY PROGRAM

Field Program Permeability Results

Dosage	In-Situ and Cores
CA + 0%	1.9 X EXP-5 cm/sec
CA 6 - 10%PC	7.5 X EXP-7 to 2.8 X EXP-9 cm/sec
CA 6 - 7 %CaO	6.4 X EXP-6 to 2.3 X EXP-8 cm/sec

Laboratory Program Permeability Results

Ash	Additive (%)	Permeability
BA	0%	1.8 X EXP-5 cm/sec
BA	6% - 10% PC	1.5 X EXP-7 to 1.7 X EXP-8 cm/sec
CA	0%	5.5 X EXP-6 cm/sec
CA	3% - 6% CaO	4.2 X EXP-6 to 8.1 X E-7 cm/sec

NOTES: All cores were tested at 28 days curing; Test Patch mixes and Laboratory Program testing were conducted at 14 days curing.

The lower permeabilities, of MSW ash treated with PC, compared to those, attained with CaO addition, may be due to less reactive CaO. Further testing, over extended curing time, is in progress to determine if lower CaO based permeabilities are achieved.

In-Situ Chemical Treatment Cost Savings

At a compacted density of 100 pound/cubic foot, one foot of CA with 10% PC should cost $3,900/acre; i.e. assuming placement and equipment by landfill operator (13). If an outside specialty contractor is employed, the cost of forming such a liner could increase to approximately $50,000. Comparison to single, double, synthetic and clay liners (costing from $250,000 to $500,000 per acre) indicates that significant cost savings ($200,000 to $450,000) can be realized by applying in-situ chemical treatment and engineering methodology to MSW ash disposal.

Monitoring Well Runoff Leachate

Table 4 reports on an 18 month field monitoring study (reported by Forrester) of leachate and runoff at an MSW ash monofill (14). These averaged results, not only indicate parity to Primary Drinking Water

Standards [DWS], but indicate one to two orders of magnitude lower Cd and Pb than reported by the EP Toxicity tests (15). Such discrepancy between field and lab data questions the EP Toxicity test to realistically predict the concrete-like behavior of MSW ash. Furthermore, comparing the leachate/runoff pH of 6.7 to CA's inherent pH of 12-13 suggests a 'set-up' reaction. The resultant monolith precludes surface solubilization of chemical specie. Based upon the operating results presented, the MSW ash from Resource Recovery systems, equipped with Flue Gas Cleaning, when properly managed in an engineering fashion, will achieve liner-like low permeable characteristics and leachate/runoff approximating primary DWS.

TABLE 4: LEACHATE RUNOFF COLLECTION RESULTS

PARAMETER	CONCENTRATION (mg/l)	PRIMARY DWS (mg/l)
Cadmium [Cd]	0.022	0.010
Lead [Pb]	0.007	0.050 0.005 [Proposed]
pH	6.7	6 - 9

ROAD CONSTRUCTION APPLICATIONS

In the past, MSW residues have been utilized for road construction (16). Incinerator ash has been tested at a few road construction applications in Pennsylvania.

Site	% Ash	PENN DOT/Technical Performance
Phila, PA (1975)	50	Acceptable
Delaware Co, PA (1975)	50	Acceptable
Harrisburg PA (1976)	100	Excellent (Fused Residue)

Conclusions derived from this work can be summarized as: (a) Loss On Ignition [LOI] < 10% - eliminate organics; (b) achieve ASTM specifications; (c) limit application to 50% ash and 50% residue; and (d) minimize fine particle component i.e. eliminate Fly Ash [FA].

BA has been used in Europe and Japan for road construction. These studies addressed not only the technical suitability issues as a road construction material, but they discussed such environmental factors as leachate, fugitivity, runoff, etc..

Analogous Chemical Comparison

Table 5 compares the Chemical Composition of MSW ash to Oil Shale Ash and to Portland Cement (Cement and Clinker). Between 4-8% gypsum was added to Oil Shale Ash to compressive strength reaching 28 MPa (4100 psi) (17). By analogous comparison, Table 5 suggests that approximately 15% lime should also be added to the MSW ash; assuming a dry lime scrubber. Based on this oil shale analogy, the resultant material would satisfy the specified (ASTM C-593) minimum compressive strength

(600 psi) (4100 kPa) for a pozzolan. Although lime addition also may be required to achieve parity with Portland Cement, based upon the chemical comparison a high potential exists for utilization of MSW ash as a cementitious by-product. Adding 10% Portland Cement to ash, without Acid Gas Cleaning Reaction Products and from an operating Mass Burn facility, yielded compressive strengths exceeding 1000 psi (18).

TABLE 5: CHEMICAL COMPARISON TO ANALOGOUS MATERIALS

COMPONENT-%WT	OIL SHALE ASH	RESIDUE/APC WASTE	
		Mass Burn	RDF
SiO2	20	24	37
Al2O3	8	6	4
Fe2O3	4	3	5
CaO	50	37	43

Composition of Portland Cement			MSW Ash	
Component	Cement	Clinker	Mass Burn	RDF
SiO2	18-24	21.7-23.8	24	37
Al2O3	4-8	5.0-5.3	6	4
Fe2O3	1.5-4.5	0.2-2.6	3	5
CaO	62-67	67.7-70.8	37	43

Particle Size Restrictions

In addition to chemical composition, potential end-uses require specific particle size distribution. Table 6A depicts the size distribution of Bottom Ash and Fly Ash; representative of a 240 TPD (218 Metric ton/day) Mass Burn facility. A comparison of these distributions show potential uses of Bottom Ash as Coarse Highway Aggregate (ASTM D 448) and of Fly Ash as Fine Cement Aggregate (ASTM C33). In both cases, additional segregation would be required to achieve conformity to size distribution requirements. Incorporating such segregation could yield approximately 75% of the Bottom Ash as suitable for Coarse Highway Aggregate and 25% of the Fly Ash as suitable for Fine Cement Aggregate. Separating (i.e. screening) coarser (>3/8" to 3/4") material from Bottom Ash improves the Combined Ash characteristics and enhances recycle potential of the coarser residues. CBR's of non-reactive ash achieved approximately 40%;i.e. suggesting that six (6) inches could be used in a pavement sub-base (19).

As indicated by Table 6B, the FA size distribution favors consideration as Soil Aggregate, for paving application (ASTM 1241). The combined Mass Burn Ash also conforms to Soil Aggregate, for paving application (ASTM 1241). Such uses may not require additional size segregation.

TABLE 6A: POTENTIAL USES OF MSW ASH - ADDITIONAL SEGREGATION

BOTTOM ASH AS COARSE AGGREGATE - HIGHWAY CONSTRUCTION

Sieve Size	ASTM (D 448)	Mass Burn Bottom Ash
	Percent Finer	
2 Inch (50 mm)	100	100
1.5 In.(37.5 mm)	95-100	88
1 Inch (25 mm)	...	---
0.75 In.(19 mm)	35-75	60
0.5 In.(12.5 mm)	...	---
0.38 In.(9.5 mm)	10-30	33
No. 4 (4.75 mm)	0-5	24

FLY ASH AS FINE AGGREGATE - CEMENT

Sieve Size	ASTM (C33)	Mass Burn Fly Ash
	Percent Finer	
0.38 Inch (9.5 mm)	100	74
No. 4 (4.75 mm)	95-100	50
No. 8 (2.36 mm)	80-100	37
No. 16 (1.18 mm)	50-85	32
No. 30 (0.59 mm)	25-65	20
No. 50 (0.297 mm)	10-30	24
No. 100 (0.149 mm)	2-10	18

TABLE 6B: MSW ASH AS SOIL-AGGREGATE SUBBASE, BASE, AND SURFACE COURSES (MINIMAL SEGREGATION)

Sieve Size	Type I-C ASTM (D 1241)	Mass Burn Fly Ash
	Percent Finer	
1 Inch (25 mm)	100	100
0.38 In.(9.5 mm)	50-85	74
No. 4 (4.75 mm)	35-65	50
No. 10 (2.0 mm)	25-50	36
No. 40 (0.42 mm)	15-30	24
No. 200 (0.074mm)	5-15	17

Sieve Size	Type I-B ASTM (D 1241)	Mass Burn Combined Ash
	Percent Finer	
2 Inch (50 mm)	100	100
1 Inch (25 mm)	75-95	80
0.38 In.(9.5 mm)	40-75	50
No. 4 (4.75 mm)	30-60	30
No. 10 (2.0 mm)	20-45	24

BOTTOM ASH AS COVER FOR SANITARY LANDFILL

Cover for Sanitary Landfills are used to eliminate exposure of the landfilled MSW. By eliminating such exposure, nuisances as fugitive litter, vermin attraction, and erosion are prevented. Furthermore, the cover material affects the passage of precipitation through its thickness (i.e. percolation) and across its surface (i.e. runoff). The percolation through the cover material directly impacts the moisture content of the underlying MSW and, consequently, affects the bio-degradation of the buried waste. The bio-degradation or decomposition contributes to the generation of methane gases and the buried waste's structural consolidation. Percolation also is directly related to the quantity of leachate produced.

o Types of Sanitary Landfill Cover

Bottom Ash [BA] is proposed to be used as cover material for a MSW Landfill. Three (3) cover applications are considered: (1) Daily Cover; (2) Side Cell Intermediate Cover; and (3) Interim Final Cover.

Daily cover is usually applied at the end of working day at six inch thicknesses. Intermediate cover is applied in six inch lifts to a thickness of one foot when the working area will be inactive for one to three months. Interim cover pertains to the material which becomes a component of the final cover of the landfill. Interim cover is applied in six inch lifts to a two feet thickness. Table 7A describes the three types of Sanitary Landfill Cover:

TABLE 7A: TYPES OF SANITARY LANDFILL COVER

Cover Type	Thickness	Exposure Application Rate	Comment
Daily	6 inch	Daily/Weekly	Compacted Daily
Intermediate	1 foot	30-90 Days between MSW lifts	6" cover lifts Compact each Cover Lift
Interim	2 feet	Within one week of placing remainder of final cover materials	6" cover lifts Compact each Cover Lift within one week

o Technical Requirements Cover Material

Traditional cover material range from using sand as Daily Cover, sandy clay as Intermediate Cover, and clay/silt as Interim Cover. The engineering requirements for each type of cover material may be categorized according to its permeability and/or particle size distribution. Table 7 B summarizes such criteria:

TABLE 7B: ENGINEERING CRITERIA SANITARY LANDFILL COVER

Cover Type	Permeability	Size
Daily	10 E-3 cm/sec	100% < 3 inches Max 25% < No. 100 Sieve Max 10% < No. 200 Sieve (NJ) Max 5% < No. 200 Sieve (NY)
Cover Type	**Permeability**	**Size**
Intermediate	10 E-4 to 10 E-5 cm/sec	
Interim	Same as Intermediate	

o Substitution of Resource Recovery Bottom Ash

Previous work in New England using Coal Ash as Sanitary Landfill Covers offers the prospect for using Resource Recovery Bottom Ash in the same applications (20). Based upon prior work Bottom Ash conforms to the Particle Size Requirements (21). Although the typical Bottom Ash exhibits a Permeability of about 10 E-5 cm/sec, such values were obtained at 95% modified proctor compaction. By applying a Standard Proctor compactive effort of 85% the resultant permeability should be increased approaching the Daily Cover requirement. The Bottom Ash generated from a 2000 TPD Mass Burn Resource Recovery facility will satisfy the daily, intermediate and interim cover requirements of a Sanitary Landfill servicing approximately 100,000 people. In the Mid-Atlantic region, final capping, composed of Bentonite Clay, costs $160/CY (f.o.b.) or approximately $300/CY (delivered) (22).

o Daily and Interim Sanitary Landfill Cover

Sweden has applied slag or bottom ash as an interim cover for several years. Daily and interim cover is applied to prevent dusting, control vermin, and provide for some passage of moisture to the buried MSW. As a general guideline, New Jersey suggests a Particle Size Distribution of < 3 inches to a maximum of 10% passing a No. 200 sieve. New York limits the percentage of fines to 5% passing a No. 200 sieve. NJ and New Hampshire recommend a maximum permeability of 10-3 cm/sec for daily cover. NH allows a lower permeability of 10-5 cm/sec for interim cover. MSW Bottom Ash conforms to such requirements.

o Effect Upon Leachate and Biological Activity Rates

McEnroe and Schroeder (23) have shown that the Leakage or Leachate Rate through the Drain Layer is directly related to its degree and depth of saturation. Since BA exhibits permeability of approximately 10 E-4 to 10 E-5 cm/sec and typical daily and intermediate cover material's permeability ranges as low as 10 E-3 cm/sec, the amount and depth of saturation will be reduced. Hence the underlying head and Leachate or Leakage Rate [QL] is reduced. Therefore, the rate of flow from underlying cells and eventually to the final liner is reduced. Using less permeable BA as Daily and Intermediate Cover hydraulically reduces the leachate/leakage flow rate.

Moisture content of MSW is directly related to biological activity in terms of Gas Production and Consolidation/Settlement Rates (24). Since the saturation and transfer rate of leachate would be reduced, due to the presence of less permeable BA, both gas and settlement rates should be reduced - reaching an equilibrium or steady-state condition. By controlling these rates both safety and cracking issues are mitigated.

o Effect Upon Leachate Quality

Gray (25) demonstrated the improvement of MSW leachate quality upon passage through a layer of coal/wood ash. Both organic and heavy metal contaminants were observed. One-third reductions of BOD and COD were observed; while Cd and Pb were reduced by 81-100%. A compositional and physical analogy has been developed between coalfired ash and MSW ash (26). BA's surface area is approximately 2 sq. cm./gm (27) and typifies

Granular Activated Carbon [GAC]. GAC media removes organics via adsorption. BA's alkaline pH [> 9] should mitigate the growth of deleterious microorganisms. The mechanisms of adsorption and biological inhibition could account for the expected reductions of organics and heavy metal contaminants.

MSW ASH AS RAW MATERIAL SUBSTITUTE - PORTLAND CEMENT MANUFACTURE

MSW ash reflects a mineralogy similar to Portland Cement Clinker. ASTM C618 Cement Product Specification requires that the total of SiO_2 + Fe_2O_3 + Al_2O_3 contain a minimum range of 50 - 70% by weight. ASTM, however, does not provide a specification for Raw Material Portland Cement Manufacture. Table 8 compares the mineralogy of MSW residues to Cement Clinker and to conventional and advanced SO_2 conversion and/or coal combustion.

TABLE 8: RAW MATERIAL SUBSTITUTE - PORTLAND CEMENT

	Percent by Weight					
	Al_2O_3	CaO	Fe_2O_3	SiO_2	LOI	sq.m/gm
COAL-FIRED FLY ASH	25	1	12	54	5	0.55
DRY FGD FLY ASH	9	25	4	21	4	6.85
LFI FLY ASH	17	38	12	16	11	4.25
AFBC FLY ASH	15	23	19	15	13	23.9
MSW ASH	6	37	3	24	<10	0.38
CEMENT CLINKER	6	62	4	22	6 (max)	N.A.

NOTE: Dry Flue Gas Desulfurization (FGD) Fly Ash = Calcium Based Spray Dryer Adsorption Applied to Coal-fired Plants

LFI = Limestone Furnace Injection; Limestone ($CaCO_3$) injected into coal-fired burners e.g. Limestone Injection Multi-Burner [LIMB]

AFBC = Atmospheric Fluidized Bed Combustion

Only 7% of the conventional coal combustion ash is used for Portland Cement manufacture. Such a low utilization may be attributed to a relatively low CaO content in conventionally fired ash compared to residues from advanced SO_2 conversion and/or coal combustion systems. Dry FGD, LFI, and AFBC reflects Clean Coal Technology in terms of advanced SO_2 conversion and/or combustion. Portland Cement represents their high potential utilization option (10). Given the favorable mineralogy and compatible surface area of MSW residues relative to typical raw materials and analogous ashes, up to approximately 71% substitution could be expected. Based on a typical 2000 TPD Mass Burn Resource Recovery facility generating 500 TPD of residue and assuming a 71% substitution, one cement plant could accommodate all of the ash from five such plants.

o Chlorides

Typically a maximum Chloride concentration of 4% by weight can be tolerated in Portland Cement Manufacture. In some instances, MSW residues may exceed such limitations. Based upon the author's experience the chloride levels can be reduced through preprocessing.

o Unburnt Carbon - Excess Organics

In addition to Chlorides affecting the cementitious reaction, excess organics (i.e. unburnt Carbon) reflects another impurity of concern. ASTM C618 requires a maximum of 6% LOI. Typically a newly designed Mass Burn facility will yield residues of LOI < 1.0 %. Warren County exhibited LOI's between 2.6 - 3.85 during their start-up and shakedown phases (1988/1989). After retrofitting an improved combustion efficiency design Westchester County consistently demonstrated LOI's of < 0.5%.

o Potential Air Emissions

Cement Kilns typically exhibit a nominal firing temperature of 2600 deg F - having a flame temperature of 3400 - 3500 deg F. At such temperatures, the emission contribution from MSW ash substitution should be < 10 ppm.

o Concrete Admixtures using MSW Ash-derived Portland Cement

Based upon the coal combustion analogy, the following represents potential Concrete Admixture menus incorporating MSW Ash as a Raw Material substitute in Portland Cement Manufacture.

Preliminary Concrete Blends - Replacement

COMPONENT	Cement WEIGHT PERCENT	Cement-Fine Aggregate WEIGHT PERCENT
Incinerator Ash - based Portland Cement	14	14
Fine Aggregate	34	32
Coarse Aggregate	46	43
Water	6	11

IMPURITIES

Since the conceptual considerations appear encouraging, research and development efforts are justified. Such efforts should include the possible adverse effect of soluble impurities. Table 9 reports constituent/impurities based on ASTM Product Specification. To ensure end-user acceptance and product conformity, further testing of MSW residues according to ASTM procedures are recommended.

TABLE 9: POTENTIAL IMPURITIES - MSW ASH

Constituent	MSW ASH w/ Lime APC	MSW ASH w/o Lime APC	Limit	ASTM Spec
A + F + S (%)	32.76 - 66.85	50.83 - 77.65	50 - 70	C 618
Sulfur as SO3 (Total - %)	0.06 - 0.51	0.14 - 0.86	3.0 - 5.0	C 595
Sulfur as SO3 (Soluble - %)	ND - 0.05	0.02 - 0,04		
Sodium as Na2O (Total - %)	1.59 - 2.97	1.59 - 2.57	1.5	C 618
Sodium as Na2O (Soluble - %)	0.02 - 0.06	0.01 - 0.05		
Water Soluble Fraction (%)	0.64 - 6.58	1.12 - 3.55	10.0	C 593

NOTE: ND = Non-Detectable
C 618 = Standard Specification for Fly Ash and Raw or Calcined Natural Pozzolans for Use as Mineral Admixtures in Portland Cement

C 595 = Standard Specification for Blended Hydraulic Cements

C 593 = Standard Specification for Fly Ash and Other Pozzolans for Use with Lime

In addition a practical chloride limitation of 4% by weight should be considered; based upon extrapolation from the NUS Study a soluble chloride concentration of 0.0034 - 0.034 % has been derived. Therefore, these derivative soluble impurities in MSW ash appear to satisfy ASTM allowable concentrations.

BY PRODUCT UTILIZATION CONCEPT - ECONOMICS

Establishing a scenario for By-Product Utilization would reduce disposal costs and offer the potential for revenue from the sales of the Waste Material. Demonstrating the concrete-like characteristics of MSW Ash and its suitability as a self-liner, suggest applying this paper's engineering principles to utilization concepts. A close approximation to Portland Cement has been shown by Tables 2, 8 and 9. Obtaining By-Product Properties may be accomplished by seeding the MSW with Standard Additives. Table 10 tabulates the Chemical Additive Unit Costs used in developing a Stabilization Treatment Cost Matrix. This matrix was based upon a typical Mass Burn facility:

- 1500 Ton/Day Capacity
- 500 Ton/Day Total Ash
- BA = 85% by weight = 425 Ton/Day
- CA = 15% by weight = 75 Ton/Day
- 300 Operating Days per Year

This matrix indicates that adding commercially available additives to MSW ash would only increase Operating Cost by $ 1.60/ton of MSW Ash to $4.20/ton of MSW Ash.

TABLE 10: STABILIZATION COST ANALYSIS OF COMMERCIAL ADDITIVES

UNIT ADDITIVE COSTS

Chemical Additive	$/Ton	Comment
Portland Cement [PC]	75	---
CaO (Pebble Lime)	60	---
Lime Kiln Dust [LKD]	12	50% reactive
Cement Kiln Dust [CKD]	12	50% reactive
Coal-Fired Fly Ash [CFFA]	3	---
Gypsum [CaSO4.2H2O]	45	Purity = 87-90%

By applying the principles of optimizing (a) Particle Size Distribution, (b) % Water of Solubilization, (c) Chemical Additive Dosage, and (d) Degree of Compaction or Densification, a conceptual Utilization System is preliminarily engineered. Table 11 presents a conservative budgetary estimate for a Utilization Plant augmented to a resource recovery facility. The Unit Process Cost of $32 per ton of ash (about $11/ton of MSW) is 1/3 to 1/2 the cost of ash monofill disposal in NJ. Rather than expend resources to discard MSW Ash, the Waste-to-Energy field (private and public sector) is urged to implement By-Product concepts.

TABLE 11: COST COMPARISON: BY-PRODUCT UTILIZATION VS. DISPOSAL

BASIS UTILIZATION:

Capital Equipment Investment	=	$ 5.5 MM
Amortization [CRF: 10%/yr @ 10 Yrs]	=	$ 0.9 MM/Yr
Chemical Additive [Dosage @ 10%]	=	$ 80/Ton
Operation & Maintenance	=	35 %
Contingency	=	15 %

UNIT PROCESS COST = $ 32 Per Ash Ton

New Jersey Resource Recovery Ash Monofill

UNIT DISPOSAL COST = $ 75 to 110 Per Ash Ton

By implementing the above Utilization Concept, savings of $12 to $16 per ton of MSW could be realized. Just donating the processed ash could save millions of dollars per year.

SUMMARY

Ashes from both Mass Burn and RDF MSW incinerator systems reflect chemical composition suggesting inherent pozzolanic behavior. These ashes were generated from Resource Recovery facilities equipped with Flue Gas Cleaning Systems. The high stoichiometrics of such systems produce considerable excess lime which promotes pozzolanic or concrete-like behavior. The principles of proper Site Management, including adding the optimum water of solubilization and attaining optimal compaction, have yielded permeability coefficients between 10 X EXP-7 cm/sec to 10 X EXP-9 cm/sec, after 14-28 days curing. Empirical Confirmation of achieving Low Permeabilities and High Leachate Quality have been Demonstrated. Collected Underdrain Leachate, from an active Ash/ Scrubber Residue Monofill approximated Drinking Water Quality for Inorganic and Organic specie and the resultant pH of 6.7 reflect low solubility and in-situ permeability (<1XE-7 cm/sec) of the landfilled Ash/Scrubber Residue. Test Patch Studies, under New England winter condition, have confirmed that achieving liner-like permeabilities is attainable and cost-effective. Applying this Field Methodology would save from $200,000 to $450,000 per acre in MSW Ash Monofill Liner Costs. The pozzolanic behavior of MSW ash mitigates environmental concerns but affords the opportunity of utilizing the ash as By-Products. Applying in-situ chemical treatment could cost between $3,900 to $50,000 per acre (depending on landfill operator capability); realizing significant savings from proposed single and double, and clay and synthetic liner (costing from $250,000 to $500,000 per acre). The pending legislation fails to discuss such properties and pozzolanic or concrete-like behavior. Such recognition would facilitate By-Product Utilization of MSW residues; attaining further cost savings of $12 to $16 per ton of MSW.

Prior experience with Electric Utilities have demonstrated that end-users have used Power Plant Wastes for Road Base Construction, Embankment, Drilling Muds and Pressure Grouting Materials. Resource Recovery Residues reflect similar Chemical Composition and Physical Characteristics as Wastes from coal-fired power plants. Resource Recovery Residue could substitute for Sand, Crushed Stone Aggregate, costing $7 per ton. In the Northeast, Daily and Interim Sanitary Landfill costs approximately $10-20/CY. In the Mid-Atlantic region, final capping, composed of Bentonite Clay, costs $160/CY (f.o.b.) or approximately $300/CY delivered. The deficiency of Portland Cement Raw Materials (shale, clay, limestone) in Waste-to-Energy intensive regions (New England, Mid-Atlantic and south eastern seaboard) provides a receptive and economically-driven scenario for MSW substitution.

Chemical Comparisons suggest adding approximately 15% lime (for Portland Cement) and 4-8% gypsum (for an ASTM pozzolan). Based on Particle Size Distribution of MSW Ash, segregation could yield approximately 75% of the Bottom Ash (suitable for Coarse Highway Aggregate) and 25% of the Fly Ash (suitable for Fine Cement Aggregate). Segregation, however, would not be required for either MSW Fly and Combined Ash for direct use as Soil Aggregate, for paving application.

This paper postulates that using Bottom Ash [BA] as interim/final cover material would better control the passage of water and encourage attaining a bio-kinetic stabilization within the landfill before placing final impermeable capping. As discussed the intermediate layers of BA and MSW would transmit a reduced hydraulic rate to the bottom liner and would reduce respective saturation and moisture contents. The BA generated from a 2000 TPD Mass Burn Resource Recovery facility will satisfy the daily, intermediate and interim cover requirements of a Sanitary Landfill servicing approximately 100,000 people.

Given the favorable mineralogy and compatible surface area of MSW residues relative to typical raw materials and analogous ashes, up to approximately 71% substitution for traditional Portland Cement Raw Material could be expected. Based on a typical 2000 TPD Mass Burn Resource Recovery facility generating 500 TPD of residue and assuming a 71% substitution, one cement plant could accommodate all of the ash from five such plants. Based upon derivative soluble impurities, MSW ash appears to satisfy ASTM allowable concentrations.

AUTHOR'S RESTRICTION

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VITRIFICATION OF MUNICIPAL SOLID WASTE COMBUSTOR ASH

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13 - 16, 1990

Vitrification of Municipal Solid Waste Combustor Ash

Ray S. Richards and Gary F. Bennett

Introduction

Nationally there is a concern for pollution that may be caused by the land disposal of solid and hazardous waste. Consequently, using the authority given to them by RCRA, the USEPA is severely limiting land disposal of hazardous waste. If land disposal is to be permitted, then the disposer will probably be required to detoxify or to immobilize his waste to the greatest extent possible. This requirement may well apply to municipal waste combustor ash (MWC ash) For ash resulting from the combustion of municipal solid waste , vitrification represents immobilization of the toxic metals to the maximum extent possible .

Why Vitrification

The vitrification process produces a glass-like, non-leachable material by melting municipal waste combustor (MWC) ash. This process is not encapsulation! The ash feed materials are no longer in their original form. Their physical and chemical form have been changed. This process is similar to dissolving sugar in coffee; the sugar crystals are gone and the flavor is changed. The glass exiting the melter is usually a homogeneous material but some compositions can partially crystalize on cooling. Both glasses and crystalline materials can be very inert and unleachable.

There are at least two benefits in this process.

1. Reduction in volume
2. Delisting
   - -Very large reduction in surface area (leaching surface).
   - -Production of chemically inert glass

MWC fly ash densities have been measured(1) at 0.37 to 0.73 gms/cm^3 and bottom ashes were measured at 0.82 to 1.04 gms/cm^3 Typical commercial glass densities are 2.6 gms/cm^3

Thus, there is a significant reduction in volume to be gained by vitrification.

The surface area of the fly ash that may be exposed to leaching is large. Moreover the toxic materials are deposited on the surface of the particles. The vitrification process combines all of these surfaces into a coarse non-leachable aggregate of minimum volume and surface area.

Occasionally MWC ashes exceed EP Tox and TCLP limits by modest amounts (2). The dissolution of the toxic materials on the surface of the ash into the glass and the multiple orders of magnitude reduction in surface area almost guarantee that any glass produced as a result of vitrification will pass the required hazardous waste toxicity tests. While the non-leachability of vitrified ash has not been certified by innumerable tests, glass technologists have little doubt that non-leachability can easily be achieved as it has been in the nuclear industry.

Vitrification of high level nuclear waste has been under study for over 20 years. The leaching standards are much more strict than those faced by MWC ash and acceptable levels of leach resistance have been attained for nuclear waste.

There are concerns for the durability of other disposal methods. Structural grade concrete bridges and roads may not last 20 years due to freeze-thaw winter cycles. "Waste material" aggregate with uncontrolled chemistry would be even more suspect. In contrast, our Toledo Museum of Art has glass objects recovered from burial sites thousands of years old which are in excellent condition.

Vitrification is <u>the answer</u> to municipal waste combustor ash disposal.

Demonstrated Capability

Several companies are actively pursuing vitrification as a method of MWC ash treatment. The following is a partial list of these companies.

Argonne National Laboratories
Argonne, IL

Penberthy Electromelt International, Inc.
Seattle, WA

Westinghouse Electric Corp., Environmental System Dept.
Madison, PA

U.S. Environmental
Mt. Laurel, NJ

Vortec Corp.
Collegeville, PA

Geosafe Corp.
Kirkland, WA

Inorganic Recycling
Worthington, OH

Associated Technical Consultants in affiliation with Glasstech, Inc.
Toledo, OH

Gas Versus Electric Melting.

Commercial gas fired glass melting furnaces, which might be considered for MWC ash vitrification, utilize more than 4 million BTUs of natural gas energy and generate over 4 tons of exhaust gasses for each ton of glass produced. These figures are for very large, efficient furnaces. The furnaces have large heat recovery systems and bag houses for dust collection and require a great deal of capital investment.

Smaller gas fired melters, called unit melters, are also available without energy recovery systems. There is a significant increase in fuel consumption for these furnaces over the larger units.

For more modest capacity melters, such as those appropriate for MWC ash, electric melting is a better choice than gas fired melters. Electric melters are smaller and cost less than a gas fired furnace of the same capacity. While electric melters are efficient, they use an energy source that normally costs over three times as much as natural gas on a per ton melted basis. However, in MWC co-generation facilities, the electric costs can be more attractive.

Special Applicability of Vitrification to MWC Ash

MWC facilities with co-generation of electricity capability present a unique opportunity to utilize electric melting for vitrification because their electric costs can be very reasonable. Some of the new electric melter designs lend themselves to very rapid on-off operation. This operational advantage will allow utilization of off-peak power.

It also is fortunate that most of the major oxide constituents of the ash stream are good glass formers. Table 1 shows the weight percent of the major components in the fly ash. One equipment supplier recommends modest additions of cullet (scrap glass) to the ash feed streams to adjust the melt chemistry for reasons described later.

Fly Ash versus Bottom Ash

Fly ash and bottom ash have different compositions and toxicities. Many papers[1-6] have been written on the chemical and physical distribution of toxic metals in MWC ash. It is generally agreed that the fly ash contains a larger portion of most of the toxic elements than does bottom ash.

A typical waste-to-energy incinerator of 600 tons/day capacity will produce approximately 150 tons per day of total ash. Of this total, about 20%, or 30 tons per day, will be fly ash .

The high surface area of the fly ash, the distribution of the toxic elements on the surface of the fly ash, and the lower weight of fly ash per ton of waste as compared to bottom ash make it the waste stream of most toxic concern and the most likely candidate for vitrification. Table 2 shows the toxic metals present in the ash.

Typical Electric Vitrifying Units

Electric glass melters which are used for bottle, window, and specialty glass around the world are available in a wide range of sizes. In electric glass melting, molybdenum electrodes are inserted into the molten glass and current is passed through the glass to heat it. There are two different melter designs: cold top and hot top.

The cold top design is a refractory box which is open on top, full of molten glass, with a layer of raw materials floating on top of the melt.

This layer insulates the furnace top and is replaced as batch melts away. There is a drain hole located elsewhere in the furnace which removes the melted glass.

The second design is a fully enclosed furnace and uses some gas firing or electric heating elements above the melt in addition to the electrodes in the melt. This is called a hot top design.

Arc furnaces, typical of those used in steel melting, also have been used for ash vitrification[7]. Since steel making involves slag or glass on top of the molten steel, it is reasonable to consider these units for ash vitrification. Herb Hollander, Wyomissing, PA, is Chairman of an ASME program which is evaluating the arc melting furnace for ash vitrification. Arc furnaces operate with very high temperature zones and can melt any residual metallic components in the ash. The plan is to process both fly and bottom ash with removal of the molten metallic fraction from the bottom of the furnace.

Stir-Melter™

Associated Technical Consultants (ATC) and Glasstech, Inc. are developing a highly stirred, electric melter (Stir-Melter™). This newly designed electric melter will be used to melt MWC ash late this summer. The work is being carried out by ATC with support from the State of Ohio under an Edison Seed Fund Grant to the University of Toledo. Glasstech, Inc. will manufacture and market the new Stir-Melter™ furnaces. These furnaces are smaller than other electric furnaces with the same capacity and are more easily sealed against vapor loss than other furnace designs.

This new furnace is a small eletric melting unit with a high speed stirrer to circulate the melt rapidly. This provides rapid melting rates and uniform operating temperatures. The small size minimizes energy consumption. They operate within a very narrow and tightly controlled temperature range and thus allow significant control over chemical reactions in the melting process. The Stir-Melters™ respond to temperature and load changes quickly and can be idled or returned to full production in minutes. In this regard, they are the most flexible of the electric melters described.

Operating Cost Considerations

The operating cost of an electric melter is highly dependent on the actual cost of the 450 to 550 Kwh required to melt each ton of ash. More energy may be required if high levels of additional materials are added to the ash stream. Off peak power at co-generating facilities should be very reasonable.

A second cost factor is the need for other materials to be added to the ash feed stream. There can be several reasons for doing this. One is to lower the melting point of the ash stream to make melting easier.

Another is to balance the chemistry to get a good durable product (high leach resistance). While optimum glass chemistry has not been determined and will vary from location to location, it seems reasonable that the cost of additions to the feed stream will be modest.

The cost of vitrification was described in general terms above. Exact costs depend upon size, electricity costs, and several chemical factors which have not yet been resolved. Based on an in-house, off-peak electricity cost of 2 cents/Kwh, it is our estimate that vitrification direct costs will be between $50 and $60/ton of glass output. One must remember that fly ash contains significant levels of carbon and volatiles and that some additional materials may have to be added to the ash stream. Our estimate is that 1 ton of fly ash will produce 1.0 to 1.2 tons of glass.

Lastly, when more sophisticated end products are being manufactured from the glass stream, there will be additions to maintain a consistent chemical composition of the glass despite seasonal variations in the ash stream . This will be discussed later.

Capital Costs

Approximations of capital costs for electric melters are not reliable because of the large variations from site to site. The type of melter selected will affect the plant space requirements, the ventilation and exhaust gas processing needs. Mass burn incinerators will have different types and quantities of ash than incinerators burning refuse derived fuel. The incinerator combustion system will heavily affect the percent of fly ash to total ash as well as the residual carbon content.

As a starting point, a furnace for vitrifying ash in the size range of 50 tons per day might cost from $1,750,000 to $2,500,000. If only fly ash were being vitrified the capacity required for a mid-size incinerator would be substantially less, although the cost per ton of capacity would be somewhat greater. Beyond this, the requirements of the individual site would need to be appraised.

Vitrification Concerns

The research currently underway at Associated Technical Consultants addresses several of the chemistry problems inherent in the vitrification of MWC ash. Although glass is known as the universal solvent, readily incorporating lead, zinc, chromium, and selenium, several toxic species can partially vaporize in addition to dissolving in the melt. Consequently, air pollution control of the furnace effluent will have to be considered. This is a problem that is routinely addressed in commercial glass melting.

Fly ash can contain significant amounts of carbon. This can lead to the reduction of some metal oxides to their metallic state and the glass melting temperature is high enough to cause boiling of some of these metals. For some tightly closed furnace designs, this is not a difficult problem and the vapors can be condensed in fairly simple systems. The concentrated condensate then can be recycled as a metal source.

One group(8) reports the following data that illustrate the volatility of two heavy metals:

	Fly Ash	Vitrified Glass
Cadmium	1000-2000 ppm	10 ppm
Lead	5000 "	100 "

In this case, the cadmium probably left the furnace in the exhaust gas stream. The lead can either be lost to the exhaust stream or found as metallic lead in the bottom of the furnace. The chlorides and sulfates in the ash also may combine with some metal species which then volatilize.

From the perspective of a glass technologist, the extreme variability of the ash stream chemistry makes melting control difficult and yields a low quality glass output. For example, the concentration of silica (SiO_2) varies between 0 to 57% as shown in Table 1. At the low end of silica concentration, sand will have to be added to the melt.

Other species such as chromium are locked in the glass structure and are also in a non-toxic valence state.

By-Products

There have been proposals too numerous to detail on potential uses for MWC ash as it comes from the combustor. Construction aggregate uses predominate and ash is utilized for aggregate in many countries. Bottom ash which has been sized and washed may be suitable for this application. This aggregate is a relatively low value product. The result is small cash return instead of an expense. Several other similar uses have been proposed. There have been fewer uses suggested for fly ash.

We at ATC-Glasstech feel that there are other products which can be made from the vitrified ash stream that would have a higher value than aggregate. However, these future higher value products, and indeed some of the ones presently being discussed, will require that the glass properties and thus its composition be under better control. This control feature is not incorporated in current MWC installations. To accomplish better ash chemistry control, stock piling and blending or chemical sampling followed by corrective additions will be needed. Long range developments will probably trend in this direction.

Summary:

Given the public concern for the potential impact of toxic chemicals in the leachate on ground water, there is resistance to siting of land fills. We feel that vitrifying of fly ash to produce a virtually non-leaching product will enhance landfill acceptance or alternative uses. In addition, discontinuing the present practice of mixing the potentially hazardous fly ash with the bottom ash also should enhance the acceptance of bottom ash for land fill or other uses.

We feel that the Stir-Melter™ can effectively and economically vitrify fly ash. Currently we are on a research and development program to scale up a lab melter to a commercial melting unit. Additional work will be conducted on producing higher value products from the vitrified ash.

As we look to the future, it is our belief that production of useful products from this vitrified ash can produce an economic benefit, secure a concomitant reduction in disposal costs and lead to a reduction of land disposal.

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TABLE 1 ASH COMPOSITION

	WESTCHESTER (3) TOTAL ASH RANGE	E.P.A.(4) FLY ASH RANGE	SWEDISH (5) RANGE	PHILADELPHIA (6)
SiO_2	40.3-46.8	0.3-57	31.6-63.6	32.8
CaO	11.3-15.4	2-38	9.4-15.5	13.1
Al_2O_3	10.5-16.3	0.9-33.2	11.5-20.6	21.9
Fe_2O_3	8.0-19.2	0.1-12	2.0-5.7	2.0
Na_2O	3.1-4.2	1.3-6.7	2.9-5.7	9.3
TiO_2	1.5-2.1	T-7.0	0.5-2.1	2.2
MgO	2.4-4.2	0.33-3.5	2.0-4.6	2.2
K_2O	1.4-3.4	1.3-8.0	2.6-7.2	10.9
P_2O_5	1.0-1.4	0.7-2.1	1.2-2.5	----
ZnO	------	0.38-19	-------	2.2
PbO	------	0.02-2.9	-------	1.1

TABLE 2

RANGES OF CONCENTRATIONS OF INORGANIC CONSTITUENTS IN FLY ASH, COMBINED ASH, AND BOTTOM ASH FROM MUNICIPAL WASTE INCINERATORS IN µg/g (ppm)

Parameter	Fly Ash	Combined Bottom and Fly Ash	Bottom Ash
Arsenic	15-750	2.9-50	1.3-24.6
Barium	88-9,000	79-2,700	47-2,000
Cadmium	<5-2,210	0.18-100	1.1-46
Chromium	21-1,900	12-1,500	13-520
Lead	200-26,600	31-36,600	110-5,000
Mercury	0.9-35	0.05-17.5	ND-1.9
Selenium	0.48-15.6	0.10-50	ND-2.5
Silver	ND-700	0.05-93.4	ND-38
Aluminum	5,300-176,000	5,000-60,000	5,400-53,400
Antimony	139-760	<120-<260	
Beryllium	ND-<4	ND.1-2.4	ND-<0.44
Bismuth	36-<100		ND
Boron	35-5,654	24-174	85
Bromine	21-250		
Calcium	13,960-270,000	4,100-85,000	5,900-69,500
Cesium	2,100-12,000		
Cobalt	2.3-1,670	1.7-91	3-62
Copper	187-2,380	40-5,900	80-10,700
Iron	900-87,000	690-133,500	1,000-133,500
Lithium	7.9-34	6.9-37	7-19
Magnesium	2,150-21,000	700-16,000	880-10,100
Manganese	171-8,500	14-3,130	50-3,100
Molybdenum	9.2-700	2.4-290	29
Nickel	9.9-1,966	13-12,910	9-226

TABLE 2
RANGES OF CONCENTRATIONS OF INORGANIC CONSTITUENTS
IN FLY ASH, COMBINED ASH, AND BOTTOM ASH
FROM MUNICIPAL WASTE INCINERATORS IN µg/g (ppm)

PAGE TWO

Parameter	Fly Ash	Combined Bottom and Fly Ash	Bottom Ash
Phosphorus	2,900-9,300	290-5,000	3,400-17,800
Potassium	11,000-65,800	290-12,000	920-13,133
Silicon	1,783-266,000		1,333-188,300
Sodium	9,780-49,500	1,100-33,300	1,800-33,300
Strontium	98-1,100	12-640	81-240
Tin	300-12,500	13-380	40-800
Titanium	<50-42,000	1,000-28,000	3,067-11,400
Vanadium	22-166	13-150	53
Yttrium	2-380	0.55-8.3	
Zinc	2,800-152,000	92-46,000	200-12,400
Gold	0.16-100		
Chloride	1,160-11,200		
Country	USA, Canada	USA	USA, Canada

ND - Not detected at the detection limit
Blank - Not reported, not analyzed for
Source: Literature (Volume IV) and Versar Study (Volume V)

CONVERSION OF MSW INCINERATION ASH INTO CONSTRUCTION AGGREGATE MEETING FEDERAL DRINKING WATER STANDARDS

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13 - 16, 1990

Conversion of MSW Incineration Ash Into Construction Aggregate Meeting Federal Drinking Water Standards

by F.H. Gustin [1] and
H.P. Shannonhouse [2]

Introduction

Opponents to municipal solid waste incineration cite two major concerns with incineration. The first is the question of ash quality and the presence of contaminants. The second is flue gas emissions. This paper describes the program developed by Municipal Services Corporation (MSC) to address the first problem. The air quality control system industry has addressed the second.

A recent estimate by the Leading Edge Report, as reported in the June, 1990 issue of Solid Waste & Power Magazine, indicates that the number of waste-to-energy plants in the U.S. is expected to double by the year 2000, to about 350 plants. Total incineration capacity will reach approximately 250,000 tons of solid waste per day.

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The number of plants in operation will increase by about 6.7 percent annually, while the annual throughput capability will increase by 12 percent.

Along with an increase in incineration capacity, there will be a corresponding increase in ash production. If a 75% reduction in weight is assumed when municipal solid waste is incinerated, the 250,000 tons of solid waste per day will result in 62,500 tons of ash per day, or almost 23 million tons of ash per year.

On the other hand, the number of permitted landfills in the U.S. is expected to decrease. According to the EPA, there are presently approximately 6000 solid waste landfills in operation in the U.S. More than half of these existing landfills will reach their capacities within the next six years. Stricter federal and state standards, Superfund, and a reluctance on the part of the general public to allow new landfills to be built in the vicinity of populated areas all play roles in the decline of the number of landfills that will be in operation in the near future.

In addition, a general trend has developed for the recycling and reuse of heretofore unusable industrial by-products. Such materials as paper mill sludge, foundry sand, municipal sewage sludge, and power plant coal fly ash and bottom ash have all found beneficial and environmentally benign uses over the past several decades.

It is for these reasons that Municipal Services Corporation has decided to pursue the opportunity of recycling MSW incinerator ash.

<u>The MSC Program</u>

The Municipal Services Corporation (MSC) program consists of contracting for removal of 100% of the MSW incinerator ash production from a waste-to-energy plant. The ash is transported to another facility owned and operated by MSC where metals are removed and the ash is converted into a construction-grade aggregate material which can be used for road construction or a variety of other uses. A small percentage of the ash is unprocessible and requires by-pass disposal.

The ash is first processed to remove metals and unburnt paper and to produce a more consistent particle size. It is then "chemically fixed" using K-20 [3], which is a patented

3 Patented - U.S. Patent Office. The K-20 Lead-In-Soil Contaminant Control System is a product of Lopat Enterprises, Inc., Wannamassa, N.J.

product using a potassium silicate formula that causes heavy metals to form metal silicates, thus permanently reducing their solubility and therefore mobility in the environment. The chemically-fixed ash is then mixed with other proprietary ingredients and pelletized into smooth round pebbles ranging in size from approximately 1/8 to 3/4 inch in diameter. Following a curing period to provide for optimum strength gain, the aggregate can be used in road construction or elsewhere as permitted by the state environmental protection agency.

Ferrous metals and mixed non-ferrous metals are relatively clean and can be sold to scrap metal dealers, steel mills, and foundries.

MSC has been awarded contracts by two counties in Minnesota: Hennepin County, which encompasses the City of Minneapolis, and Dakota County, just to the south of Minneapolis. MSC will provide MSW incinerator ash recycling services, including disposal of unprocessible residues, for up to 90,000 tons per year of ash from the Hennepin County incinerator and another 60,000 tons per year of ash from the Dakota County incinerator.

Environmental Testing of MSC Synthetic Aggregate

In order for MSC to market the synthetic aggregate for use in highway construction and elsewhere, it must first pass stringent testing for both environmental safety and physical performance characteristics.

During the course of product development, MSC has subjected the synthetic aggregate to the following tests to ensure environmental safety:

* Extraction Procedure Toxicity Method 1310, or EP-Tox, which was the standard EPA test by which a waste was judged hazardous or non-hazardous. EPA has recently dropped this test in favor of the TCLP test.

* Toxicity Characteristic Leaching Procedure Method 1311, or TCLP, which is similar to EP-Tox, but for which results are more readily replicated from laboratory to laboratory.

* Multiple Extraction Procedure, Method 1320, or MEP, which is an indication of the stability of a material in the environment over many years. The test is commonly referred to as the "Thousand Year Leach Test."

* To a limited extent, MSC has tested for 2,3,7,8-TCDD and 2,3,7,8-TCDF, Method 8270. To date, these compounds have not been detected in the aggregate.

Tables 1-3 show the results of environmental testing performed by National Analytical Laboratories of Tulsa, Oklahoma, on samples submitted by MSC.

Table 1 consists of a compilation of results of TCLP analyses of nine samples of raw combined MSW incinerator ash that MSC is presently working with in its Research and Development Facility near Atlanta, Georgia. As expected, the variability of the ash is quite high.

Table 2 depicts the results of TCLP analyses on samples of synthetic aggregate obtained from six consecutive batches made at the MSC R&D Facility. Each batch varies slightly in terms of mix design or treatment. Results were consistently in the range of federal drinking water standards.

Also tested for leachability of heavy metals using the TCLP were fines that passed through a No. 100 mesh when samples of aggregate were screened. These results are shown in Table 3. As was the case with the aggregate, results were consistently in the range of federal drinking water standards.

Physical Testing of MSC Synthetic Aggregate

In addition to meeting strict environmental standards, the MSC synthetic aggregate has been developed with the objective of meeting the physical standards necessary to withstand heavy traffic and harsh climatological conditions. As MSC has been working towards the use of its aggregate in a demonstration project in the State of Minnesota, specifications in use by the Minnesota Department of Transportation (MnDOT) have been used as the standard for physical performance of the material.

The MnDOT battery of tests consists of the following:

* Los Angeles Abrasion Test (AASHTO T96) - a measure of the aggregate's hardness and durability in relation to its resistance to abrasion.

* Soundness by Use of Magnesium Sulfate (AASHTO T104) - a determinant of the aggregate's resistance to chemical attack, primarily road salt. To a certain extent, it is also a measure of resistance to freezing and thawing.

* <u>Freeze-Thaw (MnDOT procedure)</u> - an indicator of the aggregate's durability when exposed to a series of rapid freezing and thawing cycles. The MnDOT procedure consists of 16 rapid cycles of freezing and thawing of the aggregate in a 0.5% solution of methyl alcohol in water.

* <u>Absorptivity</u> - another indicator of freeze-thaw durability, it is necessary in order to determine the amount of excess asphalt required in a bituminous paving mix to compensate for quantities absorbed by the aggregate.

* <u>Specific Gravity</u> - A measure of particle density, it is used for calculating bituminous paving mix proportions.

* <u>Sieve Analysis (AASHTO T27)</u> - different paving mixes require varying particle size distributions. The MSC synthetic aggregate is deficient in fine material (the MnDOT BA-1 bituminous aggregate specification requires 2-8% minus No. 200 mesh fines), but this is easily compensated for at the asphalt batch plant using fine material from other sources, if needed.

Typical results showing ranges of values obtained using the above test procedures are depicted in Table 4.

Minnesota Demonstration Project

The Minnesota Pollution Control Agency (MPCA) has drafted a permit to authorize MSC and Hennepin County to jointly conduct an MSW ash utilization demonstration project. The permit is currently on 30-day public notice and it is anticipated that it will be issued in July of this year.

The demonstration project will consist of the use of approximately 80 to 100 tons of MSC synthetic aggregate as a partial replacement for natural aggregate in a 2" thick overlay of bituminous pavement. The synthetic aggregate will be incorporated into the asphalt at a fixed rate, which will be determined based on physical and environmental laboratory testing.

The test strip will consist of paving approximately 1000 feet of roadway containing the synthetic aggregate and approximately 1000 feet of standard roadway using only natural aggregate. The natural aggregate roadway will be used as a control for comparing data obtained from the physical, chemical and environmental testing program that has been developed in conjunction with the demonstration.

The synthetic aggregate was produced at the MSC Research and Development Facility located near Atlanta, Georgia. It is presently in the curing period before samples are shipped to Minneapolis for testing by Braun Environmental Laboratories and Braun Engineering Testing, subsidiaries of The Braun Companies. Braun is an independent testing agency that has been certified by the State of Minnesota.

The synthetic aggregate was produced from combined MSW ash from the Hennepin Energy Resources Company facility (HERC) in Minneapolis. Prior to transporting the ash to Georgia in trucks, representative samples of the ash in each truck were obtained for testing purposes. Four samples of the ash will be analyzed using the TCLP for an extensive list of parameters contained in Table 5.

In addition to TCLP analysis of the raw combined ash, the TCLP will be performed on four samples of the synthetic aggregate, the asphalt cement, the natural aggregate, and samples of the synthetic aggregate that have been crushed into powder.

The ash will also be subjected to analyses for dioxins and furans using EPA Method 8290. This list of compounds is contained in Tables 7 and 8.

Prior to construction of the roadway, a mineralogical evaluation of the synthetic aggregate and of the crushed synthetic aggregate will be performed.

Physical testing of the synthetic and natural aggregates will be performed using the list of MnDOT procedures previously discussed in this paper, in addition to physical testing of the asphalt cement and the bituminous pavement mixtures.

Braun will conduct trial mix design testing using different proportions of synthetic and natural aggregates to determine an optimum mix design. The optimum mix design will then be subjected to a series of physical bituminous tests, the most important of which will be the Cold Water Abrasion Test.

The Cold Water Abrasion Test is used to determine the durability of compacted bituminous mixtures and as an aid in identifying mixtures that may have a tendency to strip or unravel. The test consists of subjecting 6 cylinders of the mixture to 1000 revolutions in the Deval Testing Machine using cold water as a liquid medium. The amount of material lost from the cylinders through abrasion is then calculated and reported as abrasion loss percentage.

For purposes of this demonstration, acidic water (pH <5), alkaline water (pH >9), and brine solution will be used as media in addition to conventional tap water. The liquid and particulates obtained from this series of tests will then be analyzed for the short list of the eight RCRA heavy metals as shown in Table 6.

Additionally, the following tests will be run on four samples of the bituminous mix containing the synthetic aggregate and four samples of the bituminous mix containing the natural aggregate. These include:

* TCLP for the parameters listed in Table 5.

* Multiple Extraction Procedure using the TCLP for the parameters listed in Table 5.

* ASTM Water Leach Test (ASTM 1312) for the parameters listed in Table 5.

All laboratory tests will be performed and the results will be submitted to the MPCA for review and approval prior to proceeding with construction in late August, 1990.

During construction, samples of the asphalt cement and the bituminous mixture will be obtained from the bituminous plant and tested. Results will be compared to those obtained previously in the laboratory for verification.

Within 30 days of placement, core samples will be obtained from both the synthetic aggregate roadway and the control strip and tested for mineralogical composition as previously described. ASTM Water Leach and TCLP testing will be performed on the cores for the parameters in Table 5.

The test strip will be monitored for a period of five years after construction. Each year, four core samples of the test strip and the control will be obtained and subjected to the TCLP and ASTM Water Leach Tests. In addition, an annual analysis of the mineralogical composition will be performed to detect any changes in the aggregate or in the pavement structure due to changes in the aggregate.

Two high volume air samplers will be placed near the roadway to detect if any of the materials contained in the ash become airborne due to roadway wear. Soil samples will also be obtained annually. Air and soil samples will be analyzed for the list of parameters in Table 5. Background samples of both air and soil will be obtained prior to construction.

A plan is presently being developed to evaluate the quality of run-off and airborne emissions entering the environment from normal wear and tear on the synthetic aggregate roadway. The evaluation will use the data collected from the physical and environmental testing conducted in this project in a program of mathematical analyses and computer modeling.

An additional 15 to 20 tons of the synthetic aggregate will be trucked to Minneapolis and stockpiled outdoors on a lined area. Samples of any air emissions and surface water runoff from the stockpile will be collected and analyzed for the list of parameters in Table 5.

After the synthetic aggregate roadway has been in place for two years, results of testing will be reviewed by the MPCA. The MPCA will then make the determination as to the feasibility of proceeding with a full-scale ash processing plant that will have the capability of processing up to 150,000 tons of MSW ash per year.

A permit application for construction and operation of the ash processing plant, to be known as the Metropolitan Resource Utilization Center (MRUC), has been submitted to the MPCA.

Based on information and data generated during the course of this project, a report will be prepared that can be utilized in the preparation of a Health Risk Assessment for the general use of the MSC synthetic aggregate in the state of Minnesota. This report will be used during the preparation of an Environmental Impact Statement (EIS) for the purposes of evaluating any potential fugitive dust emissions from synthetic aggregate roadways and the effects of any emissions on the environment and human health.

MSC has volunteered to prepare the EIS on the full-scale synthetic aggregate production plant that has been proposed as well as potential utilization applications of the synthetic aggregate product, in order to confirm the environmental safety of the process. The Minnesota Pollution Control Agency is the responsible governmental unit for scoping and managing the EIS.

Results obtained during the course of this year's demonstration project will be used not only in the preparation of the EIS, but in the development of standards and regulations for the use of MSW ash in the state of Minnesota as well.

It is expected that the Minnesota demonstration project and the EIS will result in what could be the most comprehensive evaluation of MSW ash utilization to this date. It is through this plan that Municipal Services Corporation intends to lead the way in safely recycling the residues from the combustion of municipal solid waste. This will extend the lifetimes of landfill disposal sites by many years, thereby helping to solve a pressing problem for incinerator operators and municipal governments throughout the United States, as well as safely returning a valuable natural resource to commerce and industry.

Table 1

Results Of Toxicity Characteristic Leaching Procedure (TCLP) Performed On Nine Samples Of Combined MSW Incinerator Ash

National Analytical Laboratories
(All Units In mg/l)

Parameter	Low Value	High Value	Average Value	Det. Limit
Arsenic	<0.1	<0.1	<0.1	0.1
Barium	<0.01	0.52	0.31	0.01
Cadmium	<0.01	1.24	0.60	0.01
Chromium	<0.01	0.36	0.09	0.01
Lead	<0.1	19.1	5.12	0.1
Mercury	<0.0005	0.0028	0.0006	0.0005
Selenium	<0.1	<0.1	<0.1	0.1
Silver	<0.01	0.02	<0.1	0.01

Note: When results indicated parameter levels below detection limits, one-half of the detection limit was used for calculation of the Average Value.

Table 2

Results of TCLP Analyses
Performed on MSC Synthetic Aggregate

National Analytical Laboratories
(All Units in mg/l)

Parameter	P-66	P-67	P-68	Det. Limit	DWS
	Batch Number				
Arsenic	--	0.004	0.003	0.002	0.05
Barium	1.28	0.92	0.78	0.01	1.00
Cadmium	--	--	--	0.01	0.01
Chromium	--	--	--	0.01	0.05
Lead	0.004	0.007	0.004	0.002	0.05
Mercury	--	--	--	0.0005	0.002
Selenium	--	--	--	0.005	0.01
Silver	--	--	--	0.01	0.05

Parameter	P-69	P-70	P-71	Det. Limit	DWS
	Batch Number				
Arsenic	0.006	0.005	0.005	0.002	0.05
Barium	0.68	0.57	0.79	0.01	1.00
Cadmium	--	--	--	0.01	0.01
Chromium	--	0.01	0.01	0.01	0.05
Lead	0.007	0.007	0.005	0.002	0.05
Mercury	--	--	--	0.0005	0.002
Selenium	--	--	--	0.005	0.01
Silver	--	--	--	0.01	0.05

Note: -- = Below Detection Limit

Table 3

Results of TCLP Analyses Performed On
Minus No. 100 Sieve Dust From
MSC Synthetic Aggregate

National Analytical Laboratories
(All Units in mg/l)

Parameter	Batch Number P-53A DUST	P-54B DUST	P-58A DUST	P-58B DUST	Det. Limit	DWS
Arsenic	0.008	--	0.003	--	0.002	0.05
Barium	0.65	0.70	0.64	0.41	0.01	1.00
Cadmium	--	--	--	--	0.01	0.01
Chromium	0.06	0.06	0.02	0.06	0.01	0.05
Lead	0.008	0.01	0.021	0.007	0.002	0.05
Mercury	--	--	--	--	0.0005	0.002
Selenium	--	--	--	--	0.005	0.01
Silver	--	--	--	--	0.01	0.05

Note: -- = Below Detection Limit

Table 4

Typical Results Of Physical Testing

Of MSC Synthetic Aggregate

Test	Range Of Values For MSC Aggregate	MnDOT Requirement
L.A. Abrasion	25-35% Loss	<40% Loss at 500 Revolutions
Soundness By $MgSO_4$	5-10% Loss	<15% Loss at 5 Cycles
Freeze-Thaw	3-18% Loss	<12% Loss at 16 Cycles
Absorptivity	12-16%	Not Specified
Bulk Specific Gravity	1.8-1.9	Not Specified
Sieve Analysis	May be varied through production techniques	Varies by Application

Note: Physical testing performed at Law Engineering, Atlanta, GA, and the MSC Research and Development Facility.

Table 5

List Of Parameters For Analysis
Minnesota Demonstration Project

Aluminum	Chromium	Potassium
Antimony	Iron	Selenium
Arsenic	Lead	Silicon
Barium	Lithium	Silver
Beryllium	Magnesium	Sodium
Boron	Manganese	Strontium
Cadmium	Mercury	Sulfur (Sulfate-S)
Calcium	Molybdenum	Thallium
Chloride	Nickel	Tin
Cobalt	Nitrate + Nitrite	Titanium
Copper	Phosphorous	Zinc

Table 6

Short List Of Parameters For Analysis
Minnesota Demonstration Project

Arsenic
Barium
Cadmium
Chromium
Lead
Mercury
Selenium
Silver

Table 7

List Of Dioxin Compounds For Analysis
Minnesota Demonstration Project

<u>Polychlorinated Dibenzodioxins</u>

Total Monochlorodibenzodioxin

Total Dichlorodibenzodioxin

Total Trichlorodibenzodioxin

2,3,7,8-Tetrachlorodibenzodioxin

Total Tetrachlorodibenzodioxin

1,2,3,7,8-Pentachlorodibenzodioxin

Total Pentachlorodibenzodioxin

1,2,3,4,7,8-Hexachlorodibenzodioxin

1,2,3,6,7,8-Hexachlorodibenzodioxin

1,2,3,7,8,9-Hexachlorodibenzodioxin

Total Hexachlorodibenzodioxin

1,2,3,4,6,7,8-Heptachlorodibenzodioxin

Total Heptachlorodibenzodioxin

Octachlorodibenzodioxin

Table 8

List Of Furan Compounds For Analysis
Minnesota Demonstration Project

Polychlorinated Dibenzofurans

Total Monochlorodibenzofuran

Total Dichlorodibenzofuran

Total Trichlorodibenzofuran

2,3,7,8-Tetrachlorodibenzofuran

Total Tetrachlorodibenzofuran

1,2,3,7,8-Pentachlorodibenzofuran

2,3,4,7,8-Pentachlorodibenzofuran

Total Pentachlorodibenzofuran

1,2,3,4,7,8-Hexachlorodibenzofuran

1,2,3,6,7,8-Hexachlorodibenzofuran

2,3,4,6,7,8-Hexachlorodibenzofuran

1,2,3,7,8,9-Hexachlorodibenzofuran

Total Hexachlorodibenzofuran

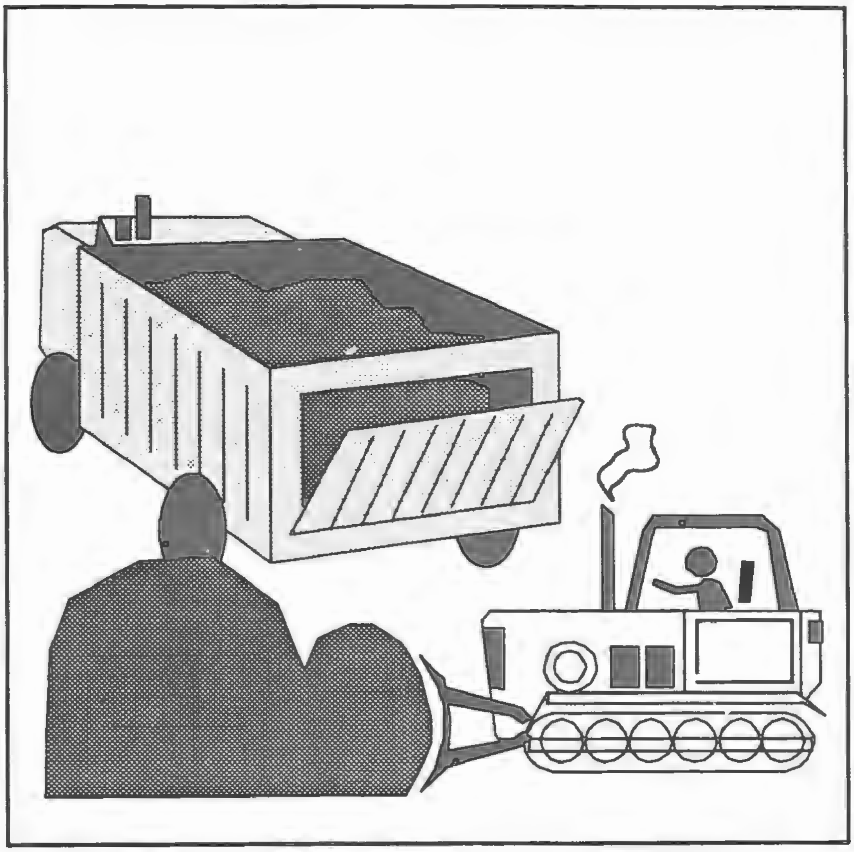
1,2,3,4,6,7,8-Heptachlorodibenzofuran

1,2,3,4,7,8,9-Heptachlorodibenzofuran

Total Heptachlorodibenzofuran

Octachlorodibenzofuran

Total Mono-Octachlorodibenzofuran



LAND DISPOSAL

COMMUNICATION, COMMUNITY PARTICIPATION AND WASTE MANAGEMENT

An Examination of Public Opinion, Citizen Participation, Education and Communication Strategy in the Siting Process

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

Communication, Community Participation and Waste Management*

It just isn't enough for managers in the field of waste siting to be good scientists, engineers or technicians. Today's administrators better know how to effectively manage staff, practice community relations, interpret public opinion, arbitrate disputes, converse with news reporters, and plan effective communication strategies.

The classic model of siting communication, top-down and one-way, is outmoded. Yet some agencies continue to promote such dated strategies only to find costly delays or even abandonment of the project. Why do such methods no longer work?

A review of waste siting case studies and journal articles reveals that unsuccessful siting campaigns have in common several, important factors -- factors which are

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*(Development of this paper was made possible by a special grant from the Cornell University College of Agriculture and Life Sciences.)

critical to the success or failure of a siting strategy: public opinion, citizen participation, continuing education, and communication strategy. And while no one can guarantee a successful outcome, those who have written about successful outcomes agree that when these four factors are fused into a workable plan, citizens are more willing to discuss siting options.

This paper examines the literature and case studies on siting of solid waste, hazardous and low-level radioactive waste facilities. While we recognize that each type of siting has its own unique problems in terms of public perception and operation management, the issues of participation, public opinion, education and strategies provide a common foundation to all of the situations we have studied.

Public Opinion and the Perception of Risk

The attitudes which Americans have about the environment serves as the backdrop to our examination of public opinion. That Americans care deeply about the environment is well-documented in opinion polls. Cambridge Reports, for example, notes that pro-environmental sentiment is pervasive among American people, who were "somewhat abstract and aesthetic" in their concerns about the environment 15 to 20 years ago. Today, however, attitudes "grow out of deeply felt and personal worries about human health and safety." Furthermore, environmental threats are highly correlated with whether people see problems as a threat to personal health and safety (Cambridge Reports, 1988).

Not only have environmental concerns taken a prominent position on the public agenda -- the power to influence and shape opinion in the environmental arena has grown concurrently. The nuclear power industry is one example cited frequently in the literature. American perceptions concerning the health and safety surrounding nuclear power have become increasingly salient, particularly after such newsmaking events as Three Mile Island and Chernobyl. Californians, for example, have rallied effectively in halting the reopening of nuclear power facilities (Sussman, 1988).

Such attitudes extend beyond the realm of nuclear energy: planners of radioactive, hazardous, toxic, and solid waste facilities also report considerable opposition to land use siting.

The general public feeling of environmentalism, coupled with self-interest, are important variables in the public opinion-land use siting equation. When self-interest is present, wrote Hadley Cantril in 1944, opinion is not easily changed. And it is this <u>self-interest</u> which has a demonstrable effect on attitudes (Newsom and Scott, 1985).

The issue of self-interest becomes critical when the benefits of locating a waste repository are weighed against the costs. Payne and Williams (1985) report that "Citizens feel they are paying high costs (in perceived risks) for benefits they do not receive in the same proportion." In discussing benefit versus cost to the community, case study writers agree that host communities bear a greater burden of cost than accrued benefits. Moreover, host communities and lay publics perceive "costs" as including unacceptable health and safety risks.

Risk Perception

Studies of risk perception by Slovic, Fischhoff and Lichtenstein illustrate that the public's perception of risk differs from scientific, quantifiable risks. For example, the lay public overestimates exotic or catastrophic risks (deaths due to nuclear power) while underestimating everyday risks (deaths due to automobile accidents.) The issue of self-interest also affects perception of risks... some types of risks associated with greater reward or benefits are more readily acceptable to publics.

Scientists and experts have difficulty dealing with what they consider the lay public's inaccurate assessment of risk, which is reflected in the case studies of siting failures. For example, members of the New York siting commission, after meeting with area residents over a low-level radioactive waste site, were troubled by the vehement public response. One commissioner called the reaction "hysterical" while another said opposition would diminish "once people hear the message that there's no hazard to the environment." Opposition did not diminish, and local citizens to date have been effective in stymieing the siting process (Coleman, 1989).

Experts, like the New York commissioners, relied on the traditional model of scientific persuasion, which involves trying to convince publics that their attitudes about risk are unfounded. Communication and risk scholars generally concur that this technique doesn't work. Instead of persuading publics of the low (actual) health risks of sitings, some pragmatists have recommended offering compensation packages to host communities. Zeiss, who studied 21 facility siting attempts, reports that, due to the imbalance of cost over benefit, compensation alone is not enough to cinch a siting agreement. Zeiss proposes a package which includes compensation and reduction of perceived community "costs" or losses.

Another central aspect of risk perception is the issue of voluntary and involuntary control. Slovic, Fischhoff and Lichtenstein, 1987, note that acceptability of risk depends on such factors as catastrophic potential, uncertainty, familiarity and voluntariness. The literature supports the notion that, when communities believe they have no voice in the siting process, projects are doomed to fail. "Community control," write Matheny and Williams (1985), is a key element in achieving acceptance.

The issue of community control is more than attitudinal, however. According to researchers, community participation, which leads to the perception of control, serves as a linchpin in the siting process.

Citizen Participation

Common to much of the siting literature is the notion that community publics play a vital role in land use siting. But, judging from case studies, public input is either ignored or invited too late in the siting process.

Planners need to examine siting "in a radically new way," suggests Edeburn, 1988. She calls on government agencies to redirect their communication focus away from ratification to input. "The public's role should be defined clearly, preferably by citizens and officials together." Involvement in the planning process, Edeburn adds, "leads to greater understanding of, and appropriate reactions to, environmental, health and economic risks." Other experts agree. In writing about knowledge versus NIMBY (Not in My Backyard), Matheny and

Williams make a strong case for involving the Florida public at the decision-making level, noting that "it's largely a matter of community participation in management" and that residents and facility operators need to share in the decisions about the disposal of wastes. Involving the public at this level, the authors note, may not reduce risks, but will shift the perception of risk "from an involuntary to a voluntary consciousness."

Blackburn and Reed, 1985, take the example one step further, suggesting that increased involvement by citizens in the siting process leads to acceptance of the project. In their study of a low-level radioactive waste facility siting in Texas, the authors report that planners established avenues for community comment early in the siting process. The purpose of these meetings was not to reach consensus but to promote "free-flowing question and answer sessions," allowing planners to hear concerns first-hand. Formation of citizen committees, funding of surveys, and sponsorship of visits to disposal sites paved the way for community involvement.

Abrams and Primack, 1980, suggest that timing is important in citizen input. When comments are invited too early, "plans are vague," and if participation is requested too late, the public perceives the project as a fait accompli. Moreover, agencies are unfamiliar with how to involve citizens <u>throughout</u> the process. "Often agencies don't know how to maintain citizen input."

One solution borrowed from marketers, is segmentation of publics. Abrams and Primack offer a blueprint of typical publics, including local elected officials, business owners, opinion leaders, scientists, special interest groups, etc. By segmenting publics into special groups, planners greatly increase their ability to understand audience needs while identifying specific channels to each special publics.

Albrecht and Thompson, 1988, have examined the issue of special publics more closely. In their paper on attitudes in repository sitings, they note that citizens find meaning in a <u>community</u> frame of reference. If researchers develop methods to examine deep social values which people attach to their communities, planners can build a more complete composite of community concerns. It's not enough to interpret attitudes and public opinion; planners need to understand against the community influences and norms which influence beliefs and behaviors.

Three central themes appear in the literature concerning involvement of publics in the siting process: reaching consensus, willingness to negotiate, and segmentation of publics.

Planners should resist trying to reach consensus on issues, according to Payne and Williams. In their article on conflict and public communication, the authors make a case for incorporating citizen input to reduce long-term strife. And while it may seem antithetical to waste managers, conflict has a positive consequence, the authors report. "Managers should not become discouraged... conflict is normal."

Another benefit to opening dialogue between planners and citizens, according to Vincenti (1985), is that planners thereby send signals to the public that they value the input -- assuming planners take comments to heart. "Citizen involvement must be more than just names on a register" and public groups must be willing to spend time examining issues, not just time sounding off, warns Vincenti.

One way to gain the most from citizen input is segmentation of publics. Although this is best accomplished on a case-by-case basis, publics are typically divided into these types of groups: concerned local citizens; involved citizens (teachers, business owners, other professionals); environmentalist groups; opinion leaders (official and unofficial); news media; elected officials and representatives; appointed officials; city, county and regional planners; myriad government agencies involved in the planning process; scientists, university professors and experts; etc.

A critical public is the group of local officials, whether appointed or elected. Blackburn and Reed note that involvement of these key people in projects can greatly help the siting process. New York planners bore the wrath of local officials when the news media learned about low-level site selection prior to local citizens and local officials. Because they were snubbed in the siting process, local decision-makers vowed to fight the state agencies.

Payne, 1984, notes that involvement of community groups is more manageable than hammering out solutions with individuals. Groups can bring concerns and priorities into focus better than individuals. By segmenting publics, discovering their concerns and suggestions, and getting a range of opinions, planners can get a better handle on salient issues.

Involving the public, however, does not guarantee the success of an unwanted landfill siting facility. Jubak, 1982, points out that "Public participation can make a difference in people's attitudes. It can raise the level of trust by providing good information and a chance to get answers to genuine worries. Trust is absolutely vital to siting a facility." Yet, having an informed public does not necessarily translate to successful siting. Matheny and Williams caution that raising awareness may also "encourage the NIMBY syndrome" and that "too much public involvement leads to rejection of proposed sites." The authors suggest complementing public involvement with a public education program in an effort to gain acceptance of community sitings. We believe that public education must happen <u>prior</u> to any specific siting activity.

<u>Public Education</u>

Matheny and Williams propose that the combination of citizen involvement and education "is necessary for legitimate decision-making." Participation isn't enough without enlightened decisions, they add. In California, for example, a grassroots educational campaign paved the way toward public acceptance of a low-level radioactive facility. Pasternak, 1985, notes that the state's well-planned campaign, which focused heavily on targeted groups, "had a positive impact on local government officials, leaders of the business community, journalists, and other citizens in potentially affected regions of the state." Public and private organizations joined together to establish specific, concrete objectives in siting a facility and educating California publics on radioactive uses and disposal. The organization hosted a speakers bureau, conferences and field inspection trips to acquaint publics with disposal information. The League of Women Voters and other groups sponsored public forums in several locations, and lobby

In other education programs, Texas officials changed their opinions following site visits to waste facilities; in Pennsylvania, strategists worked directly with the news media in developing a series of news programs on radioactive waste, while communicating with concerned individuals via direct mail and by sponsoring programs for officials and leaders in 42 of the state's 67 counties; and a state-wide education program in Florida included promotion of "Amnesty Days," an event which allowed citizens, small businesses, schools and local governments to have small quantities of hazardous wastes collected free of charge, bringing the siting issue into focus for targeted publics and the news media.

Waste siting authors concur that special events, educational programs, and targeted news stories must directly tie in with forums which allow for public discussions. And researchers also agree that communication must be truly two-way and symmetric, to allow for give-and-take on both sides of the waste siting issue. If these essential components -- public education, citizen participation, and an understanding of public opinion and risk -- are not well-grounded in the siting management, communication strategies will fall short of meeting the requisite goals.

Communication Strategy

As we suggested earlier, planners who report successful sitings borrow from the marketing, public relations and strategy areas in designing effective communication strategies.

Unfortunately, and too often, strategies rely on techniques, rather than broad-based research and public input, in developing effective strategies.

Working with news media, for example, is problematic for many managers and planners. While the news media may provide an effective and powerful source of informing publics, the public media cannot be controlled by waste planners. The controversial nature of siting does, however, guarantee placement of such issues on the news media agenda, and it's likely that the siting opposition will be adroit at obtaining media coverage. Unfortunately, planners often lack the skills to carry their messages to the news media, and resist or refuse opportunities to present their case to reporters. In the example of New York's Cortland County, siting opponents effectively set the media agenda through a series of welltimed and targeted protests and recurring demonstrations. Siting officials were less available and less willing to discuss issues publicly with members of the press. Officials were on the defensive, and their public posture in the press reinforced this.

Waste facility managers can be more effective in their relations with the news media, but are reminded that good press relations are no substitute for dealing with targeted publics face-to-face. In an article about the "new environmentalism," Lukaszewski, 1989, points out that "Success means keeping your own interests on the agenda." Reporters generally <u>want</u> to explain both sides of controversy to their audiences, but managers must take the initiative in addressing concerns via the public press. "Start early, speak often, and don't let the other side get away with framing the issue for the media," Lukaszewski counsels. Vincenti notes that "Government cannot rely on news media to educate the p*blic on issues that may be controversial."

The issue, therefore, becomes one of information versus education. While the news media may inform publics concerning events, waste managers need to take over the reins for public education -- and this is best done prior to controversy erupting on television or in the newspaper.

Communication strategists and public relations practitioners can provide numerous, proven techniques for channeling messages and information to audiences... public service announcements, feature articles, special newsletters, brochures, television talk shows, slide presentations -- but the literature supports the view that interpersonal communication -- face-to-face interaction with host community publics -- is the sine qua non of successful siting.

Recommendations

Local government officials are faced with a difficult and unique situation. On one side is the need to make efficient decisions in the best long-term interest of the community. In the past that meant making the site selection, holding a public hearing to discuss the decision with a few concerned members of the community, and then proceeding with site development. Today, however, the public is less trustful of government and science and technology. Today the public questions decisions more, and demands to be involve in decision-making. And while a full discussion of the issues with members of the public and involvement of the public in decision-making may appear to be inefficient, it is often not only the best, but the only way communities can make effective decisions on some issues.

Three recommendation emerge from this study.

1. Utilize community expertise. Treat the public as an equal partner in decision-making. Encouraging and actively using citizens advisory and study groups bring the public into the decision-making process. It also helps focus attention on the real issues and real risks involved in the siting of waste management facilities. Focus should be on citizens who have special expertise: the local cooperative extension agent or educator may help develop an educational plan for the community; a communication specialist at the local college or university may help design an overall communication strategy; local business owners may help develop a speakers bureau of volunteers to talk with organizations about various aspects of the program, etc.

2. Develop a team oriented approach. No one individual or group can manage all the aspects of a community risk

situation. Recognize and believe that others can contribute valuable ideas to the discussion.

3. Keep the process open to the public. Even the hint of secret decisions can destroy credibility and create an adversarial feeling in the community. Every effort must be made to make members of the community feel that "this is our problem, we must make the decision."

4. Be proactive in your communication efforts. Take your concerns to the public as soon as you can. Don't wait for the final study or more information. Be honest -- if you don't know, say so and explain why.

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"CONSIDERATIONS IN THE DESIGN OF LINERS FOR MUNICIPAL SOLID WASTE LANDFILLS"

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 14-16, 1990

INTRODUCTION

Landfill containment systems consist of liners in combination with a system for withdrawal and treatment of landfill leachates. Residues from the treatment of leachate are returned to the landfill. In the idealized landfill, liners are impermeable and treatment of leachate insures that no contaminants are released to the environment. In practice, impermeable liners do not exist. Consequently, the landfill developer is faced with a variety of landfill design alternatives that offer a trade-off between cost and containment efficiency.

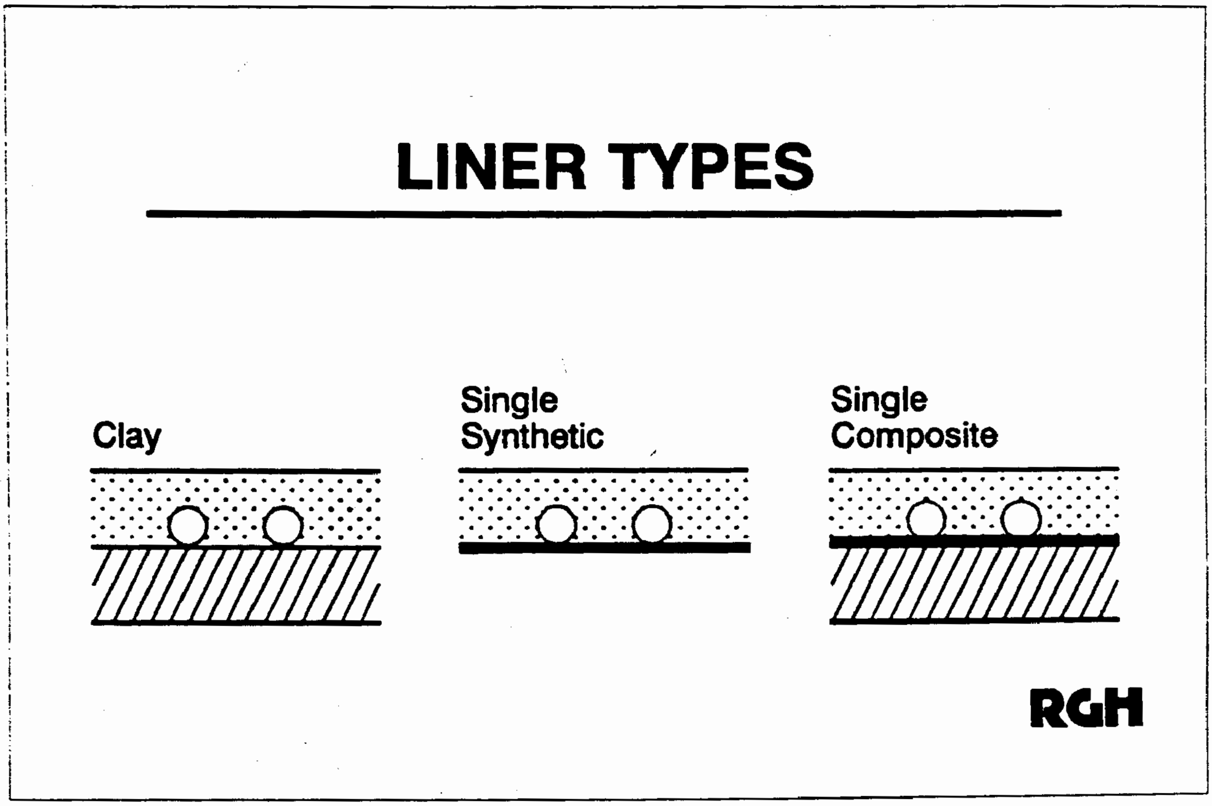
Conventional landfill liners consist of layers of clay or synthetic membrane intended to impede the release of leachate. Composite liners include a clay layer overlain by a synthetic membrane (See Figure 1). Different liner types vary greatly in their capacity to contain leachate and in their cost of construction. In choosing a containment system suited to his specific needs and conditions, the landfill developer should evaluate the degree of containment required to prevent significant contamination of soil or groundwater.

CONTAINMENT

Impermeable liners do not exist. Normal migration of leachate through a liner as anticipated by the designer is termed "permeance" to distinguish it from "leakage", which is the product of imperfections or damage sustained by the liner.

Most conventional liners are designed with leachate collection systems that will limit the depth of leachate over top of the liner to about one foot. Under these conditions, a carefully constructed liner consisting of a two-foot layer of remolded clay with an in-place permeability of

FIGURE 1



1 x 20^{-7} CM/SEC will sustain a permeance of about 16,000 gallons of leachate per year per acre (GPY/AC). Flaws in the clay liner resulting from poor compaction, desiccation or fissuring may result in leakage flow which is much higher.

By contrast, a liner consisting of a 40 mil (.0035 foot) layer of synthetic membrane should permit no more than 100 GPY/AC of permeance when the maximum depth of leachate on top of the liner is one foot (See Figure 2). This permeance rate is based on a hydraulic permeability of 1 x 10^{-12} CM/SEC for a typical synthetic liner material. Liner permeabilities are difficult to measure and may be significantly lower in many cases. The superior containment properties of synthetic membrane liners are partially offset by the vulnerability of these materials to damage during construction. For membrane liners constructed over a subbase consisting of soil with a permeability of 1 x 10^{-5} CM/SEC, only eight penny-sized holes per acre are required to reduce the containment efficiency to that of a two-foot layer of clay (K.W. Brown et al. Quantification of Leak Rates through Holes in Landfill Liners, 1987. EPA/600/S2-87/062). Moreover, only 16 holes the size of a pinhead may be just as damaging. The task of constructing synthetic liners to eliminate such tiny imperfections is daunting. In practice, some damage to liners during construction must be anticipated.

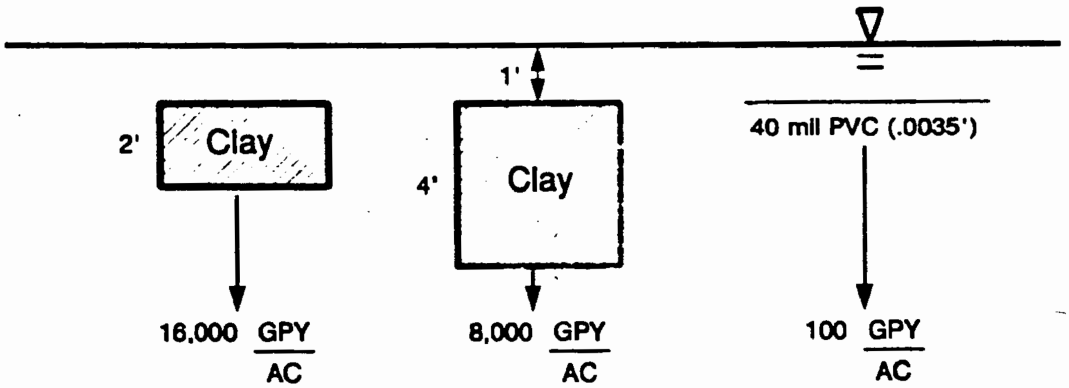
LEAK MINIMIZATION

Leakage flow is the result of imperfections in a liner. As previously discussed, leakage can occur in liners constructed of either clay or synthetic membrane materials. The rate of leakage flow is directly proportional to:

1) depth of leachate over the liner
2) size of the imperfection
3) permeability of the underlying subbase (membrane liners only)

FIGURE 2

LINER PERMEANCE *



Note: EPA "De minimus" rate = 300 GPY/AC

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* Not Leakage

Of course, the first line of defense against leakage is the careful construction and inspection of the liner system. Quality assurance programs for liner construction should be rigorous and well documented. Detailed construction specifications and extensive testing of in-place liners are essential to eliminate problems associated with bad materials, poor workmanship, or accidental damage to liners.

Effective methods of reducing leakage include reduction in the depth of the leachate on top of the liner. This can be accomplished by either utilizing a more permeable drainage medium, or by reducing the spacing of leachate withdrawal conduits. New products that incorporate geotextiles and plastic grids offer relatively inexpensive methods of improving the effectiveness of leachate collection systems.

An alternative method of reducing leachate leakage is to construct a double liner. The double liner incorporates two liners of identical design, with one immediately overlying the other. Double synthetic membrane or double clay liners are commonly found in current landfill designs. Since leakage through the upper or primary liner will be a small fraction of total leachate generated, the depth of leachate over the lower or secondary liner will always be much less than that over the primary liner. The potential of leakage from the combined system is thus proportionately decreased. The effectiveness of double liners is further enhanced by the probability that a flaw in the secondary liner will not directly underlie a flaw producing a leak in the primary liner. In practice, a ten-fold improvement in overall containment efficiency of double liners compared to single liners can be anticipated.

The influence of puncture diameter in synthetic membrane liners is much less important than the permeability of the subbase in determining the importance of leakage flow. Decreasing the diameter of a puncture by an order of magnitude will only cut leakage flow in half. By comparison, an order of magnitude reduction in subbase permeability, without any reduction in puncture size, will reduce leakage flow by an order of magnitude also (K.W. Brown et al. Quantification of Leak Rates through Holes in Landfill Liners, 1987. EPA/600/S2-87/062. This suggests a method of compensating for the vulnerability of synthetic membrane liners to leakage related to small perforations which may escape detection. By utilizing a low permeability subbase in combination with a synthetic membrane liner, a liner with containment efficiency and reliability that is superior to both clay or synthetic liners can be achieved. This is the composite liner.

Figures 3 and 4 illustrate the effectiveness of different strategies for the reduction of leachate leakage. The optimal strategy for a landfill developer will depend upon the local costs of construction. However, the adoption of composite liner designs will in most cases produce the greatest improvement in containment efficiency per dollar spent. Composite liners are most attractive in localities where clay is relatively inexpensive.

HYBRID LINER DESIGNS

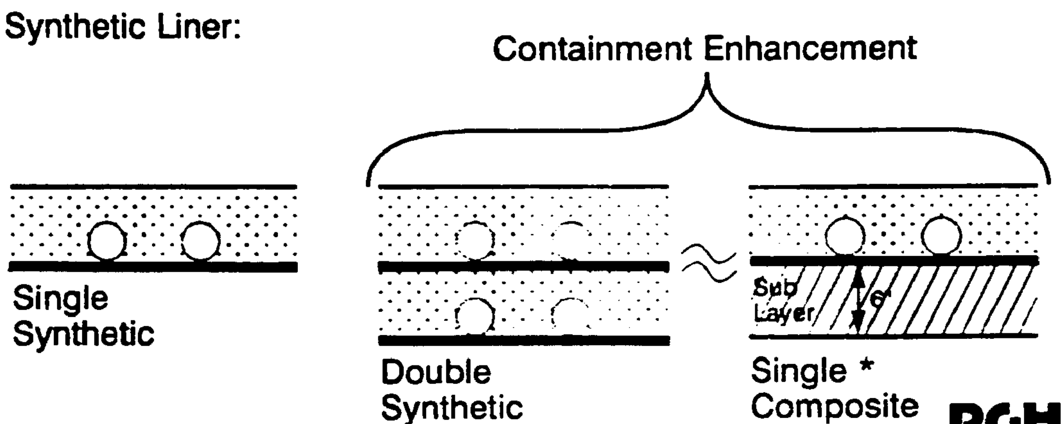
Hybrid liners, first cousins of double liners, have gained acceptance in various designs. Like double liners, hybrid liners are composed of two liners with one system directly overlying the other. However, in hybrid designs the two liners are constructed of different materials and have inherently different containment efficiencies.

There are two philosophies of hybrid liner designs. The first approach is to place the liner with the greatest containment efficiency on top. Examples are synthetic-over-clay liner and composite-over-synthetic liner. In these designs, it is typical to describe the upper drainage layer that overlies the upper liner as the leachate collection system, and the lower drainage layer that occupies the space between the upper and lower liners as the "witness" or "leak detection" system. The implication is that the "witness" layer is intended to verify that the containment system is working. Since all liners have a normal permeance flow, this approach introduces the possibility that the detection of normal leachate flow in the "witness" section will be misinterpreted by regulatory or third party observers as a liner failure. Since the lower liner is acknowledged to have

FIGURE 3

EQUIVALENT LEAKAGE MINIMIZATION STRATEGIES

(Reduction of Leakage Flow by 90%)

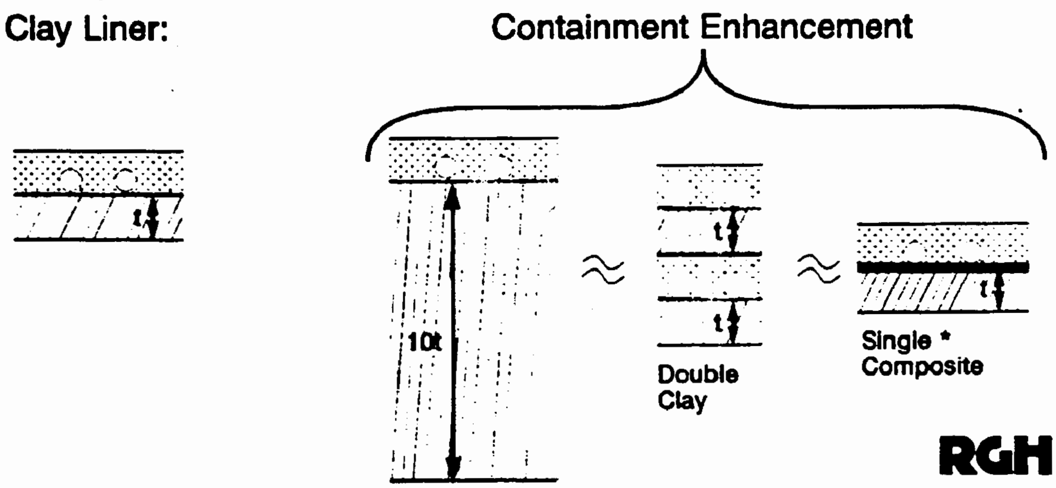


* Sublayer permeability lower than native soil by one order of magnitude

FIGURE 4

EQUIVALENT LEAKAGE MINIMIZATION STRATEGIES

(Reduction of Leakage Flow by 90%)



* Reduction in leakage flow typically exceeds 90%

a lower containment efficiency, it also difficult for the landfill operator to argue that leachate observed in the "witness" system does not constitute a threat to the environment.

The alternative approach in hybrid liner design is to place the liner with the greatest containment efficiency on the bottom. The most common example of this type is the synthetic-over-composite liner design. In effect, this a double synthetic liner constructed over a clay subgrade layer. In this configuration, like the double liner design, it is natural to regard the lower liner as an integral part of the leachate containment system. The lower drainage layer, which lies between the upper and lower liners, is properly described as a "secondary leachate collection" system. Leachate observed in the "secondary leachate collection" system does not reflect a failure of the containment system and is anticipated in the provision of an amplified secondary liner.

ELIMINATING WEAK POINTS

The leachate containment strategy for a landfill extends beyond the selection of a liner type. The overall design must be examined to minimize weak, failure-prone elements. Among the most important considerations is the design of the leachate collection system. Most conventional designs require that piping associated with the leachate collections system penetrate the liner at three points (See Figure 5). The advantages of these designs is that the leachate flows by gravity to the treatment works. However, penetrations are difficult to seal reliably and are prone to damage associated with settlement of the landfill and its foundation. Potential problems associated with penetrations can be minimized by reducing the number of penetrations, providing for local monitoring of penetrations, adding secondary containment at penetrations, and by making penetrations more accessible to repair in the event of a leak. The single penetration design, illustrated in Figure 5, satisfies these requirements. Alternatively, all penetrations can be eliminated by the introduction of on-liner sump pumps.

The vulnerability of synthetic membrane liners to damage during construction has been well documented. The most common cause of liner perforation, other than negligent construction practices by the installer, is the puncture or abrasion of liners by coarse rock fragments in granular liner subbase or cover material. Recent research by the EPA (D.L. Lane, et al. Loading Point Failure Analysis of Geosynthetic Liner Materials, 1988, CER1-88-20. Proceedings of USEPA 14th Annual Research Symposium, Cincinnati, Ohio.) has shown that all liner materials are vulnerable to this sort of damage. However, by providing a geotextile sheathing for the liner, puncture and abrasion resistance can be significantly improved. Furthermore, the use of geotextiles is much more effective in improving puncture resistance than is increasing liner thickness. The landfill developer should consider the potential improvement in containment efficiency that can be obtained at the cost of incorporating geotextiles in the liner design.

Construction-related and post-construction damage to liners can also be minimized by eliminating hard or brittle materials from the leachate containment and collection system. Among these are brittle plastic pipes and steel or concrete manholes and sumps. The entire containment and collection system should be engineered to deform without failure due to yield, puncture, or misalignment. To the extent possible, plastics used in the construction of the liner should be compatible so that penetrations, extensions, and connections can be sealed with confidence.

QUALITY CONTROL

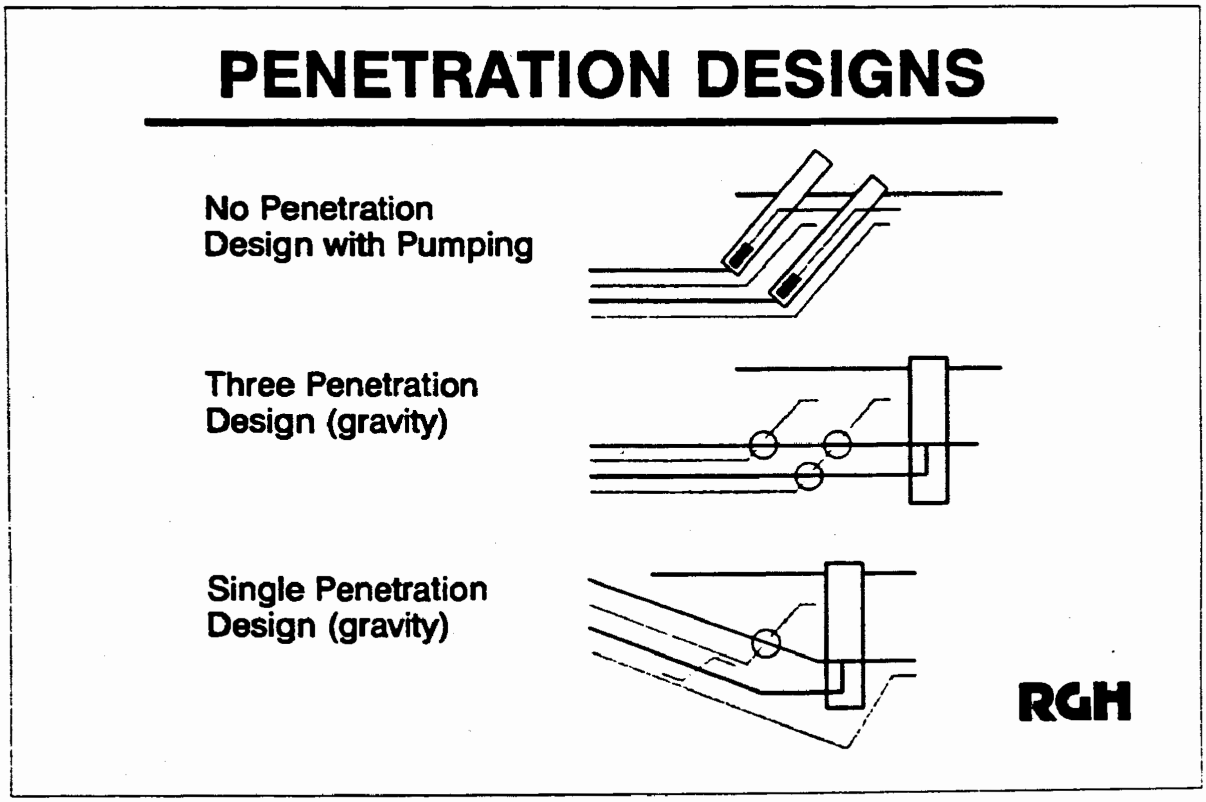
The reliability of any containment system depends upon the quality of the construction All landfill construction projects should incorporate a detailed construction specification coupled with rigorous inspection and documentation. Synthetic liners are the easiest of the liner types to inspect, but also the most prone to damage during construction. Landfill developers should insist upon the testing of 100 percent of all liner seams. In addition, destructive testing of randomly selected coupons of the seams should be conducted. Where double or hybrid liners are installed and the base of the landfill is gently sloping, pond testing of the liner prior to acceptance should also be considered.

Clay liners are more difficult to inspect, since small inhomogeneities in a clay layer may escape a gridded sample coring and testing program. Furthermore, flaws associated with dehydration or variation in moisture content may be difficult to identify. Consequently, a very rigid construction specification, including frequent measurement of clay composition, moisture content, and compacted density is the best protection against poor liner performance.

LANDFILL FAILURES

The only accepted evidence for liner failure is the measurable release of contaminants into the environment. This usually is associated with the detection of degradation of groundwater or surface water resources by a network of monitoring wells and stream sampling points. The observation of leachate in "witness" or "secondary leachate collection" systems does not indicate a failure of the landfill's containment system. A certain amount of permeance and leakage flow into these systems should be anticipated as a normal feature of any liner design. However, unexpectedly large leachate leaks in the upper liner should be regarded as indicating potentially significant flaws or damage to the system as a whole and should be investigated by expanding and intensifying monitoring functions. It is one of the responsibilities of the landfill designer to establish realistic estimates of line permeance and leakage against which containment permeance can be judged.

FIGURE 5


PENETRATION DESIGNS
No Penetration
Design with Pumping
Three Penetration
Design (gravity)
Single Penetration
Design (gravity)
RGH

CONTROLLED LANDFILLS - A SYSTEMATIC APPROACH TO SOLID WASTE DISPOSAL

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

Introduction

Landfills are and will likely continue to be the most frequently employed method for disposal of solid wastes. Unfortunately, landfills have not been managed well in the past, and that lack of good management has resulted in problems with leachate and gas migration and adverse environmental impacts. As a consequence, the continued use of landfills has become a major societal issue which has often stifled or delayed the development of new solid waste disposal systems. Yet these same concerns have led to a variety of technological developments, ranging from landfills designed and operated for total containment and isolation to controlled disposal. Therefore, the choice of technology applied today is often dependent on not only designer preference, but a desire to accommodate public perception, economic constraints, and regulatory inertia. In the final analysis, the relative priority and effectiveness of integration of each of these elements determines which landfill management option is selected and successfully implemented.

This presentation provides a review and summary of the nature of landfills as potential generator sources of leachate and gas, and couples this with a discussion of the relative merits of available techniques for containment, control and treatment. It begins with a brief perspective of the nature and characteristics of landfill leachate and gas, and the factors affecting their magnitude and intensity. This is followed by a discussion of the principles of controlled landfill stabilization as provided by *in situ* leachate management with leachate containment, collection and recycle. Finally, options for ultimate disposal or utilization of leachate and gas are addressed, including discharge to municipal wastewater treatment systems, land application, and energy recovery.

General Perspective

The development of rational, economically sound and publicly acceptable approaches to landfill disposal of solid wastes involves the recognition that a given landfill potentially will affect and be affected by prevailing site-specific hydrologic and geologic conditions that must be understood in order to minimize human health and environmental risks. The environmental consequences of leachate and gas formation and potential migration, and their dependence on the availability of moisture from external sources as well as from associated waste decomposition, are of particular importance. Therefore, leachate and gas generation must be controlled to transform landfill behavior from a realm of uncertainty to one of predictability.

Such predictability is enhanced by understanding the causes for changes in the magnitude and intensity of leachate and gas production as the landfill matures and progresses through a sequence of microbially-mediated phases toward stabilization. Operational control over the release of waste constituents is possible either through the preselection or conditioning of the source waste, or by management of the rates of generation and transfer of waste constituents to the principal transport media (leachate and gas). The latter approach appears to be a more logical choice in the case of municipal landfills, whereas the former, perhaps coupled with features of the latter, would seem more attractive for codisposal landfills receiving inputs of both municipal and industrial wastes or where source separation or recycle are practiced.

Based upon an understanding of the processes determining leachate and gas characteristics, management of generation and transfer rates can be implemented by controlling the moisture regime within the landfill. Without moisture, a principal transport medium will not exist and the conversions and interactions determining leachate and gas production and quality, as well as the overall progress of waste stabilization, will be suppressed. Such "dry" landfills, whether induced by climatic conditions or impervious containment systems (liners and caps), may reduce the rate, amount and intensity of leachate and gas generation, but may also extend the intrinsic reactivity and, therefore, the environmental impact uncertainty into perpetuity. In contrast, the availability of sufficient moisture, either accompanying the waste or permitted to accumulate under controlled conditions during operations, may be used to advantage to: accelerate the inherent processes producing and converting leachable constituents; extract waste constituents and reaction products from the waste mass; dilute out inhibitory and/or refractory; distribute microbial seed, nutrients or buffer capacity necessary for viable microbial activity; and, transport residuals for ultimate treatment or disposal. Because of the attendant acceleration of the microbially-mediated conversion of the waste constituents and the contracted time for stabilization of the readily available organic substrates, rates and amounts of gas production are concomitantly increased, thereby encouraging energy recovery and utilization. Such "wet" landfills create opportunities for innovative design and operation as a controlled biochemical systems which enhances predictability and minimizes long-term liabilities after closure.

Implicit in this latter management concept are requirements for containment and ultimate removal, disposal or utilization of the leachate and gas residuals. Current technology provides a sufficiency of techniques for containment with natural or fabricated liners and for leachate and gas management with collection, distribution and treatment systems. Ultimate disposal requires an inspection of the sensitivity of the eventual environmental receptor, whether it be the land, water or air. With prevailing regulatory constraints and implementation of state-of-the-art technology, all of these potential receptors may require some degree of residual pretreatment before ultimate disposal of leachate or gas is acceptable. Such pretreatment can be best provided by either on-site or off-site engineered systems that have the flexibility to accommodate the predicted and actual changes in leachate and gas characteristics.

Characterization of Landfill Stabilization

As indicated previously, most landfills progress through a series of rather predictable stages or phases of stabilization, the longevity and significance of which are determined by local conditions and the operational strategies being applied either externally or internally. Fortunately, these phases can be detected and monitored by leachate and gas analyses which are physically, chemically and biologically interrelated.

To direct the choice of analyses to be employed to characterize a particular phase of stabilization, it is necessary to recognize that a landfill exists throughout most of its active life as an anaerobic microbially-mediated process. This process is analogous in principle to an anaerobic batch digester, with limited inputs or outputs except for the solid waste originally deposited and the moisture which may have gained access by infiltration, and the eventual leachate and gas production and their possible migration. In a sense, therefore, landfills become large, long-term, anaerobic leach-bed reactors consisting of compartments or cells that progress through the various stabilization phases at different rates and somewhat independently, unless influenced by operational control or connected by an absence of confining barriers. If connected, the principal transport media (leachate and gas) tend to merge and dampen oscillations in characteristics, yielding a combined and temporally-averaged leachate and gas quality for the contiguous cells.

Phases of Landfill Stabilization. Using the anaerobic process analogy, and recognizing that the functional retention times for landfills extend over periods of years rather than days, it is possible to describe landfill stabilization on the basis of certain performance-related and time-dependent descriptors. Accordingly, most landfills experience a lag or initial adjustment phase which persists until sufficient moisture has accumulated to encourage the development of a viable and abundant microbial community. The evidence of this adjustment phase is first apparent with the initial production of gas (mainly carbon dioxide), possibly accompanied by elevated temperatures due to incipient aerobic conditions. The existence and relative persistence of elevated temperature serves to catalyze the initial microbial activity, but ordinary is short-lived, depending on the insulating conditions prevailing within the landfill system and the opportunity for dissipation of heat. This lag phase becomes more evident when leachate is formed and released after "indicated field capacity" is reached. Thereafter, further incremental saturation of the waste mass with moisture and the concomitant distribution of nutrients will promote the development of an active anaerobic and interdependent microbial consortia of acid-forming and methane-forming bacteria in each compartment of the landfill. The evidence of this consortia will be manifested in the changes in magnitude and intensity of various indicator parameters used for leachate and gas characterization. As readily available supporting substrates are exhausted, these changes become diminished and the associated indicator parameters will reflect an approach to stabilized conditions. Accordingly, five sequential stabilization phases can be described in this manner and include: <u>Initial Adjustment</u> (Phase I); <u>Transition</u> (Phase II); <u>Acid Formation</u> (Phase III); <u>Methane Fermentation</u> (Phase IV); and, <u>Final Maturation</u> (Phase V).

Since this sequential development is a natural landfill phenomenon, all of these phases are encountered at one time or another in landfills receiving municipal solid waste, provided that the associated microbially-mediated conversion processes have a sufficiency of moisture and nutrients and are not inhibited. As indicated previously, because the manifestations of these phases often overlap within a landfill setting, it has become customary to characterize them in a combined fashion. This has tended to obscure and limit a mechanistic understanding of landfill behavior and the corresponding potential for the operational control necessary for process optimization. Moreover, no landfill has a single "age", but rather a family of different ages associated with the various landfill cells as they evolve toward final maturation.

The rate of evolution through the phases of stabilization, as determined by leachate and gas analyses, will vary depending not only on waste characteristics, but on the physical, chemical and microbial conditions established within each cell with time. For example, low pH conditions established during acid formation (Phase III) may delay or preclude the onset of active methane fermentation (Phase IV), inhibition or retardation of microbial activity may be induced by the presence of toxic substances, and high physical compaction or the use of impermeable intermediate and final covers may restrict the movement and accessibility of moisture and essential nutrients. Collectively, these constraints could decrease or neutralize the *in situ* mechanisms of attenuation and assimilation responsible for stabilization of the waste constituents, prolong the time required for ultimate stabilization to occur, and extend the period and uncertainty of environmental liability after site closure.

Indicator Parameters. A variety of indicator parameters may be used to detect and describe the presence, intensity and longevity of the phases of landfill stabilization. Many of these apply for the analysis of leachate and whether physical, chemical or biological, each has a particular utility and significance in terms of monitoring and control. For instance, of those parameters included in Table 1, pH and ORP are physical parameters indicative of acid-base and oxidation-reduction conditions, respectively, and important in evaluating the acid formation and methane fermentation phases (Phases III and IV); COD and BOD_5 are chemical and biological parameters, respectively, but are both indicative of relative leachate strength and biodegradability; and, nitrogen and phosphorus are chemical parameters important in the determination of nutrient sufficiency and condition (aerobic/anaerobic) of a particular phase. Similar importance can be assigned to the other parameters such as alkalinity (buffer capacity), heavy metals (potential inhibition), conductivity (ionic strength/activity effects), chlorides (tracer/migration potential), sulfates and sulfides (oxidation condition/precipitation potential), and coliforms and viruses (potential health implications).

Ranges in intensity and concentration of these indicator parameters will vary throughout each phase of stabilization, again dependent on the principal function of the phase as defined, the physical influence of dilution or washout, and the continuing flux of moisture. Relative moisture availability during leaching will tend to affect concentrations, and will influence the total mass potentially leached. It will also influence reaction opportunity and intensity and thereby lead to either accelerated or diminished microbially-mediated transformations. Unfortunately, dilution effects are often poorly measured or recorded, leading to variances in interpretation when analyses are based upon concentration alone. Nevertheless, it is possible to provide general ranges of intensity and concentration of the various indicator parameters throughout the landfill phases when leachate (and gas) is available for analysis. Although reported in more detail elsewhere (Pohland and Harper, 1985), the general pattern is presented in Figure 1 which serves to demonstrate the linkage between a few important indicator parameters and the phases of landfill stabilization.

As illustrated in Figure 1, the initial lag or adjustment phase (Phase I) is eventually followed by: a transition from aerobic to anoxic or anaerobic conditions with increasing production of leachate (Phase II), active acid (TVA) formation with high leachate strength (COD), low pH, and mobilization of ionic species (Phase III); methane fermentation with high gas production and quality, reduced leachate strength (COD and TVA), increased pH, low ORP and enhanced complexation and reduction of ionic species (Phase IV); and, final maturation (Phase V) when nutrients may become limiting, more difficult to degrade substrates are utilized, gas production decreases dramatically, and poststabilization conditions are established. .

Accelerated Landfill Stabilization

The progress of landfill stabilization and concomitant attenuation and assimilation of waste constituents can be accelerated by the elimination of the constraints indicated previously and by optimizing operational features. One technique to accomplish this goal is to nurture the microbially-mediated conversion process by leachate containment, collections and recycle as originally conceived and demonstrated by Pohland (1975, 1980), and subsequently extended to include codisposal with both inorganic and organic priority pollutants (Pohland <u>et al</u>., 1985; Pohland and Gould, 1986; Graven and Pohland, 1987). Indeed, recent surveys (Pohland and Harper, 1985; EPA, 1988) have indicated rather widespread application of the technique, with over 200 landfills sites in the Unites States now practicing some form of leachate recirculation.

The inherent advantages of accelerated landfill stabilization by leachate and gas management over conventional landfill practice can be demonstrated by selected results of laboratory simulations. Accordingly, laboratory-scale landfill cells, consisting of identical 208-L containers were filled with shredded (10-15 cm) municipal solid waste (MSW). The cells were operated with and without leachate recycle as indicated schematically in Figure 2. After loading each cell with a total of 54.6 kg (dry) shredded MSW with an indicated density of 482 kg/m^3, distilled and deionized water was added to attain indicated field capacity, and measurements on resultant leachate and gas production were commenced.

In terms of mass concentrations of leachate COD and TVA accumulated or released (Figure 3) and associated gas production and quality (Figures 4 and 5), it is apparent that accelerated stabilization and conversion of readily available substrates to intermediate volatile acids and gas occurred rapidly in the recycle cell, but slowly and only to a limited extent in the single pass cell. In fact, considerably more of the available substrate measured by leachate COD and TVA was converted to gas by *in situ* processes in the recycle cell (Figure 5), whereas the major portion of these leachate constituents were routinely discharged as washout from the single pass cell without equivalent gas production. Such a release of high-strength leachate without further treatment would be unacceptable in practice, thereby incurring the additional costs and operational uncertainties of separate treatment. Moreover, the opportunities for potential gas recovery as an energy source without separate treatment are lost.

In addition to a lack of conversion of the organic constituents in the leachate from the single pass cell, greater amounts of inorganic species were released routinely with time. This is demonstrated by the data in Table 2 where the low pH condition, consequenced by the abundance of organic acids and lower buffer capacity (alkalinity) of the single pass leachate, confirmed the progressive washout of constituents and the absence of viable methane fermentation (Phase IV). The time for stabilization was thereby prolonged beyond that required with leachate recycle, and is analogous to circumstances at conventional landfills where extended periods of time (decades) are required for such stabilization to be completed. Moreover, with leachate recycle, many of the heavy metals were removed *in situ*, leached constituents were contained within the system (unless converted to gas), and the quantity of leachate accumulated and managed was reduced to that required for recycle and to accommodate associated mass loading considerations. Accordingly, leachate recycle should be operationally discontinued and the leachate pool removed for ultimate disposal at controlled landfills when accelerated stabilization of the readily available organic substrates has been completed at the end of Phase IV. Such physical removal of the leachate also deprives the landfill of the principal transport medium as well as the moisture and nutrients necessary for continued conversion of more resistant waste substrates. As a consequence, active biological activity dramatically declines, and the landfill becomes essentially dormant.

The data in Table 2 also may be used to reflect the relative acceptability of the respective leachates for ultimate discharge either to an existing sewerage/waste treatment or land disposal system. It is apparent that the single pass leachate would require additional organic removal by pretreatment before ultimate discharge, whereas the recycled leachate could be discharged without such pretreatment other than by dilution or possible ammonia removal. In this latter case, physical removal of the residual leachate from the landfill and discharge either to a publicly owned treatment works (POTW) or management by land spreading (irrigation) would be appropriate technology after Phase IV of *in situ* stabilization had been completed. As indicated in Table 3, similar leachate management practices already are being applied at full-scale landfill sites.

When compared to conventional landfill practices, a number of options are available for leachate and gas management either as produced at the landfill during operations and maintenance or prior to ultimate disposal.

Before final discharge onto land or into a POTW, landfill leachate may require polishing by biological and/or physical-chemical methods after either on-site or *in situ* treatment. It is also widely recognized that the quantity and quality of landfill gas essentially determines when it may be captured and treated for possible beneficial use. The more leachate treatment accomplished within the landfill before final discharge, the less polishing treatment required. Moreover, if such *in situ* treatment is accelerated through leachate recycle, the opportunities for energy recovery from the associated gas production are greatly enhanced, whether the gas is used directly or pretreated to pipe line quality.

Future Prospects and Conclusions

Leachate recirculation is being more routinely considered as a landfill management option, and its advantages in terms of comparative costs and enhanced predictability will likely promote more frequent implementation in future. The arguments against such implementation are largely due to a lack of understanding of the technology required for successful application, and of the environmental setting within which the method is applicable. In locations where the infiltration of moisture and leachate production are inevitable, leachate collection and controlled recycle becomes particularly attractive. As more operating data and experience becomes available, these issues will be clearer and better resolved, and controlled stabilization with leachate management will also be more readily accepted as a technically and environmentally sound solid waste management option. Therefore, development of future controlled stabilization landfills will more effectively harness the potent *in situ* attenuating and assimilating capacities of landfills and will link these directly to energy recovery. Elements of design, operation and maintenance necessary to accommodate such controlled stabilization will include:

- o engineered containment with fabricated liner, cover, and confining barrier systems (natural or synthetic or both) to facilitate leachate and gas management;
- o appurtenances for leachate and gas collection, management and ultimate disposition, including drains, filters, collection/distribution systems, wells, vents, pumps and energy recovery systems; and,
- o integrated solid waste disposal and operating schedules to permit sequential cell construction and operation, controlled segregation, leachate and gas management, closure, and final use implementation.

In the final analysis, such an integrated approach to control and regulation of landfill stabilization will not only provide greater assurances against adverse environmental impacts, but will enhance opportunities for resource recovery and allay public concerns about landfills and their essential role in municipal solid waste management.

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TABLE 1. Landfill Leachate and Gas Indicator Parameters

Parameter Identity	Utility
Physical	
pH*	acid-base indicator
ORP*	oxidation-reduction indicator
Conductivity	ionic strength/activity indicator
Temperature*	reaction indicator
Chemical	
COD*, TOC	biodegradability indicators
TKN*, NH_3-N*, PO_4-P*	nutrient indicators
TVA*, SO_4/S, NO_3-N	stabilization phase indicators
TS*, Chloride*	dilution/environmental tracer
Total Alkalinity*	buffer capacity indicator
Alkali/Alkaline Earth Metals*	toxicity/environmental fate indicators
Heavy Metals*	toxicity/stabilization phase indicators
Gas (O_2, CH_4, CO_2, H_2, N_2)*	stabilization phase indicators
Biological	
BOD_5*	biodegradability indicator
Total/Fecal Coliforms	potential health hazard indicator
Fecal Streptococci	potential health hazard indicator
Viruses	potential health hazard indicator
Pure/Enrichment Cultures	stabilization phase indicator

*Parameters frequently used for evaluation.

Table 2. Comparative Characteristics of Leachates from the Single Pass and Recycle Cells after Completion of Accelerated Stabilization

Parameter	Single Pass Cell	Recycle Cell
Chemical Oxygen Demand (COD), mg/L	6222	2006
Total Volatile Acid (TVA), mg/L as CH_3COOH	4670	133
pH	5.3	7.1
ORP, mV E_c	-198	-232
Total Alkalinity, mg/L as $CaCO_3$	1829	3222
Conductivity, μmhos	1475	4084
Cadmium, mg/L	0.05	0.05
Calcium, mg/L	13	316
Chromium, mg/L	0.1	0.1
Copper, mg/L	0.1	0.1
Iron, mg/L	298	1.2
Lead, mg/L	0.3	0.3
Magnesium, mg/L	5.9	25.2
Manganese, mg/L	4.0	0.1
Nickel, mg/L	0.04	'0.1
Potassium, mg/L	1.6	266
Sodium, mg/L	5.6	913
Zinc, mg/L	0.3	1.8
o-Phosphate, mg/L P	0.1	0.1
Ammonia, mg/L N	1.6	105
Sulfide, mg/L	0.06	0.3

Table 3. Landfill Leachate Management Practices and Operating Status in the United States

Leachate Management Practice	Number of Landfills			Relative Costs
	Closed	Active	Planned	
Recirculate by Spraying	40	158	185	L
Recirculate by Injection	10	36	16	L
Recirculate by Other Means	11	34	22	L
Land Spreading	15	84	60	L/M
Truck to POTW	48	76	245	M/H
Discharge to Sewer to POTW	53	118	135	M
Other or Unknown Off-Site Treatment	5	21	23	-
On-Site Biological Treatment	41	102	108	H
On-Site Chemical/Physical Treatment	34	61	60	H

Source of Landfill Data: EPA, 1988 (Some facilities use more than one practice.)

Relative Costs: L (Low), M (Moderate), H (High); includes capital and operating/ maintenance costs.

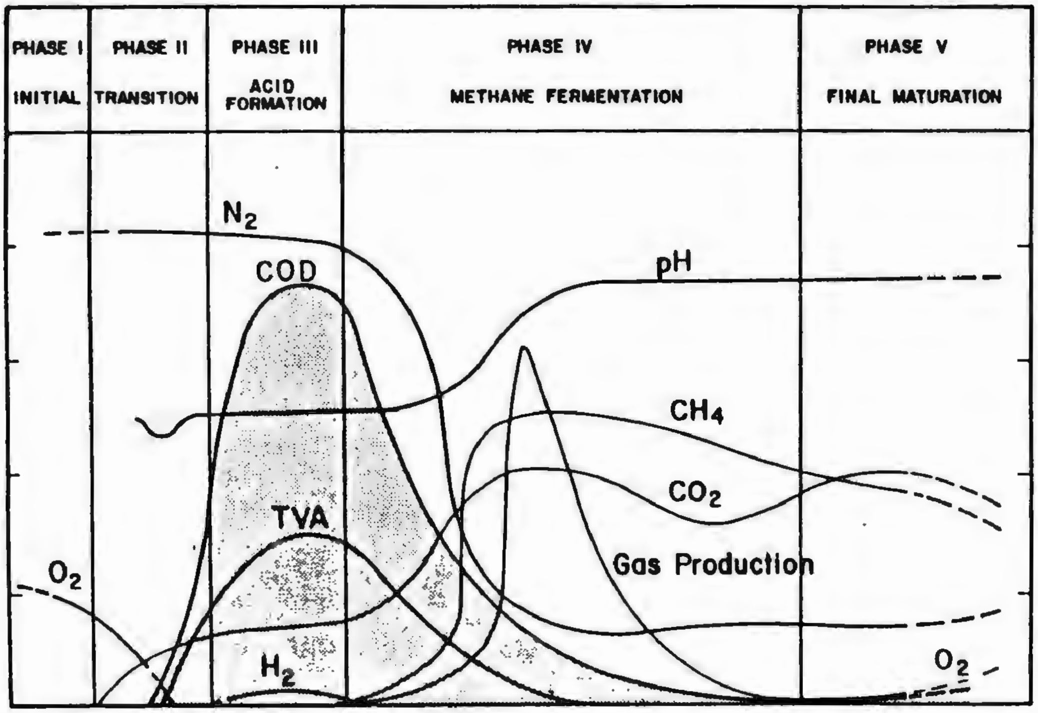

Figure 1. Changes in Selected Indicator Parameters during the Phases of Landfill Stabilization

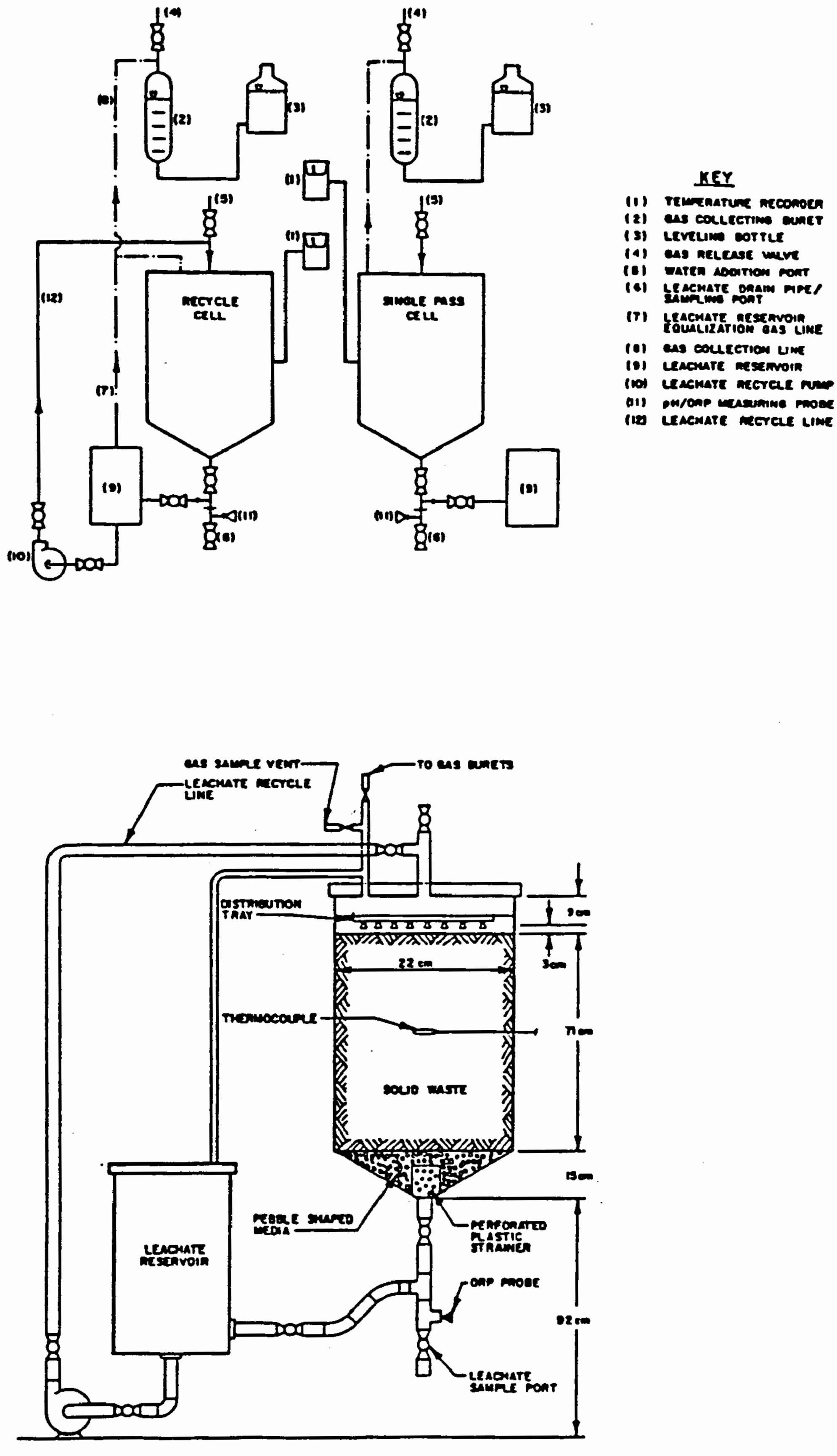

Figure 2. Operational Features and Configuration of Simulated Landfill Cells

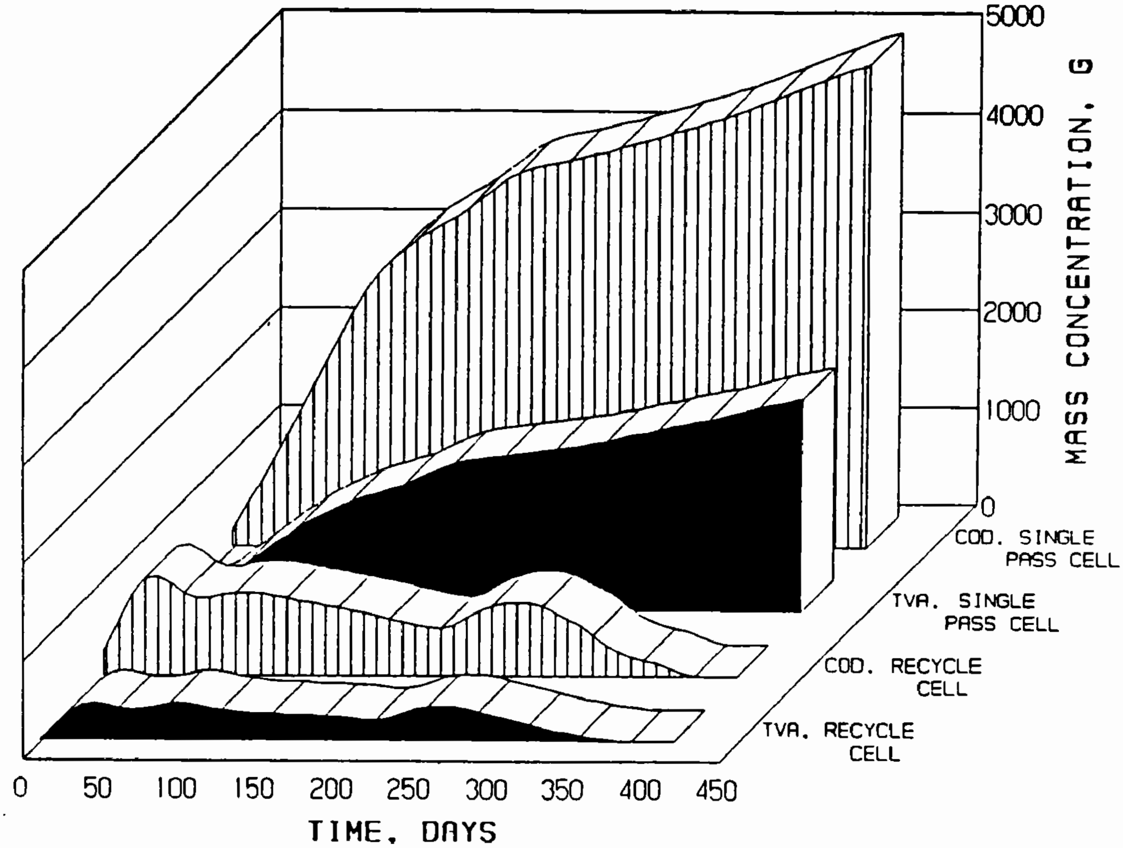

Figure 3. Mass Accumulations and Releases of Leachate COD and TVA during Single Pass and Recycle Operations

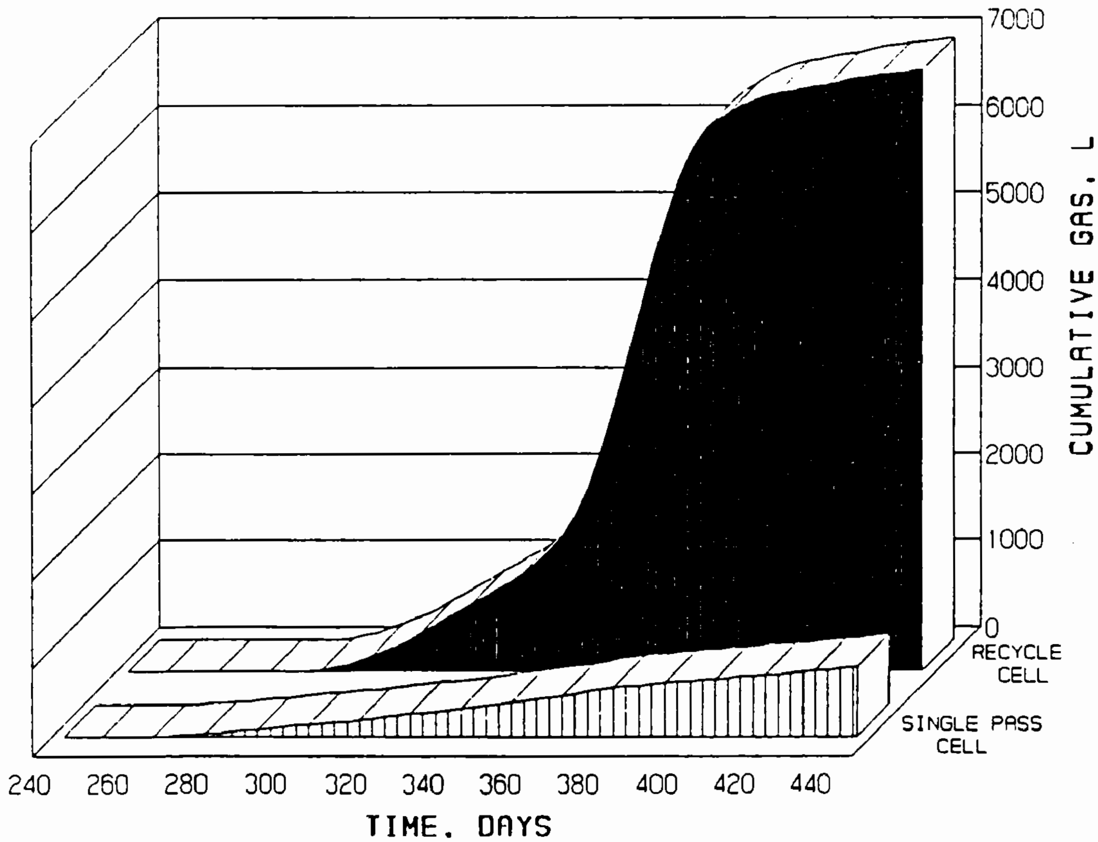

Figure 4. Comparative Accumulated Gas Production during Single Pass and Recycle Operations

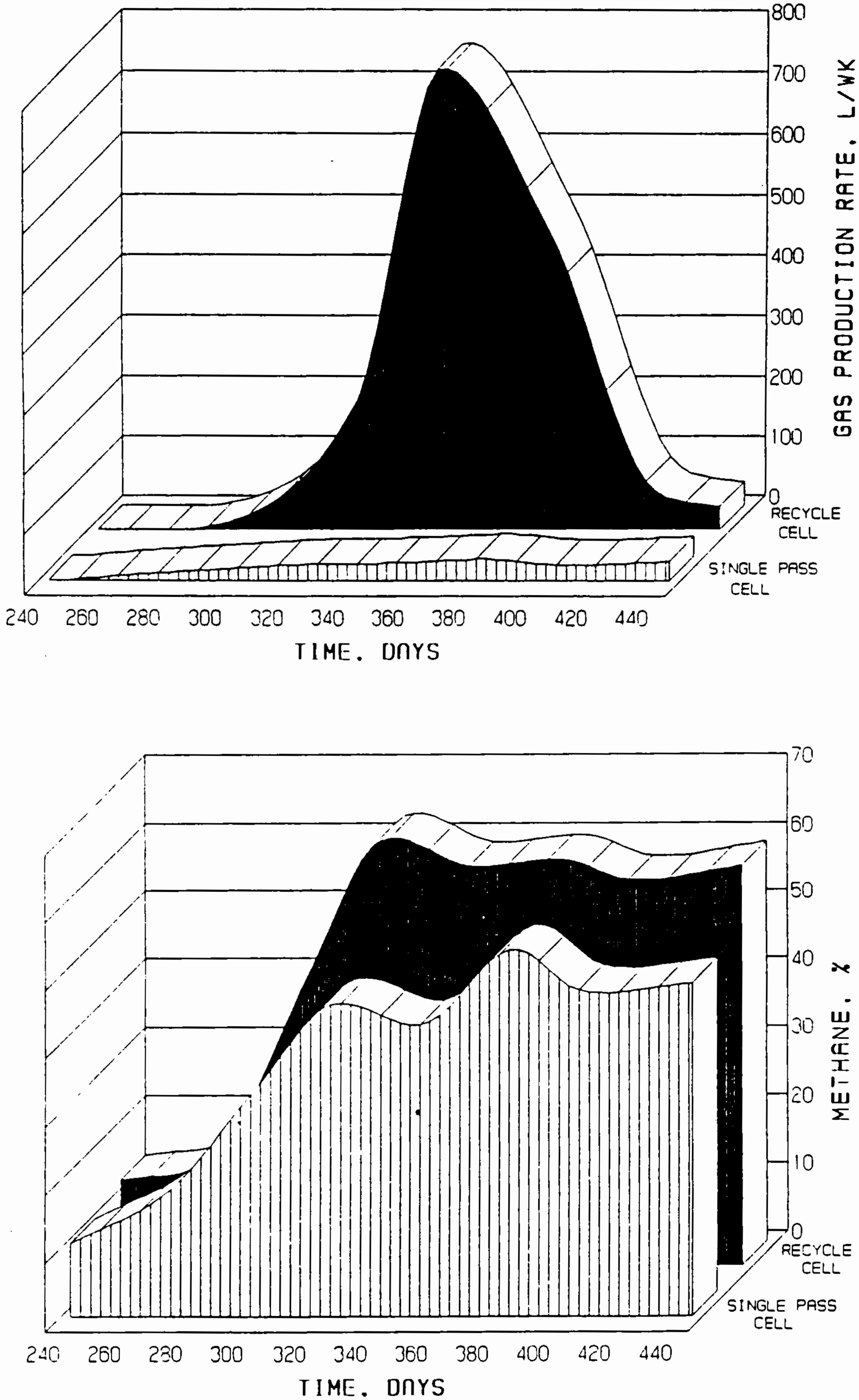

Figure 5. Changes in Gas Production and Quality during Single Pass and Recycle Operations

DESIGN AND CONSTRUCTION
OF
SOLID WASTE CONTAINMENT SYSTEMS

by

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

INTRODUCTION

The past decade has witnessed an ever increasing emphasis on the implementation of technical advances in the design and construction of solid waste disposal facilities. Driven both by public outcry and regulatory requirements, this direction has been to minimize the potential environmental impacts of disposal sites by enhancing the integrity of their containment systems. Concurrently, the reduction in available landfill airspace and the difficulty in siting and permitting new disposal facilities has significantly increased the value of existing and permitted airspace as an asset. These two trends have caused landfill designers and developers to reassess existing technology and evaluate new materials and design methodologies in an effort to improve the performance of these facilities while maximizing their disposal capacity.

Traditionally, natural or processed soils have been the materials used to construct landfill liner, cover and leachate collection systems. However, increasingly stringent regulatory standards for both barrier and drainage layer performance have led the solid waste industry to utilize synthetic products in coordination with, or in place of, natural materials. If properly designed and installed, synthetics can improve both containment and drainage, resulting in a more environmentally sound facility. Increases in available airspace, without sacrificing facility performance, can be realized when synthetics are substituted for all or a portion of relatively thicker layers of natural materials. Consistency of material and relative ease of installation are additional factors that have made synthetic components a staple of current landfill design.

This paper reviews the regulatory history and assesses current practice in the utilization of natural and synthetic materials for the design and construction of containment systems for solid waste disposal.

REGULATORY BACKGROUND

Containment technology and design methodology for solid waste disposal facilities over the past five years has followed in the wake of Resource Conservation and Recovery Act (RCRA) requirements for hazardous waste disposal facilities. Under Subtitle C of RCRA, the United States Environmental Protection Agency (USEPA) promulgated initial regulations on 19 May 1980 that established criteria for disposal facility liner and leachate collection systems. RCRA was reauthorized and amended on 8 November 1984 by the Hazardous and Solid Waste Amendments Act (HSWA), which implemented even more stringent technical standards, the most significant of which was the requirement for all hazardous waste facilities to have double liner systems.

In order to implement the facility standards mandated by RCRA and define performance standards, USEPA has employed a sequence of Minimum Technology Guidance (MTG) documents. The initial MTG document, issued in July 1982, required a single synthetic liner and "strongly recommended" a composite synthetic-clay liner. As a result of the HSWA requirement for double liner systems, USEPA issued an MTG document on 19 December 1984 specifying a synthetic primary liner and a composite synthetic-soil or soil secondary liner and introducing the requirement for a formal construction quality assurance plan for each disposal unit. The 1984 MTG was updated with 24 May 1985 and April 1987 documents. This guidance, the most current, increased the minimum permeability requirement of the primary leachate collection system from 1×10^{-3} cm/sec to 1×10^{-2} cm/sec and extended this criteria to the secondary leachate collection system. It also increased the soil component of the secondary composite liner from two to three feet of 1×10^{-7} cm/sec clay. The 1985 MTG document allowed for the use of composite primary liners. In October 1985, USEPA issued the first draft of the construction quality assurance requirements originally outlined in the 1984 MTG document. In addition, a July 1989 technical guidance document refined the final cover system requirements defined in the 1982 MTG document.

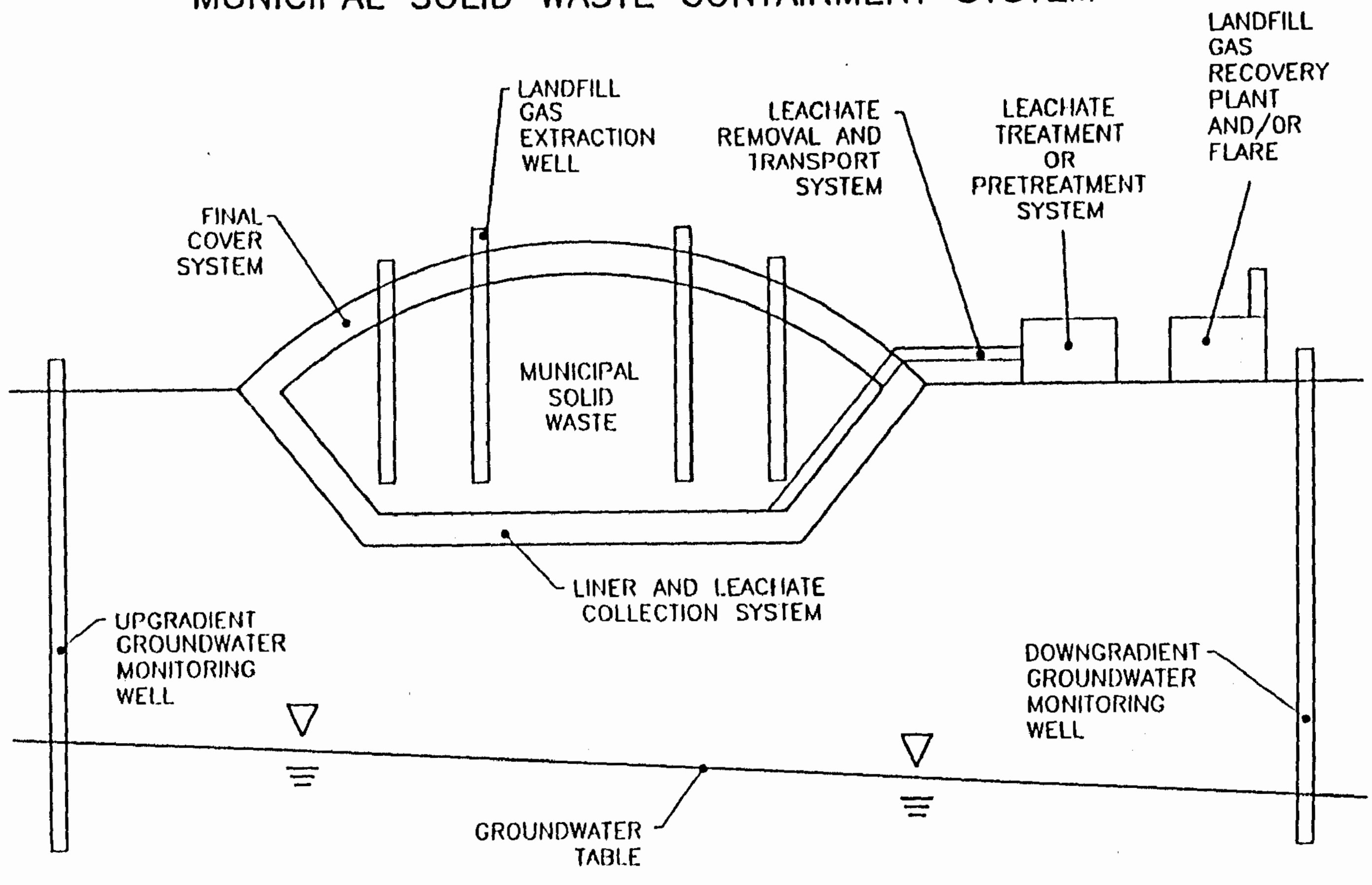
While federal solid waste regulations, to be promulgated under Subtitle D of RCRA, are still in internal USEPA review, many states have enacted solid waste regulations as stringent or more stringent than what is required by Subtitle C. Several states require double synthetic liner systems and a number even require double composite liner systems. Even in states where regulations call for minimal design requirements, some facility owners have implemented containment systems based on Subtitle C MTG in order to improve the environmental integrity of their facilities and protect themselves from long term liability.

CONTAINMENT SYSTEMS

From both a concerned public and regulatory perspective, three issues are raised by the land disposal of solid waste. These are the containment of the waste and the control of its by-products, leachate and landfill gas. No single material or layer can adequately perform these functions. It is only through the design of a multiple component containment system that an environmentally "secure" facility can be developed. Equal emphasis must be placed on both cover and liner systems in order to minimize the accumulation and accelerate the removal of liquids in the landfill. The components of a complete containment system are illustrated in Figure 1.

FIGURE 1

MUNICIPAL SOLID WASTE CONTAINMENT SYSTEM



The technical basis for the multi-layer containment system, in its many variations and alternative configurations, is to minimize liquid detention time on the barrier layers by expediting its removal through highly transmissive drainage layers. The relative difference in the transmissive properties of the barrier and drainage layers is therefore a major consideration in the design of an effective containment system. For this reason, composite barrier layers utilizing both synthetic and natural materials benefit from the qualities of both - the lower permeability and low lateral flow resistance of a synthetic supported by the self-healing and attenuative properties of a natural soil.

Synthetic and natural materials are used in four basic applications in the liner and cover portions of a containment system. The two primary functions are to provide a barrier and drainage. The two support functions are to provide interface layers, such as filters or protective cushions, and to provide reinforcement.

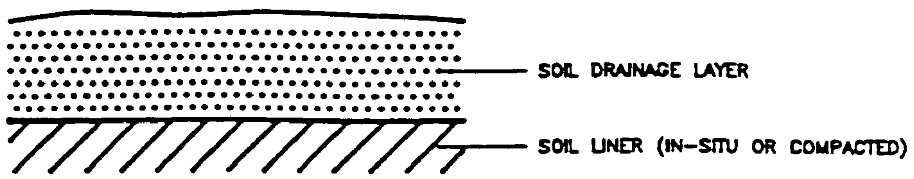
The landfill designer must consider a number of criteria in developing the most effective containment system for a specific facility. The appropriate regulatory requirements are clearly the foremost consideration. However, there are others which impact each specific design. Where airspace is at a premium, synthetics can be utilized to design an effective containment system while reducing the need for thicker soil layers. The availability of natural materials is also a consideration. The economics of containment system components as compared to airspace may also impact the configuration for a specific facility. For example, synthetic drainage layers such as geonets see more frequent use as increasingly stringent transmissivity requirements dictate the use of highly processed, potentially difficult to obtain, and often very expensive granular soils.

Utilizing the advantages of both natural and synthetic materials, a number of liner and cover systems can be developed to satisfy the various regulatory requirements and environmental concerns which need to be addressed in the design of any solid waste disposal facility. Figure 2 illustrates some of the more frequently seen multi-layer liner and cover systems.

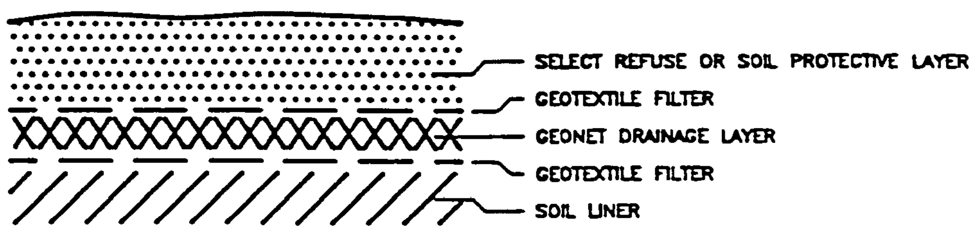
DESIGN CONSIDERATIONS

As discussed above, various natural and synthetic materials are used to perform the four functions - barrier, drainage, interface and reinforcement - of a solid waste containment system. The component layers are used either individually or in

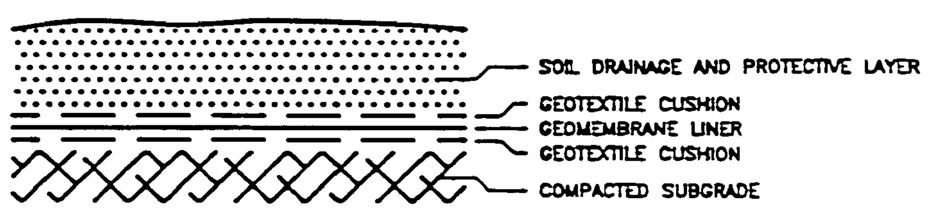
FIGURE 2



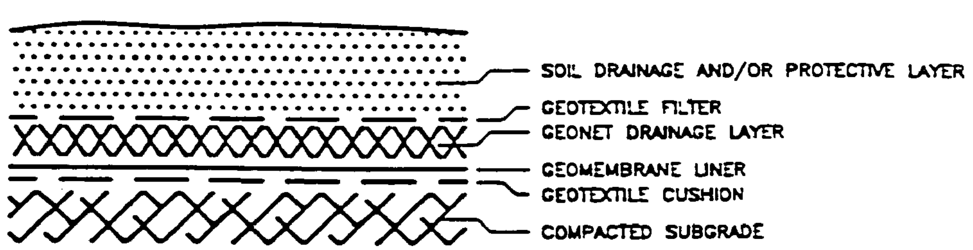
SINGLE SOIL LINER



SINGLE SOIL LINER

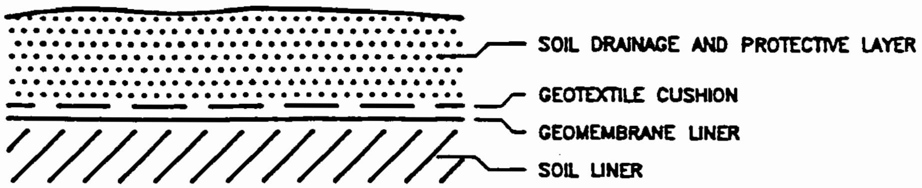


SINGLE GEOMEMBRANE LINER

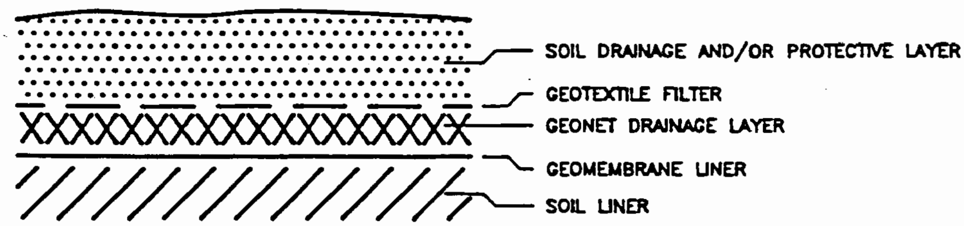


SINGLE GEOMEMBRANE LINER

FIGURE 2
(CONTINUED)



SINGLE COMPOSITE LINER



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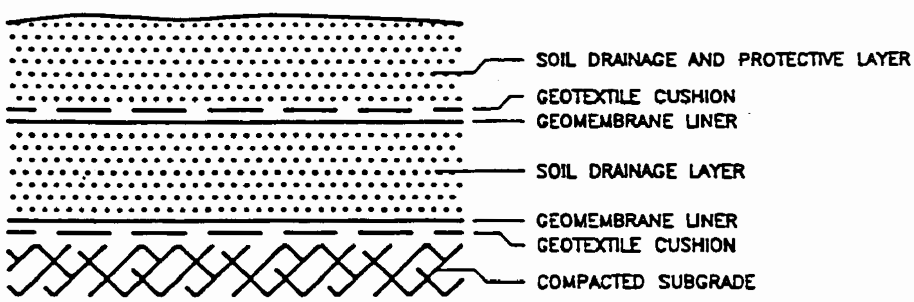
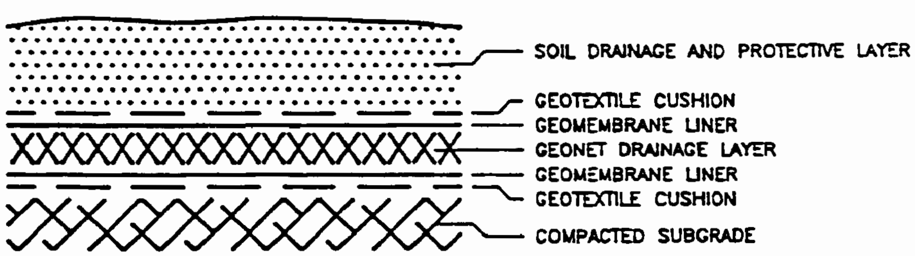
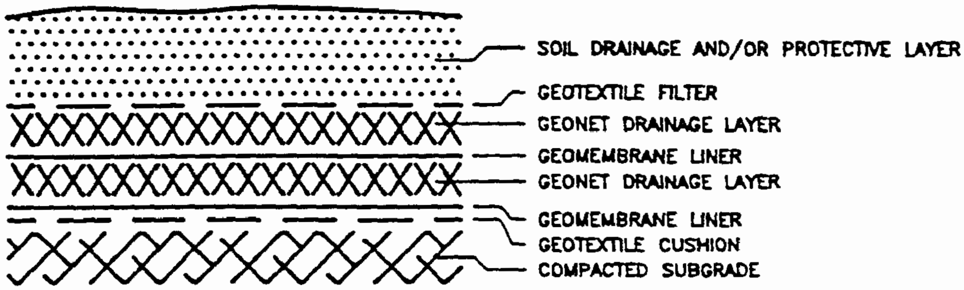


DOUBLE GEOMEMBRANE LINER

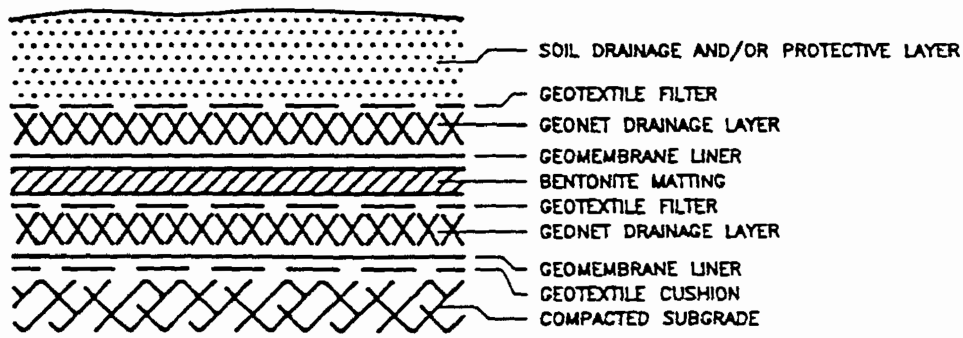


DOUBLE GEOMEMBRANE LINER

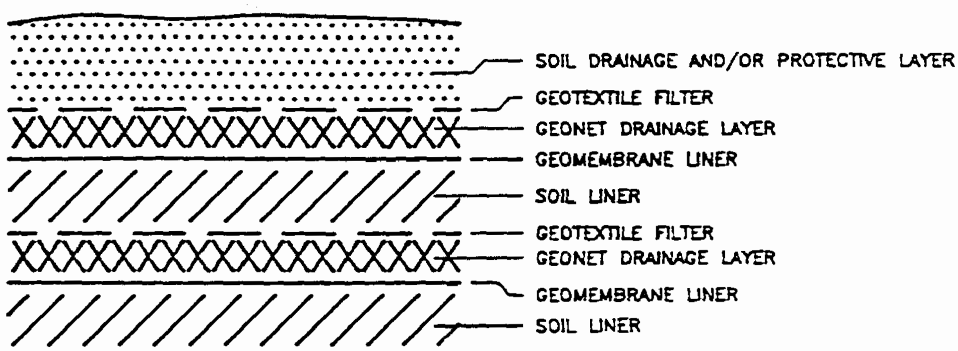
FIGURE 2
(CONTINUED)



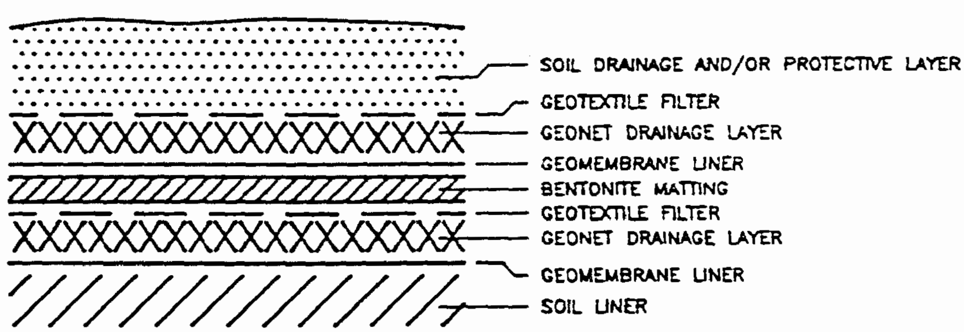
DOUBLE GEOMEMBRANE LINER



DOUBLE GEOMEMBRANE LINER
WITH COMPOSITE PRIMARY LINER

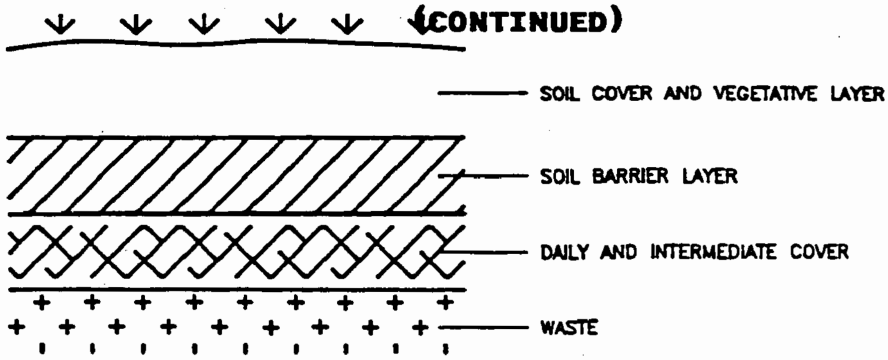


DOUBLE COMPOSITE LINER

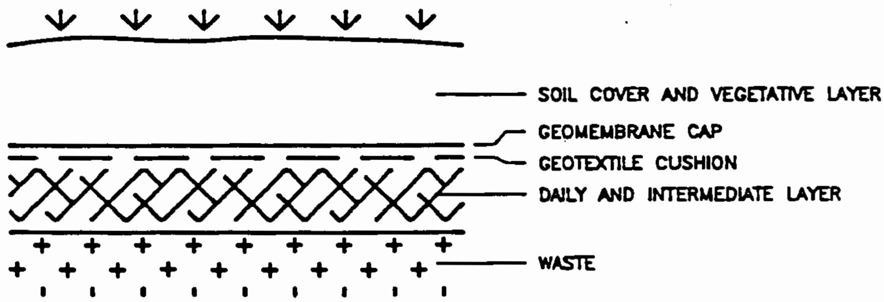


DOUBLE COMPOSITE LINER

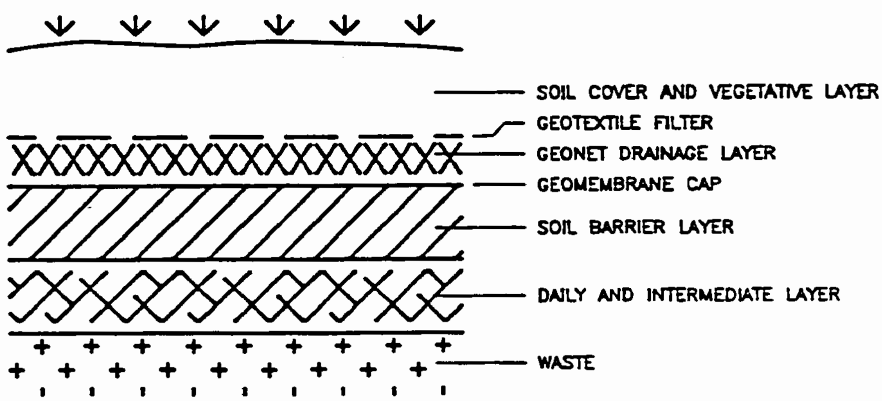
FIGURE 2
(CONTINUED)



SOIL FINAL COVER



GEOMEMBRANE FINAL COVER



COMPOSITE FINAL COVER
WITH DRAINAGE LAYER

combination with each other to meet the required design criteria and performance standards. These component layers are generally described as follows:

- Soil Barrier Layer
- Synthetic Barrier Layer
- Soil Drainage Layer
- Synthetic Drainage Layer
- Interface Layers
- Synthetic Reinforcement and Stabilization Layer

A description of the general characteristics of the materials that comprise these components and the design considerations associated with each is presented below.

Soil Barrier Layer

Traditionally, naturally occurring or processed clay soils have been used as liners to prevent leachate migration and as final cover to prevent stormwater infiltration. Both in-situ and compacted clays have been used for liners. Typically, in-situ and compacted clays have been used for liners. Typically, in-situ clay liners have been ten feet thick with coefficients of permeability of 1×10^{-6} cm/sec or less. Compacted clay liners, because of their consistency and uniformity, have usually been thinner (three to five feet) and resulted in permeabilities an order of magnitude less than in-situ clay. While many states still allow the use of clay liners for municipal waste disposal, the trend has been to utilize clay in conjunction with a synthetic to construct a composite liner system.

In-situ clay liners require extensive geotechnical testing programs to verify their thickness and consistency. Continuous and discontinuous pockets of relatively high permeability granular materials are often encountered in natural clay deposits. To assure that these types of materials are not in contact with leachate, the uppermost three feet of an in-situ liner should be excavated and compacted.

Compacted clay liners should be placed and compacted at a moisture content slightly wet of optimum. Since clay liners are constructed in nine to twelve-inch thick lifts, the surface of each lift should be scarified prior to placement of the subsequent lift in order to achieve a homogenous liner and prevent lateral pathways for leachate migration.

Either in-situ or compacted, soil liners occupy valuable landfill airspace. When used with a synthetic, the thickness of clay required is substantially reduced. Eighteen inches of compacted clay underlying a synthetic liner provides an effective composite barrier. The surface of clay liners are only as smooth and consistent as construction equipment can make them. As a result, leachate can pond in localized low spots and infiltrate into the soil liner. Used with a synthetic, the self-healing and attenuative capacities of clay are exposed to a significantly lower volume of leachate and can function effectively with a thinner layer.

An innovative method of gaining the benefits of a clay liner without sacrificing airspace has been developed over the past five years. Bentonite matting consists of dry bentonite between two geotextile layers. While this matting is only a quarter of an inch in thickness, it consists of at least one pound of bentonite per square foot and testing has demonstrated its effectiveness in plugging a leak in an adjacent synthetic liner.

The bentonite can achieve permeabilities of 1×10^{-9} cm/sec or less when hydrated. Reduction in sheer strength and frictional characteristics when hydrated make the placement of bentonite matting within a containment system a stability concern that should be evaluated by the landfill designer. An alternative application would be to place the bentonite matting beneath a clay liner in lieu of a portion of the required clay liner thickness. Stability is less of a concern in this applicaiton. It is imperative that construction be staged so that the bentonite matting be covered immediately by the next adjacent layer in order to prevent it from being exposed to inclement weather.

Vegetative soil layers in final cover systems also serve to reduce infiltration along with low permeability barrier layers. Soils capable of establishing strong vegetative cover increase surface water runoff and decrease infiltration and resulting leachate generation.

Synthetic Barrier Layer

Compatibility with waste and leachate, physical properties and seamability are the major considerations when selecting a geomembrane for use as a barrier layer in a liner or final cover system. Leachate compatibility will become a secondary concern in the design of a cover. For a liner system, however, the geomembrane will be exposed to leachate for many years. As a result, it is critical that immersion testing such as the USEPA 9090 protocol be performed with the anticipated leachate as part of the geomembrane selection process. A wide range of geomembranes - polyvinyl chloride (PVC), chlorosulfonated polyethylene (CSPE or "Hypalon"), high density polyethylene (HDPE), and numerous others - have been utilized in solid waste containment applications. At the present time, however, it is the consensus of both the disposal industry and the regulatory community that HDPE is the best available product for this use.

Testing has shown that HDPE has the widest range of chemical compatibility of geomembranes on the market and that it is virtually unaffected by municipal solid waste leachate. A specific gravity of 0.93 or greater is generally specified for HDPE resin to be used for geomembrane manufacture. A carbon black content of two to three percent is required to protect HDPE geomembrane from degradation resulting from exposure to ultraviolet light.

Physical properties of a geomembrane may require special consideration during design and installation. It is important that the design engineer consider the construction and operating conditions to which the geomembrane will be exposed. Conditions the designer must address include anchoring, tensile stresses developed over long slopes, dynamic loads resulting from equipment operation, functional interface with adjacent materials, and the effects of settlement and subsidence.

While HDPE has the best overall leachate compatibility, its physical properties are difficult to design with and require site-specific evaluation. It has a high coefficient of thermal expansion which makes the placement of adjacent layers difficult under extreme weather conditions. In the 60 mil or greater thicknesses used in landfill applications, HDPE can be inflexible and difficult to work with in the field. Stress cracking is also a concern, although mainly in liquid impoundments. HDPE has a relatively hard manufactured surface which results in low interface friction angles. Design of HDPE must be limited to within its ten percent elastic yield point, beyond which permanent deformation will occur.

Soil Drainage Layer

Granular soils such as sand and gravel have been utilized for leachate collection and detection and for surface water above and gas diversion below the final cover barrier layer in solid waste landfills. Because granular leachate collection layers are at least one foot thick, they also provide protection for the underlying barrier layer from drainage during waste placement.

There are a number of concerns that must be addressed when designing a granular leachate collection layer. Design standards over the past five years have seen the permeability requirements for leachate collection layers increase from 1 x 10^{-3} cm/sec to 1 cm/sec. The objective has been to allow no more than one foot of leachate head buildup on the liner. This criteria has virtually eliminated sand from consideration. Even gravel and crushed stone must be washed and free of fines in order to perform satisfactorily. As a result, granular leachate collection zones can be costly in a number of ways. They consume airspace, are often difficult to locate, and in many instances require expensive processing prior to use.

Another concern is compatibility with leachate. In many areas, the available granular soils are derived from limestone. Testing has shown that limestone-based materials react with municipal solid waste leachate to form a precipitate which can eventually clog the collection zone. An effective design guideline has been to avoid materials having a calcium carbonate content in excess of ten to fifteen percent. This limitation also makes acceptable granular soils difficult to obtain and, resultingly, very expensive.

The designer should evaluate the interface of granular drainage layers with both clay and synthetic liners. With clays, the potential for fines to migrate into the drainage zone needs to be considered. A soil or geotextile filter layer may be required for the containment system to function as designed. With a geomembrane, the concern is to protect the liner from damage during construction and operations. It is generally good practice to use a nonwoven geotextile as a cushion above the synthetic liner to protect it from angularities in the drainage stone. At least eighteen inches of soil should be placed above the geomembrane prior to operating equipment above it. While the full eighteen inches does not need to satisfy the permeability criteria, it is often designed to do so.

Other design issues that must be addressed are the stability of granular soil on side slopes, clogging of the soil by biological activity and sediment deposition and physical and drainage interaction of the soil with the embedded pipe network. Removing leachate from the landfill is the first step in maintaining an effective containment system. To achieve this, composite collection systems consisting of granular soils, geotextile filters and geonets may be an alternative for the design engineer.

Synthetic Drainage Layer

Both geotextiles and geonets can be used as drainage layers within containment systems. However, the much higher transmissivities of geonets have made them the synthetic of choice for most drainage applications. Geonets can be used in leachate collection and detection and final cover systems in place of, or in conjunction with, natural soil layers.

Geonets being considered for use as drainage layers should be subjected to carefully controlled laboratory testing to determine the material's transmissivity and its response to overburden loading. Laboratory tests should carefully model the anticipated field conditions and include the materials which will be placed adjacent to the drainage layer, realistic overburden loads, and be conducted under a range of hydraulic gradients (usually less than 1.0). The overburden loads applied should be increased incrementally to at least the maximum overburden load anticipated in the field. If possible, testing should be performed with applied overburden pressures which exceed the maximum anticipated pressures by at least 50% to check that significant transmissivity reduction will not take place if overloading does occur. Transmissivity reductions may be the result of material compression, strand rollover, or the intrusion of adjacent materials into the drainage channels.

Variations in drainage layer transmissivity are, in part, a function of the components of the drainage system and the immediately adjacent materials. Typical observed variations for drainage systems utilizing geonets are outlined in Table 1. The transmissivity values shown are for extruded geonets approximately 0.2 inches thick, nonwoven geotextiles and cohesive soils.

Transmissivity tests described above are generally performed at various load increments, with these loads being applied for a time duration ranging typically from less than one hour up to 24 hours. Limited testing has been performed on samples subjected to static loads with longer durations. Testing performed on geonet samples that have been loaded for almost two years indicates only slight transmissivty reductions after one day.

Other factors which may impact the long term performance of the drainage layer are its creep characteristics, response to elevated temperatures, and the potential for biological or mechanical clogging. Laboratory studies and field monitoring to evaluate the long-term effects of these factors have only begun recently. A conservative design approach is recommended until conclusive results are available.

Synthetic drainage materials exhibit preferential drainage directions which should be taken into account during design and construction. Geonets exhibit a wide range of directional drainage behavior. Some geonets have transmissivity anisotropies

TABLE 1

GEONET DRAINAGE SYSTEM TRANSMISSIVITIES

Drainage System Configuration	Typical Transmissivity @10,000psf. i=1.0	Granular Material Equivalency
geomembrane geonet geomembrane	$1 \times 10^{-3} M^2/sec$	12" @ $k=3x10^{-1}$cm/sec
soil geotextile geonet geomembrane	$5 \times 10^{-4} M^2/sec$	12" @ $k=1.5x10^{-1}$cm/sec
soil geotextile geonet geotextile soil	$1 \times 10^{-4} M^2/sec$	12" @ $k=3x10^{-2}$cm/sec

that are insignificant and require no special construction considerations. Others have drainage preferences that are nearly unidirectional and the use of such products may require significant design consideration and careful construction control to be effective. In general, overall transmissivity behavior can be significantly effected by the orientation of the strands which compose the geonet.

Compatibility with leachate is also a consideration for synthetic drainage layers. Like geomembrane barrier layers, geonets will be subjected to leachate contact for many years. Therefore, geonets should undergo testing to verify compatibility with the anticipated leachate composition. As a result, most geonet products are manufactured from HDPE resin.

<u>Interface Layers</u>

In order for the materials utilized for the primary functions - barriers and drainage - in a containment system to perform as designed, "interface" layers are often required. Interface functions include filtration, separation and protection and can be performed by either natural or synthetic materials. As is the case for barriers and drainage layers, synthetics have the advantage of accomplishing the same function while occupying less space than natural materials.

Filters must be provided to maintain the integrity of the leachate collection zones. In designing either an aggregate or geotextile filter, the criteria conforms to traditional geotechnical engineering practice. The filter layer must provide adequate vertical drainage (referred to as permittivity) to the lateral flow zone; prevent piping of the overlying soils; and provide durability against chemical and biological degradation. While the use of non-carbonate aggregates or polyester or polypropylene geotextiles should provide protection from leachate attack, the effects of biological growth on filter performance is only now being investigated by researchers. Industry experience indicates that nonwoven geotextiles are generally superior in performance to woven geotextiles, particularly when fine-grained soils are being filtered.

Cushion layers are generally required to protect synthetic liners from the relatively large granular soils required to meet current transmissivity requirements. When synthetic liners first came into general use, a thin layer of sand was placed both above and below the geomembrane in order to provide protection. This practice prevented the construction of effective composite liners. It also hindered the rapid removal of leachate from the top of the liner by allowing a relatively low permeability (fine sand compared to clean gravel) zone immediately above the geomembrane. Nonwoven geotextiles, generally at least twelve to sixteen ounces per square yard, have proven effective in protecting HDPE and other geomembranes. Thickness and bulk density are the material characteristics required for an effective cushion. A laboratory testing program incorporating the actual containment system configuration and anticipated overburden loads should be performed in order to evaluate a specific design.

Synthetic Reinforcement and Stabilization Layers

Synthetic reinforcement layers, known as geogrids, can be used to support containment systems constructed over normally unsuitable foundation soils and existing waste materials in "overfill" or "piggyback" landfills. The necessity for this aplication increases along with the difficulty in siting and permitting new disposal facilities and the resulting need to expand or maximize the utilization of existing facilities. Geogrids are placed during the construction of the subgrade soils to provide tensile reinforcement to counter the effects of anticipated deflection, subsidence and differential settlement.

Another application for geogrids in containment systems is to stabilize the placement of protective soil cover on side slopes. The natural characteristics of the granular materials generally used for protective cover often limit the length of slope which can be covered at a given time. Incorporating geogrids in the design can allow for the placement of a greater amount of protective cover at a given time, facilitating construction and operations.

As with all synthetic components, geogrids must be compatible with leachate and resist chemical attack. Most geogrid products currently used in landfill applications are manufactured from polyethylene resins.

Stability

During both construction and operation of a disposal facility, the frictional characteristics of the containment system components can be of significant importance. Stability considerations control the integrity of below-grade and above-grade slopes and govern the sequence of landfill operations. Published data suggest that synthetic interfaces have lower friction angles and are therefore more critical than natural soil or soil/synthetic interfaces. Geonets and geotextiles are often situated adjacent to geomembranes in a variety of applications. Because laboratory data indicate relatively low friction angles for these interfaces, the stability of the entire disposal facility may be dependent on an accurate analysis and design of these components. Conservative friction angle values or site-specific test results should always be used as a basis for design.

Leachate Compatibility

Discussions concerning compatibility with leachate are generally directed at the geomembrane component of a liner system. However, in order to function as designed, it is critical that all components of the containment system be evaluated for compatibility. All of the synthetic components can be immersed in the anticipated leachate and tested for physical property retention at various time intervals in a similar protocol to USEPA 9090 for geomembranes. Both USEPA and the American Society for Testing and Materials (ASTM) are currently developing specific protocols for immersion testing for geonets, geotextiles and other synthetics. Soil barrier and drainage layers can be evaluated by using leachate to perform permeability and transmissivity tests, respectively. USEPA 9100 outlines the protocol for clay liners.

CONSTRUCTION CONSIDERATIONS

The translation of an engineering design to a constructed facility is always an area requiring careful monitoring and observation. However, it becomes extremely critical when the facility is a solid waste containment system the integrity of which is paramount to protecting the environment and public health. In order to achieve the most secure facility possible, the development and implementation of both stringent construction specifications and a comprehensive construction quality assurance program become imperative.

In order to develop and implement a quality assurance program, it is first necessary to define what is meant by the term "quality assurance" and how it is related to the activities encompassed by the term "quality control". These terms are often used interchangeably, resulting in a misinterpretation and lack of clarity in the intent of each term. Quality control can be defined as the measures taken by a contractor to determine if the work performed is in compliance with the project specifications and contract requirements. Quality assurance refers to the measures taken by the facility owner using an independent engineer to determine if the work performed by the contractor complies with project specifications and contract requirements. Quality assurance, then, is the assessment of the contractor's performance by the facility owner's third party representative.

Quality Control

Since the synthetic and natural materials to be used in the landfill containment system have been specified by the design engineer based on laboratory testing, it is critical that the materials used in the construction of the landfill have identical properties as those tested in the laboratory. Particularly for synthetics where critical properties can vary significantly even if manufacturing processes are varied only slightly, it is necessary that good quality control be exercised during manufacturing or processing. Samples should be taken on a regular basis during manufacturing and tested to evaluate relevant properties. The manufacturer should maintain detailed quality control documentation and be able to provide certification of the quality of each roll of material produced.

It is advisable to use only thoroughly tested products from manufacturers who have a record of consistently producing a quality product and to carefully review their quality control procedures with them prior to running the product for a specific site. Any supplier who hesitates to fully cooperate with all quality control efforts or is unwilling to produce historical quality control records should be disqualified from consideration for the project.

For natural materials, the line between quality control and quality assurance testing becomes more difficult to distinguish. It is necessary to sample and test a clay liner or granular drainage stone at its source in order to define its properties. The soil must be in the condition in which it will be actually utilized in construction, such as a processed clay or washed stone. In this way, the properties determined as part of the quality control program will be the basis of assessment for the quality assurance program during construction.

Quality Assurance

The principal objective of a construction quality assurance program is to minimize potential problems by achieving the best installation possible. To reach this goal, the quality assurance program must provide for the utilization of uniform standards and practices; the verification of compliance with material specifications, installation and testing procedures, and applicable regulatory requirements; and a defined route to obtaining as-built documentation and certification that the project was constructed in accordance with the specifications.

An effective quality assurance plan must define how it will achieve its stated objectives. It will need to provide an explanation of the qualifications, roles, responsibilities, authority and interaction of all parties involved. It must identify and describe all quality assurance activities and procedures and allow for well thought out in-field decisions by identifying actions to be followed when a problem occurs and by providing the basis for problem resolution. A preconstruction meeting, involving all parties, is required at the outset of the project to clearly outline the site-specific quality assurance plan, construction procedures and lines of communication to be adhered to during the course of the project. A basic outline for a construction quality assurance plan is presented on Table 2.

In addition to the quality exercised by the manufacturer during production, conformance testing should be performed on samples taken from the rolls of synthetics delivered to the site. Samples should be taken at a predetermined interval (typically, one per 100,000 ft^2) and the tests performed will depend on the type of synthetic being used. These tests should indicate whether or not the materials delivered to the site have the same properties as the designer intended. Conformance testing is the primary way in which the quality assurance program is applied to manufacturing of the synthetics. An additional step which should be taken either on a regular basis or for major jobs is to perform an inspection of the manufacturing facility. At a minimum, a plant inspection should be an integral part of the prequalification of any manufacturer.

The handling, storage, and transportation of the synthetics should be carefully controlled so that they are not damaged between the manufacturing plant and their delivery to the site. The importance of this intermediate handling should be stressed to all parties involved. All rolls of synthetics delivered to the site should be visually inspected for possible damage. All damaged rolls should be rejected. Synthetics used for drainage or filter applications, such as geonets or geotextiles, must be kept clean and free of debris which might impact their performance in the containment system. These materials must be stored in a dry, covered area prior to installation. If this is not done, extensive cleaning may be required at a minimum and rejection of the rolls may be necessary in the worst case.

Careful attention must be paid to installation requirements including placement, orientation, and joining techniques. In general, geotextiles should be sewn and geonets overlapped and tied. Geonet ties should not contain any metal and should be of a contrasting color to the geonet to allow for easy inspection. Typically, geonets are overlapped a minimum of four inches and ties spaced on the order of five feet along slopes, two feet across slopes, and six inches in anchor trenches. It is also important that the installation procedures (placing, cutting, and joining) performed for each synthetic not be allow to adversely impact the performance of adjacent synthetics.

TABLE 2

CONSTRUCTION QUALITY ASSURANCE PROGRAM

- Qualifications and Responsibilities of Parties
- Chain-of-command, Meetings and Reporting Structure
- Soil Components of Containment System
    - Pre-construction Testing of Soil Sources
    - Test Fill Construction and Testing
    - Construction Testing for Material Evaluation
    - Construction Testing for Performance Properties
- Geosynthetic Components of Containment System
    - Manufacturing
    - Fabrication
    - Handling, Storage and Transportation
    - Installation
    - Construction with Other Materials
- Documentation and Certification

All geomembrane seams must be visually observed during the installation process. In addition, seams must be evaluated through non-destructive and destructive testing. Extrusion seams can be non-destructively assessed for continuity using a vacuum box or a spark tester. Fusion and extrusion seams between the geomembranes can be split to create a channel in the center of the seam. In this instance, the seam can be non-destructively evaluated for continuity with air pressure testing through the seam channel. The parameters for non-destructive testing must be defined in the quality assurance plan. Destructive evaluation includes shear and peel testing for both fusion and extrusion seams. The quality assurance plan must outline a program for destructive testing, including the frequency of sampling, sample size, in-field and laboratory testing, criteria for acceptance and rejection, and corrective measures when necessary.

Quality assurance procedures should be developed to ensure that the installation of adjacent materials does not result in any damage to the synthetics. It is always necessary to place soil cover prior to allowing any equipment traffic on areas covered with synthetics. The thickness of soil cover may range from one to three feet, depending on the type of equipment to be used. In general, at least eighteen inches of protective soil should be placed prior to initiating disposal activities within a synthetically-lined landfill.

Quality assurance measures for soil liner components are based on the need to perform tests representative of actual field conditions while not damaging the actual compacted liner. One approach is to do all destructive (sample removal for laboratory testing) and in-situ (field permeability) testing on a "test fill" constructed with the identical equipment and methods as the actual liner. In this way, the compacted liner will only need to be tested to verify that it is in the same condition (density, moisture content) as the test fill to confirm its performance properties. In-situ permeability testing on a 1×10^{-7} cm/sec or less clay liner can take several months to perform. The use of a test fill can prevent construction delays and prolonged exposure and resulting damage to the liner. Scarification and bonding between lifts and maintaining correct moisture are other clay liner construction concerns to be addressed by the quality assurance program.

As a result of having implemented a comprehensive quality assurance plan, it will be possible for the independent engineer to certify the installation and for the facility owner to accept the final product. The third party engineer should prepare a final certification report at the conclusion of the project. This report should include, at a minimum, an outline of the project, the quality assurance methods used, the test results, and the as-built documentation and drawings. This report will serve as a basis for the formal acceptance of the final product by the facility owner and, where required, by the regulatory agency.

SUMMARY

The design and construction of solid waste containment systems incorporating natural and synthetic components have been discussed in this paper. Since the utilization of synthetics in conjunction with or in lieu of natural soils is relatively new, it is important that designs be based as much as possible on carefully modeled laboratory testing and verified by field observation and testing. Significant design considerations included stability and interlayer frictional characteristics, transmissivity, filter characteristics and compatibility with waste and leachate. However, design is only one of the issues that must be addressed when dealing with synthetics. By far the most important part of a successful installation is the implementation of a comprehensive quality control and quality assurance program during manufacturing and construction. The importance of this aspect for a solid waste disposal facility cannot be overstated.

It is anticipated that in the future synthetics will find increased use in a variety of functions at solid waste landfills. This increased use will be driven by technical criteria directed at designing and constructing more secure containment facilities and minimizing environmental impacts as well as by economic and site life considerations. In some cases, synthetic materials can offer significant advantages over the use of natural materials. The proven performance and widespread acceptance of these products dictate that they be routinely considered in conjunction with natural components during the conceptual design phase of solid waste containment systems for all new disposal facilities.

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AN ENVIRONMENTAL ASSESSMENT OF RECOVERING METHANE FROM MUNICIPAL SOLID WASTE BY REFCOM ANAEROBIC DIGESTION PROCESS

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

AN ENVIRONMENTAL ASSESSMENT OF RECOVERING METHANE FROM MUNICIPAL SOLID WASTE BY ANAEROBIC DIGESTION

Abstract

The full scale development of the RefCoM process which produces biogas or synthetic natural gas (SNG) by anaerobic digestion of municipal solid waste (MSW) is evaluated. This technology would be utilized in lieu of incineration or directly landfilling waste. An environmental assessment describing the principal impacts associated with operating the MSW anaerobic digestion process is presented. Variations in process configurations provide for SNG or electricity production and digester residue incineration, composting, or landfilling. Four RefCoM process configurations are compared to the conventional solid waste disposal alternatives of mass burn incineration and landfilling. Value analysis techniques indicate that the RefCoM process was preferred to mass burn incineration or direct landfilling of MSW.

I. Introduction

New methods and processes are being sought to cope with the ever increasing quantities of municipal solid waste (MSW). Approaches include source reduction, recycling, waste processing and separation, energy recovery, and better sanitary landfilling methods. One such approach, the RefCoM process, produces biogas by anaerobic digestion of municipal solid waste. This technology would be utilized in lieu of incineration or directly landfilling a portion of the waste.

II. The Anaerobic Digestion Process

A group of obligately anaerobic bacteria will, in the absence of O_2, consume various types of organic wastes producing methane, a major component of natural gas, carbon dioxide, and water (Stanier, et al., 1965). The speed and degree to which the digestion process is completed will depend on the bacterial community, nutrient balance, temperature, and the specific nature of the waste material. This process occurs naturally in many places and, in addition, has been extensively used to break down organic wastes in the sewage treatment process.

Laboratory scale experiments to anaerobically process municipal solid waste and sewage sludge were described by Pfeffer (Pfeffer, 1974; Pfeffer and Khalique, 1976; Pfeffer and Liebman, 1976). A single stage anaerobic digestion unit was tested. The experimental unit was operated over a temperature range of 35 to 60 degrees C and 4 to 30 days detention time. Volatile solids destruction ranged from 16 to 52 percent. Based on Pfeffer's work, operation of a 100 ton per day pilot plant located in Pompano Beach, Florida, began in 1978 (Mooij and Pfeffer, 1986). Based on the results of the pilot plant test, Isaacson, et al., (1987) estimated the necessary waste processing fee for various combinations of natural gas, electricity prices and concluded that the RefCoM process has "significant commercial potential."

III. RefCoM Configurations Evaluated

Alternative RefCoM process configurations were compared to the conventional solid waste disposal technologies of mass burn incineration and landfilling. The four alternative processes were:

1. RefCoM synthetic natural gas production with residue incineration (REFCOM SNG/INC), see Figures 1-3;
2. RefCoM biogas and electric production with residue incineration (REFCOM ELEC/INC), see Figures 4 and 5;

Figure 1. RefCoM SNG / Incineration Process Diagram

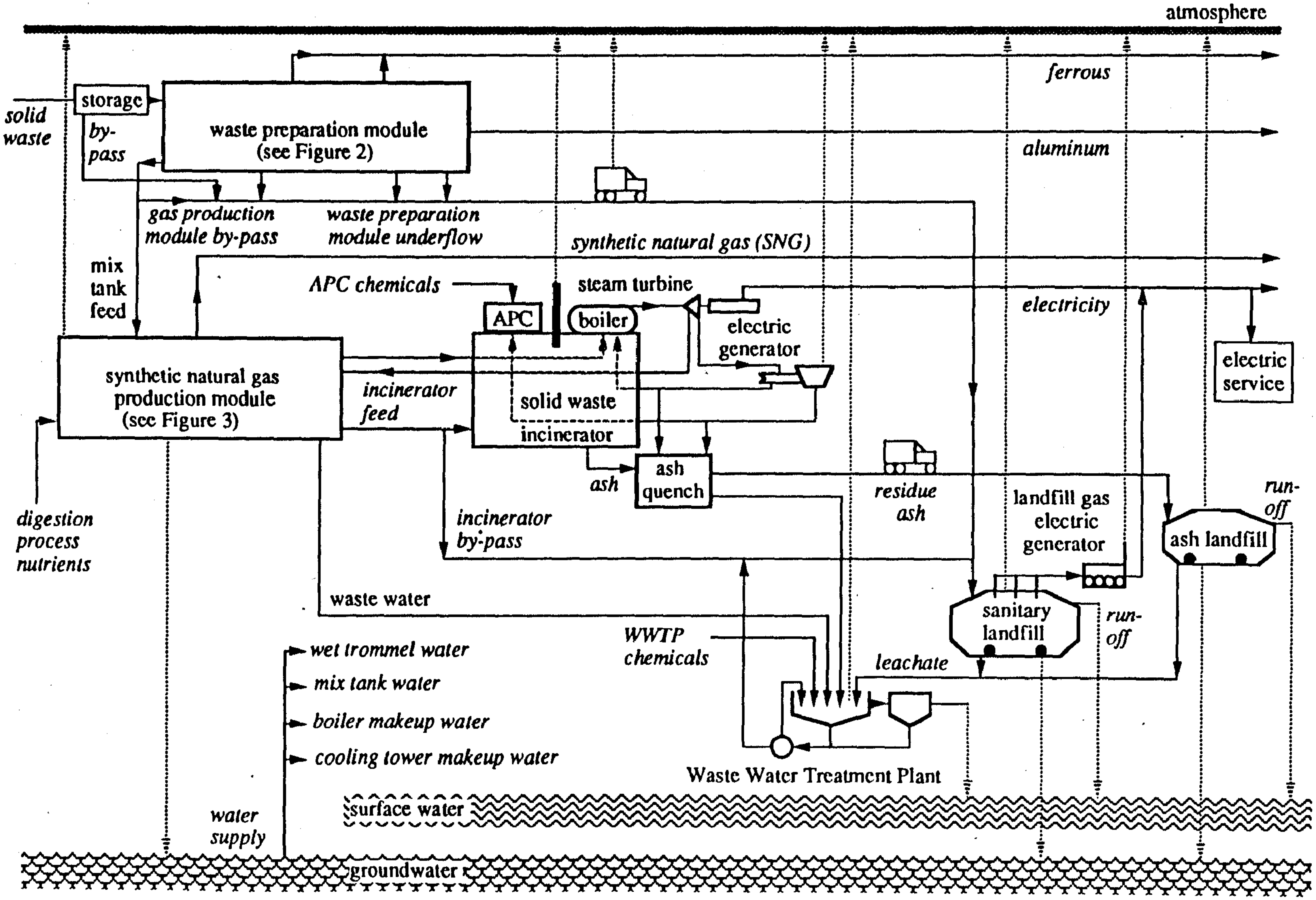


Figure 2. RefCoM Waste Preparation Module Process Flow Diagram

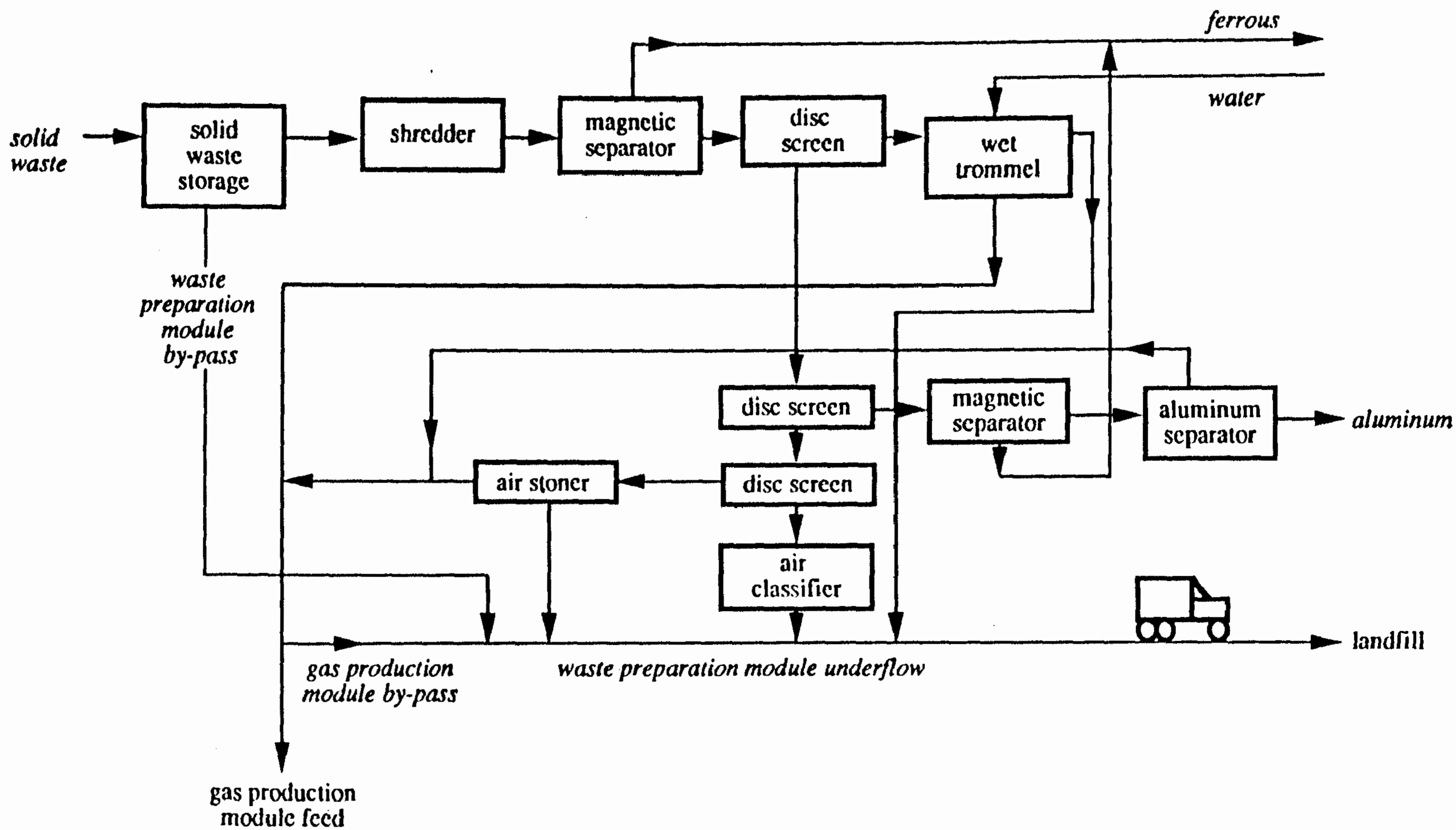


Figure 3. RefCoM Synthetic Natural Gas Production Module Process Diagram

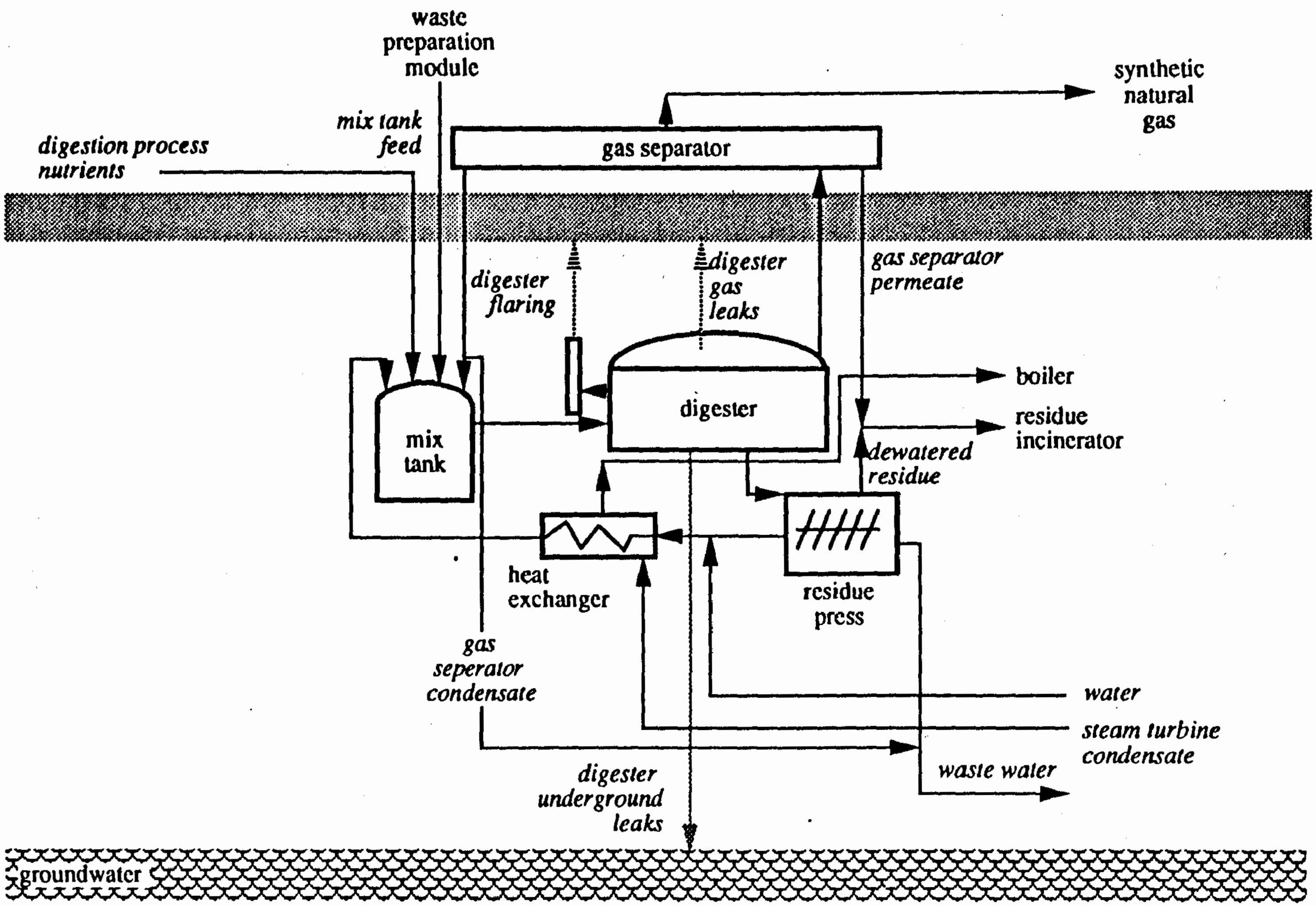


Figure 4. RefCoM Electric / Incineration Process Diagram

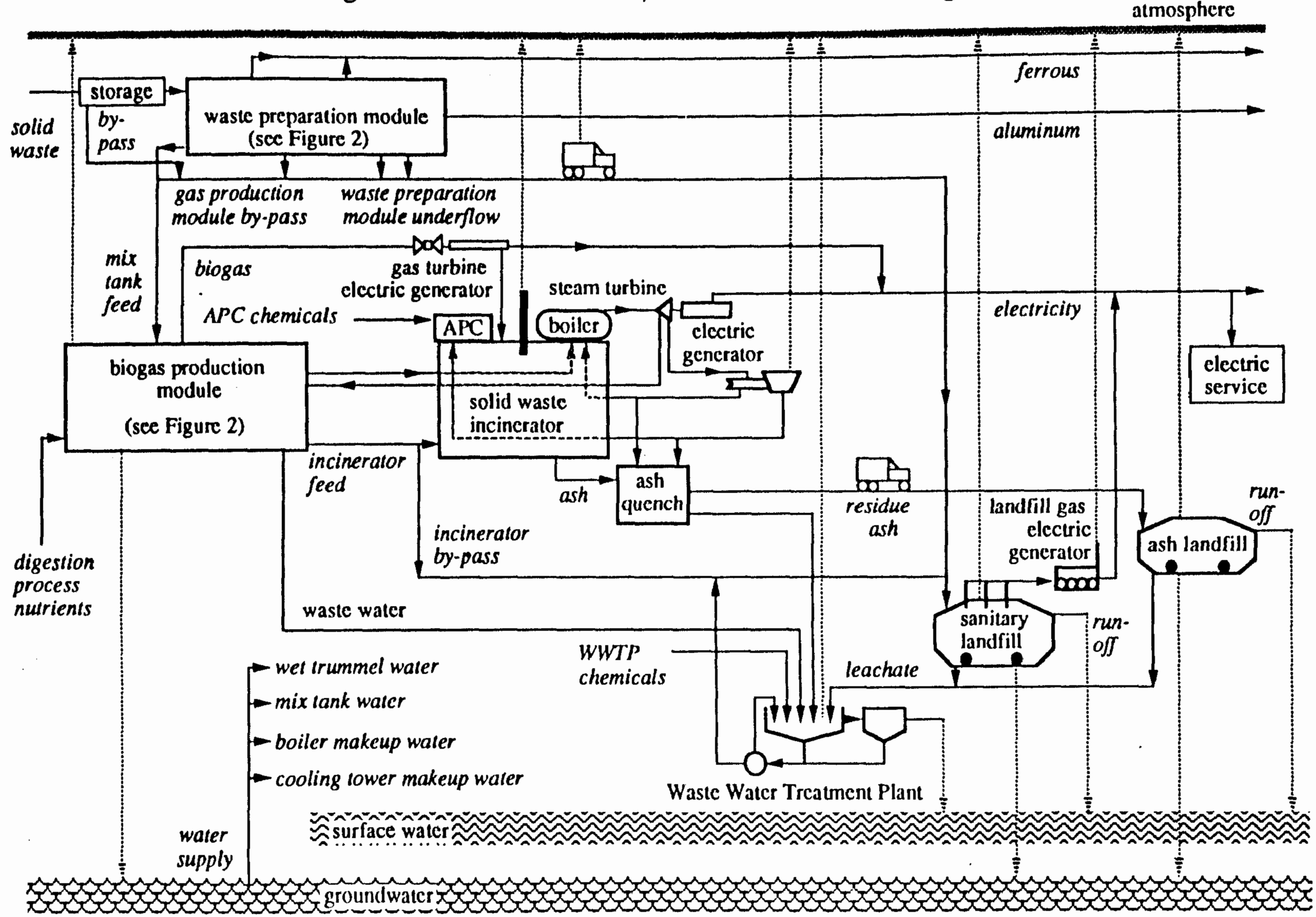
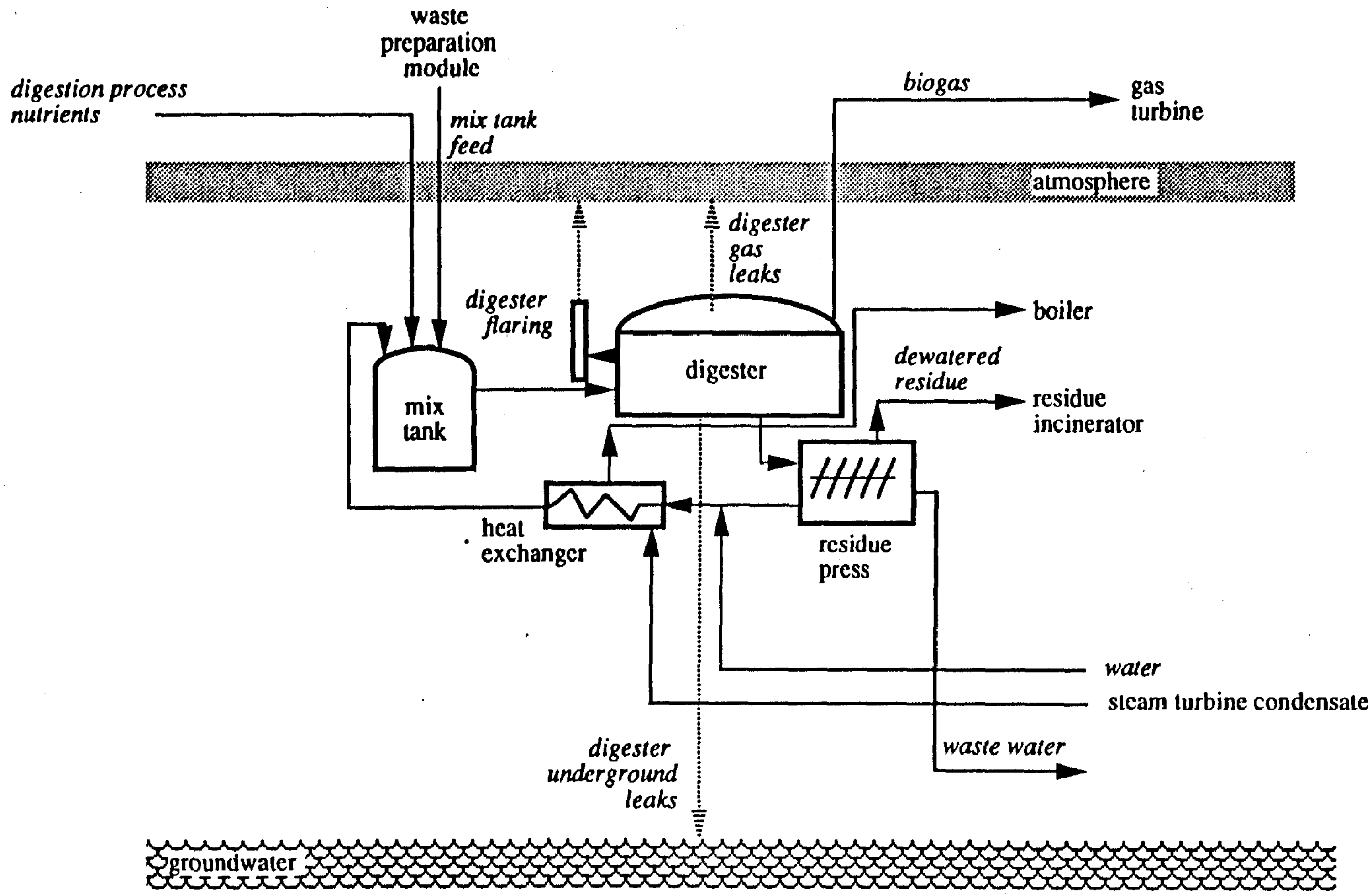


Figure 5. RefCoM Biogas Module Process Diagram



3. RefCoM SNG production with residue composting (REFCOM SNG/COM), see Figure 6;

4. RefCoM SNG production with residue landfilling (REFCOM SNG/LF), see Figure 7.

The conventional mass burn incineration system and the sanitary landfill are depicted in Figures 8 and 9.

Each configuration has the same waste preparation module which shreds and separates waste into degradable and non-degradable fractions plus aluminum and ferrous metals. The degradable fraction is directed to the gas production module while the non-degradable portion is landfilled.

The gas production module has a mixing tank where water and possibly nutrients are added. The slurry is then pumped into an air tight tank where the material is continuously stirred, maintained at a constant temperature, and allowed to decompose anaerobically. The product gas, a 55-45 percent mixture of methane and carbon dioxide, is collected from the digester. In the SNG configuration the CO_2 is removed and the resulting methane rich gas is pumped into a natural gas pipeline. With the REFCOM ELEC/INC configuration, the gas is not purified and instead powers a turbine/electric generator unit.

Figure 6. RefCoM SNG / Composting Process Diagram

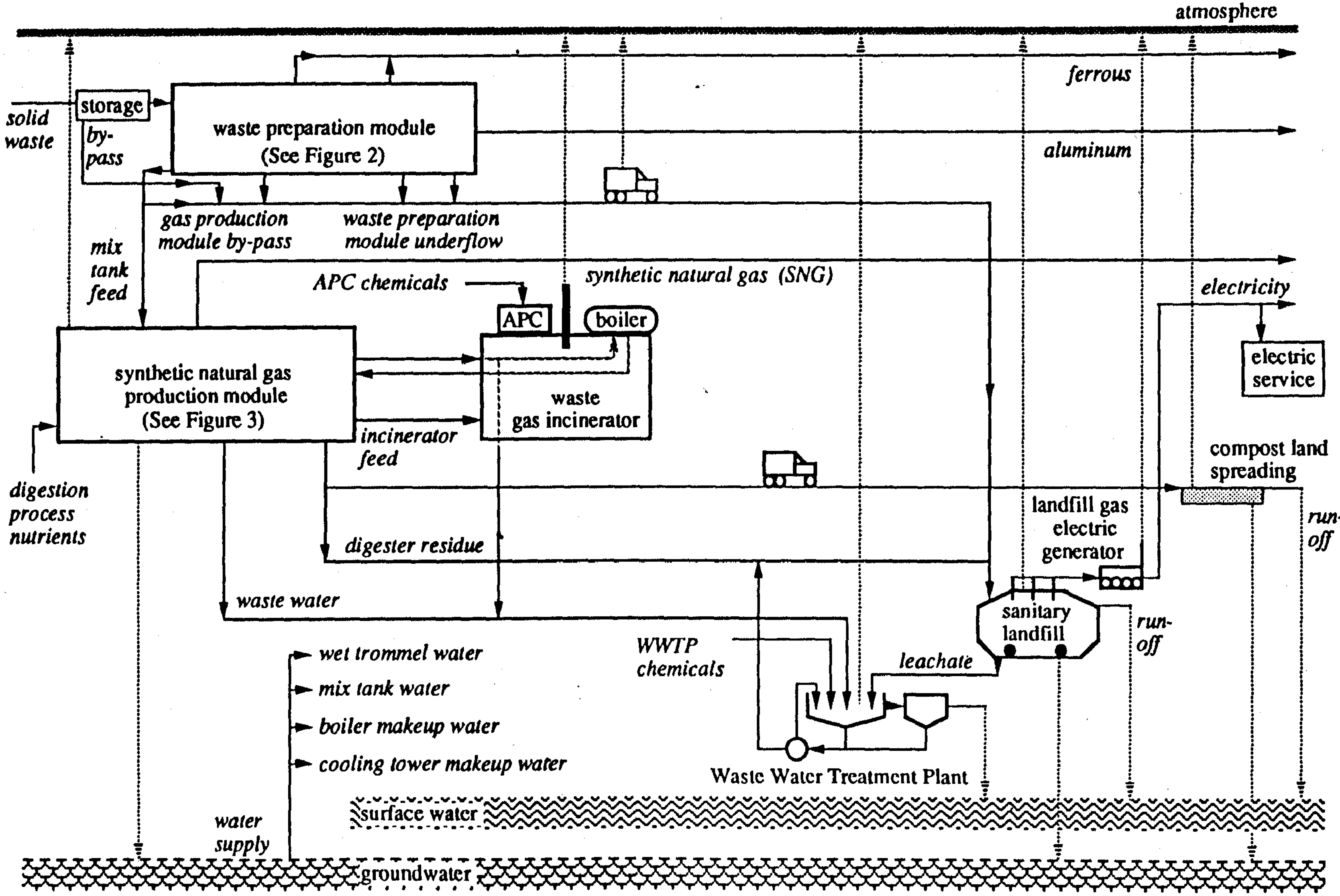


Figure 7. RefCoM SNG / Landfilling Process Diagram

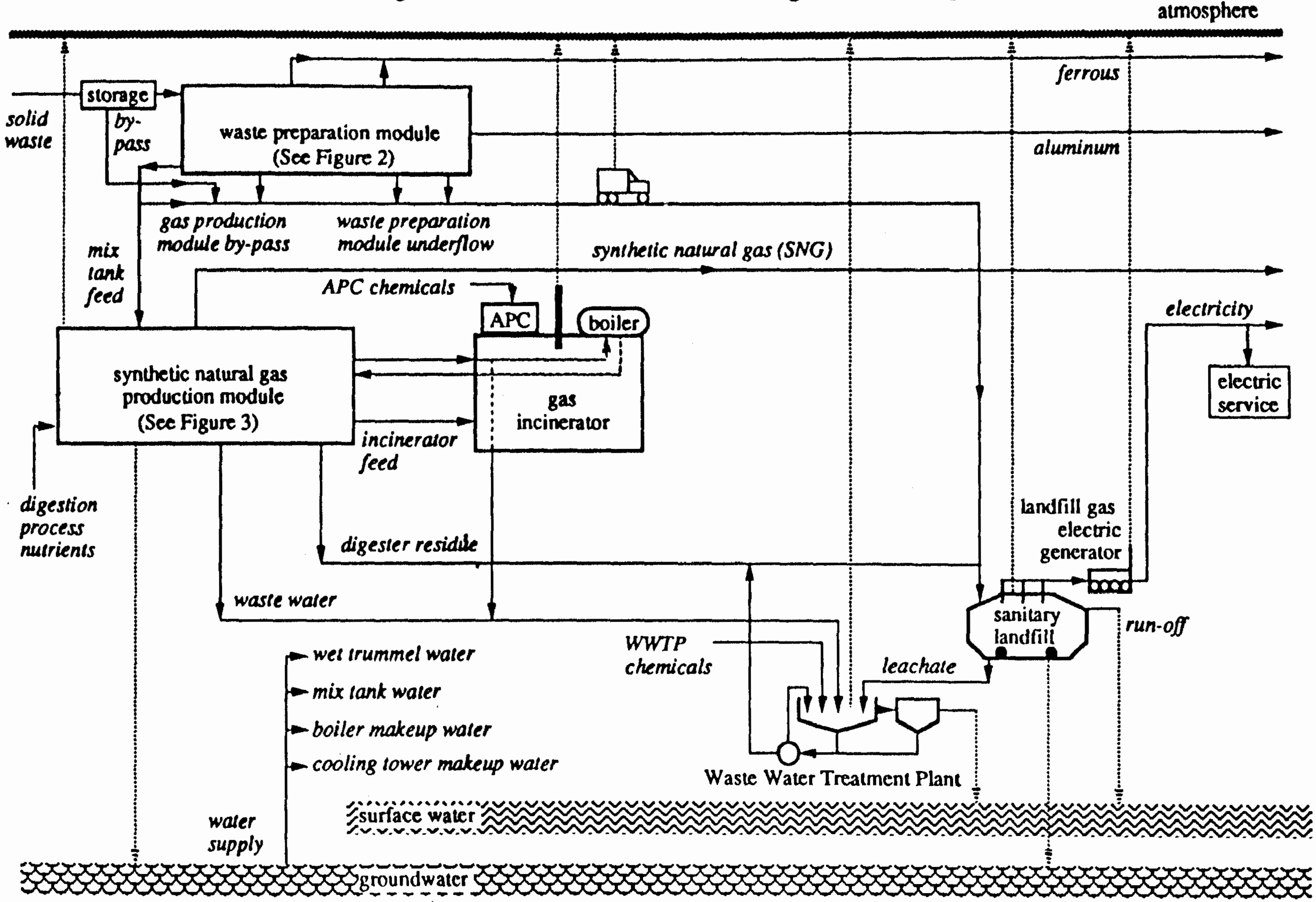


Figure 8. Mass Burn Incineration System Process Diagram

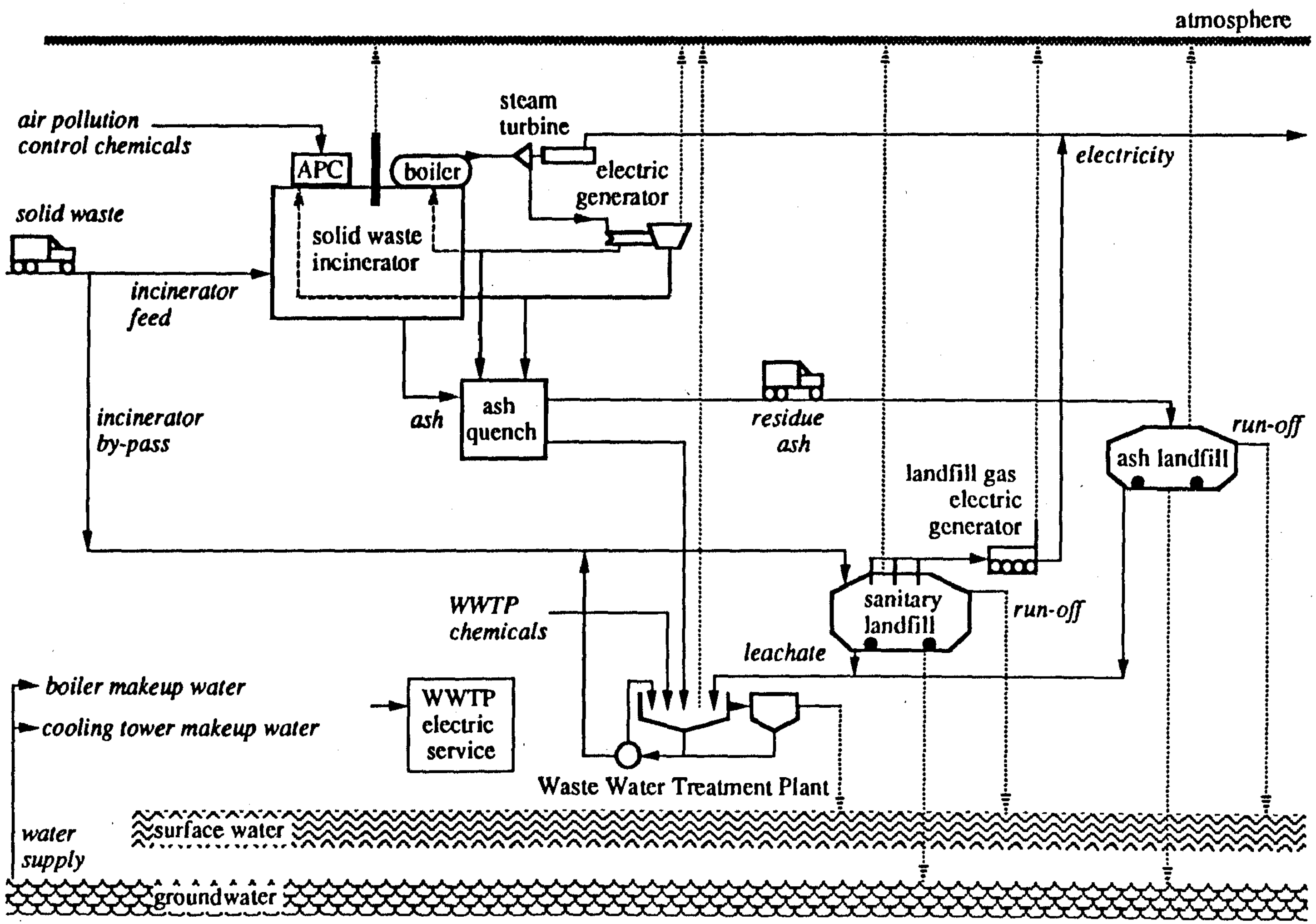
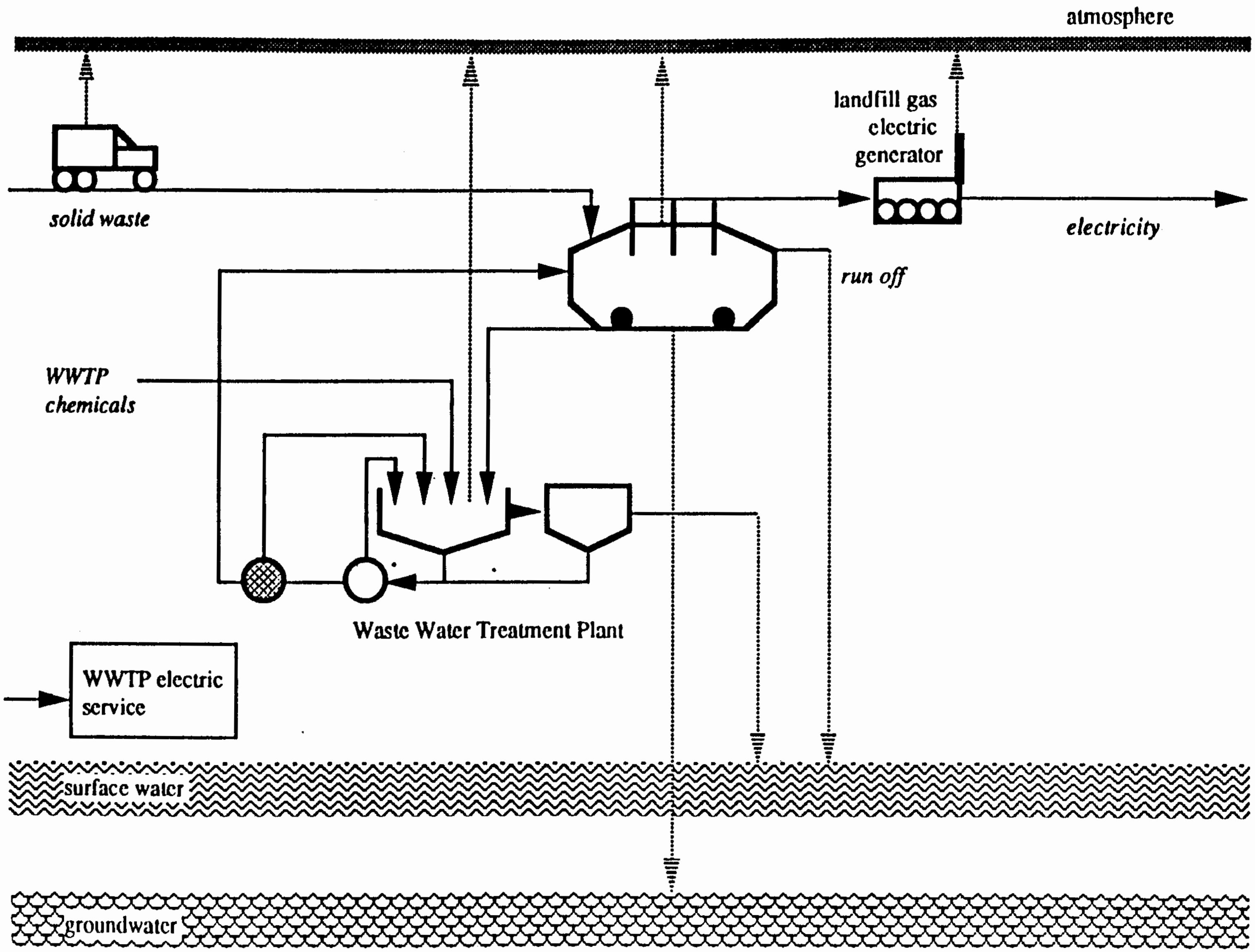


Figure 9. Landfill Process Diagram



IV. Comparison Procedure

A mass flow model estimated the quantity of gases and liquid wastes which will be released to the environment by each configuration and alternative waste disposal system under consideration. In addition, the amount of land permanently occupied by the landfill alternative and the landfills associated with the RefCoM process and the mass burn incinerator was projected.

The comparison used a systems approach where each RefCoM configuration and alternative disposal method has the same function. Within the system boundaries, landfills received RefCoM and incineration residues, and a waste water treatment plant received landfill leachates. Emissions and effluents from the original production and manufacturing of natural gas, electricity, aluminum and iron were estimated to account for the environmental discharges avoided when the RefCoM process has SNG, electric energy, and recovered metals as products.

Each RefCoM process configuration and the alternative mass burn and landfill systems were assumed to be designed to comparable technical and regulatory standards. The standard selected represents United States Environmental Protection Agency "new source performance" and, if not defined, "best implemented control technology."

Air emissions from the RefCoM process residue incinerator and mass burn incinerator were characterized from stack test data at three new incinerators which have advanced air pollution control technology. Landfill gas emissions which are characterized by California and Wisconsin stack tests. Liquid discharges from the landfills were predicted with the U.S. EPA HELP Model. Air and water emissions from natural gas, electric, aluminum and iron production were estimated from U.S. EPA new source standards and emission factors studies.

The purpose for predicting the emission, effluent, and land use quantities for the RefCoM process and mass burn and landfilling alternatives was to make comparisons and draw conclusions regarding the best system, environmentally. A more stringent test was provided by comparing the RefCoM process to mass burn incineration and landfills which are designed to the latest standards. Undoubtedly, the RefCoM process will reduce reliance on landfills, many of which comply with only minimal standards. Assuming stringent environmental standards for natural gas, electric, aluminum and iron production further strengthened the test.

Residue from the anaerobic digester is dewatered and two configurations, REFCOM SNG/INC and REFCOM ELEC/INC, incinerate this residue. The REFCOM SNG/COM configuration assumes the residue is composted and spread on land. The residue is landfilled with the REFCOM SNG/LF configuration.

V. Predicted Results

The results of this predictive and characterization work are summarized in Table 1. Emissions, effluents,and land use from the systems are separated into three locational categories:

1. On-site: occurring at the RefCoM process facility or mass burn incinerator;
2. Off-site: associated with the ash and sanitary landfills, waste water treatment plant and the vehicles hauling solid waste, ash and sludge;
3. Remote: resulting from electric power generation and natural gas, aluminum, and iron production.

From Table 1, it is not possible to deem one system inherently better than the rest. To make this judgement, a value analysis was conducted. Four people with broad environmental backgrounds provided their subjective assessment of the relative importance of the emissions, effluents, and land use along with locational judgements. The four people were:

1. a former local government official
2. an environmental attorney/educator
3. an energy management engineer
4. a state official

These subjective importance weighting factors, when applied to the estimates in Table 1, give the results in Table 2. The

Table 1. Predicted Performance of Four MSW Anaerobic Digestion Process Configurations, Mass Burn Incinerator, and Sanitary Landfill.

	REFCOM SNG/INC	REFCOM ELEC/INC	REFCOM SNG/COM	REFCOM SNG/LF	MASS BURN	LANDFILL
SOLID WASTE RECEIVED (tons/yr)	104000	104000	104000	104000	104000	104000
RECOVERED RESOURCES						
Ferrous (tons/yr)	5860	5860	5860	5860	0	0
Aluminum (tons/yr)	311.2	311.2	311.2	311.2	0	0
SNG Production Rate (SCF/yr)	3.6E+08	0	3.4E+08	3.4E+08	0	0
Total Electric Generation (MWH/yr)	5552	50579	-7411	-5714	36791	6032.284
ON-SITE AIR EMISSIONS						
particulate (tons/yr)	1.956	2.681	0.298	0.298	3.477	0
SO2 (tons/yr)	21	36.28	4.03	4.03	48.43	0
NOx (tons/yr)	103	178	19.7	19.7	237.5	0
PCCD (tons/yr)	2.1E-07	3.6E-07	4.0E-08	4.0E-08	4.8E-07	0.0E+00
CO2 (tons/yr)	53270	72883	8455	8455	93978	0
OFF-SITE AIR EMISSIONS						
particulate (tons/yr)	1.24	1.245	1.293	2.433	0.94	4.555
SO2 (tons/yr)	10.4	10.5	13.6	16.5	11.4	24.7
NOx (tons/yr)	2.68	2.7	3.14	4.81	2.45	8.25
vinyl chloride (tons/yr)	0.0369	0.0369	0.0369	0.0686	0.027	0.1231
CO2 (tons/yr)	31432	31473	66585	66406	21467	125840
OFF-SITE DISCHARGE TO GROUNDWATER						
leachate leakage (tons/yr)	5044	5051	5004	8435	2704	16593
OFF-SITE SURFACE WATER EFFLUENTS						
WWTP effluent (tons/yr)	25684	26514	20513	34499	37954	67636
OFF-SITE PERMANENT LAND USE						
landfill area (acres/yr)	0.902	0.922	0.776	1.306	1.062	2.564
REMOTE AIR EMISSIONS						
particulate (tons/yr)	5.9469	0.0389	8.8094	8.5516	21.5398	27.1278
SO2 (tons/yr)	240.4	117.8	314.1	305	262.6	458.9
NOx (tons/yr)	120.33	1.14	155.01	150.48	79.49	177.81
CO2 (tons/yr)	44126	1150	56875	55211	30087	66142

Table 2. Value Analysis Ranking of Four MSW Anaerobic Digestion Process Configurations, Mass Burn Incinerator and Sanitary Landfill

	REFCOM SNG/INC	REFCOM ELEC/INC	REFCOM SNG/COM	REFCOM SNG/LF	MASS BURN	LANDFILL
FORMER LOCAL OFFICIAL						
VALUE	0.8555	0.7615	0.9176	0.8391	0.5694	0.4555
RANK	2	4	1	3	5	6
ENVIRONMENTAL ATTORNEY/EDUCATOR						
VALUE	0.7431	0.7027	0.8195	0.7095	0.5913	0.2805
RANK	2	4	1	3	5	6
ENERGY MANAGEMENT ENGINEER						
VALUE	0.7656	0.7837	0.7698	0.6581	0.5981	0.1808
RANK	3	1	2	4	5	6
STATE OFFICIAL						
VALUE	0.5894	0.6169	0.6191	0.5329	0.5190	0.2952
RANK	3	2	1	4	5	6
MEAN VALUE	0.7384	0.7162	0.7815	0.6849	0.5695	0.3030
RANK	2	3	1	4	5	6

NOTE: Possible value ranges are from 0-1 with 1 being best.

RefCoM process ranking is always higher than the mass burn or sanitary landfill rankings.

Sensitivity analysis showed that less than optimum RefCoM process performance does not change the ranking. Changes in MSW management such as source separation of newspaper, yard waste and aluminum and ferrous metals also do not impact the ranking. Sensitivity testing of the value analysis weighting factors shows that even when the local air emissions weighting is doubled, the same ranking of RefCoM relative to mass burn and landfilling is maintained.

VI. Conclusions

This study concludes:

1. There is less environmental impact as measured by emissions, effluents, and landfill area resulting from the RefCoM process than:
   a. mass burn incineration;
   b. sanitary landfilling.
2. The above conclusions are sustained even if source separation, suchas recycling of newspapers, yard wastes, aluminum or ferrous metals, significantly changes the nature of the waste stream;
3. The REFCOM SNG/COM configuration compares favorably with the other RefCoM processes but should be given a site specific evaluation to confirm this result. In

particular, the land spreading of composted residue which contains quantities of plastics, glass, and metal needs site specific evaluation.

Acknowledgement

This study was funded by a grant from Renewable Energy Systems, Inc., Palos Park, Illinois. The support and guidance of Peter Benson, President, is gratefully appreciated.

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LANDFILL REMEDIATION

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FIRST U.S. CONFERENCE ON MUNICIPAL SOLID WASTE MANAGEMENT

JUNE 13-16

Introduction

Contemporary waste containment cells rely on a layered system of soil liners, synthetic liners, and liquid collection layers to prevent the migration of leachate generated in the waste to the surrounding subgrade. Such systems have been in common usage for 10 years in RCRA related waste containment cells, but are just now achieving similiar usage in municipal solid waste (MSW) waste containment facilities. This paper discusses three landfill failures and the remediation efforts being performed. The waste category and type of failure for the three cases are as follows:

1 - MSW Landfill, General Foundation Failure,

2 - Industrial Landfill, Sidewall Failure, and

3 - CERCLA Closure, Cap Stability Failure.

The MSW case will illustrate the need for design review of daily landfill operations. The remaining cases deal with stability problems inherent in the multi-layered lining systems.

Case 1 - MSW Landfill, Maine

In mid-August 1989, a 500,000m^3 landslide occurred at a commercially operated landfill in central Maine. The landfill material consisted of municipal solid waste (MSW) that rested on a thick deposit of marine clay-silt which provided a natural barrier to leachate seepage.

The movement lasted about 15 seconds. During the slide, huge vertical crevices formed in the landfill. Trash dropped 6 to 9 meters into scarps formed in the underlying clay as the soil slid out from underneath the landfill. The landslide occurred following a 10 day period when over 125 mm of rain fell. During the slide, 6 large crevices opened up in the trash pile. Some of the crevices were 15 meters wide and up to 9 meters deep. Soil was disturbed by the landslide up to 100 meters beyond the original toe of the landfill. Due to remolding, some of the clay lost 90% of its original undrained shear strength. At some locations, the remolded clay and silt flowed over undisturbed soil at a shallow depth. Analysis of the slide indicated that a rotational failure first occurred under the original landfill slope. The rotation left steep unsupported slopes within the trash pile and the underlying clay and silt. Blocks of trash and clay then followed the direction of the initial movement.

While the marine clay and silt offers an ideal natural barrier to the seepage of leachate, the strength of the soil limits the weight of fill which may be placed on top of it. As the landfill expanded, monitoring wells were installed and laboratory tests on soils were run. Some of the monitoring wells included field vane shear tests (ASTM D2573-72) and 76mm Shelby tube sampling. Laboratory testing included classification, strength, and consolidation testing. Figure 1 shows typical laboratory Atterberg and consolidation test data, as well as vane shear data, for the marine clays and silts.

Using the vane shear data and what was thought to be a reasonable value for the density of the landfill, a height limitation of 17 meters was placed on the existing MSW landfill in mid-1986. With fill above that level, it was calculated that the factor of safety against a slope failure would be below 1.25 for short term conditions and that was not acceptable. Laboratory testing subsequent to the landslide and back-calculations from the slide itself have shown that the field vane test values were in fact considerably lower than the shear strengths developed in the clay-silt.

However, another factor that strongly influenced the stability of the landfill slopes was the density of the landfill material. In the early stages of the operation, the owner had little historical on-site data to indicate the landfill density. Consequently, a density that seemed appropriate, based on the appearance of the fill was used. A value of 590 kg/m^3 (1000 lb/cy) was estimated and this value seemed to be corroborated by historical information. In retrospect, it should have been recognized that landfill technology was changing. More compactive effort was being applied in an effort to squeeze greater amounts of trash into limited landfill space. In addition, more daily cover material (sand and gravel) was being added to control odor, birds and blowing trash. These factors all contributed to a much higher density than originally anticipated and used in the stability analyses that were originally performed.

By mid-1987, weight and volume data was available to indicate the density of the trash and cover was on the order of 1250 kg/m^3 (2125 lb/cy). At that time, the height of the landfill was nearing 12 meters. The reader will recall that an earlier 17 meter height limitation was based on an analysis that used a landfill density of 590 kg/m^3. Without strength increases in the clay, the computed factor of safety against a slope failure would have been less than 1 with the height at 17 meters. Considering clay strength increase, the minimum calculated factor of the landfill slopes was approximately 1.25 with the height at 12 meters and the density at 1250 kg/m^3.

As an additional tool to monitor the stability of the slopes while the fill height was gradually being increased, slope inclinometers were installed on three sides of the MSW landfill. Those were the east, south and north sides. The owner recommended against placing the inclinometers on the west side. The company reasoned that since expansion to the west was thought to be imminent, inclinometers in that area would quickly be in the way of new landfill construction. In hind sight, it was to the west that the inclinometers would have been most useful. As discussed below, slopes in that direction ultimately failed because of the expansion construction activities.

From late 1987 to early 1988 to early 1989, the height of the MSW landfill was gradually increased to about 18 meters. Biweekly readings on the inclinometers indicated a maximum lateral movement of 19mm per year. This rate was judged to be high, but acceptable.

In early 1989, a re-analysis of the landfill slope stability was performed. The re-analysis used the latest height and density information, and extrapolated strength data from the field van shear data. The re-analysis indicated that the safety factor for the landfill slopes was very close to 1. To increase the safety factor, the owner decided to step back the slope at the present fill height and add a berm where possible around the landfill. Berms were built on the east and south sides of the landfill to add counter weight to the slopes. Waste piles to the north and south also provided buttressing in those directions. Again, however, the owner was reluctant to add a stabilizing berm on the west side of the landfill due to planned westerly expansion.

Construction began on the westerly expansion in the late Spring of 1989. Trees cleared, the topsoil was stripped from the clay and silt, and all weathered soil was removed below the topsoil. Some of the weathered soil was mined for cover material for other landfills. Since digging into the clay and silt would also increase the capacity of the landfill, the plans called for the removal of 2 to 2.5 meters of soil in the expansion area. Because the new area was to be lined and the original area was not, a leachate collection trench was dug adjacent to the toe of the old landfill.

In hind sight, it was probably obvious that removing strong soil at the toe, which was supporting the existing landfill

slope, and then cutting a leachate collection trench deeper into the ground at the toe, were not prudent steps to take.
Following a 10 day period when over 125mm of rain fell, the landslide occurred.

To permit more accurate back-calculation of the clay and silt shear strengths under the landfill just before the slide, the owner performed a dozen large-scale density tests and 6 direct shear tests in the trash. Each density test involved digging about 8 m^3 of trash out of the fill cross sectioning the excavation to measure its volume, and then weighing the excavated material. The results of the density tests indicated an average density of 1534 kg/m^3 (2600 ld/cy). Those values compare reasonably well with the overall density calculated from 1989 tipping data, truckloads of cover material hauled to the site and volume change computed from different photogrammetrically produced topographic maps (1503 kg/m^3).

To measure the shear strength of the trash, the owner constructed a $1.5m^2$ square shear box. The box was loaded with large concrete blocks to vary the normal force in the test. Figure 2 provided a summary of the results.

Summary...The predicted stability failure at this MSW landfill demonstrates the need for ongoing engineering review of the operations of such facilities. Additionally, the measured density of the MSW greatly exceeded that predicted by general historical data. Thus, as even greater efforts are being expended to maximize airspace utilization, the designer must improve such design assumptions. Design of a new MSW lined cell is proceeding for this facility. Future stability will be ensured by limiting the depth of waste and slope of the working face. These limits are being established using slope stability analyses using the measured waste densities and shear strengths.

Case 2 Industrial Landfill, Ohio

During the construction of an industrial landfill in Ohio, a layer of cover soil being placed over the synthetic liner collapsed. This collapse resulted in much of the synthetic liner being dragged to the base of the sideslope. The design profile of the sidewall liner system is shown on Figure 3. As is commonly the case, the sidewall liner system was the product of both state regulatory demands and the designers original intent. Interestingly, the failure occurred between the HDPE liner and the lower slit-film woven geotextile.

Just such a failure had concerned the design engineer. Early calculations indicated that the cover soil would be marginally stable if the slope length was less than 79 feet. To provide a greater margin of safety, the designer required that no more than 15 feet of cover soil be placed in advance of the waste.

As construction progressed, concern was expressed regarding the ability of heavy equipment to operate on the dredge spoils to be placed within the cell. Fearing the future inability to advance the cover soil protecting the liner, a field decision was made to place the entire cover layer. A sliding failure occurred as placement of the cover soil neared completion and prior to placement of waste in the cell.

Post failure laboratory testing indicated that the coefficient of friction between the HDPE liner and the slit-film woven geotextile was approximately 9-degrees. This confirmed that the weight of the cover soil was carried by tension in the upper geotextile and the liner, by the frictional components between the layers, and by the compressive strength of the cover layer itself. An analysis was performed to estimate the minimum cover soil cohesion required to maintain a minimum factor-of-safety against sliding of 1.0. Figure 4 shows the results of this analysis and the range of cohesion values actually obtained from samples of the cover soil. The cause of the failure became evident when field surveys indicated that slope lengths exceeded 120-feet.

Remediation of the sideslopes involved replacement of the smooth HDPE liner with textured HDPE, and the use of nonwoven geotextiles. Both measures dramatically increased the interface friction angles between the geotextiles and the liner. This successfully reduced the load being carried within the plane of the cover soil. Additionally, note that the geonet drainage layer was bonded to the geotextiles bounding it. This was necessary to prevent placing the geonet in tension.

Case 3 - CERCLA Cover, Connecticut

In a CERCLA closure common to the northeast, sludges generated from the closure of settling lagoons at an electro plating operation were to be consolidated within the footprint of the original lagoons and secured with an impermeable cover. While no specific regulatory criteria exists for CERCLA covers, EPA has generally assumed that RCRA Minimum Technology Guidance provides a reasonable minimum cover profile. This results in a cover that contains the following layered systems:

- Low-Permeability Barrier Layer,
- Drainage Layer, and a
- Protective Layer.

The design profile for this cover and the slope toe drainage detail are shown on Figure 5.

The low-permeability barrier was an effective composite formed by the 30-mil PVC geomembrane and the bentonite mat. However, the bentonite mat has an upper surface composed of a woven polypropylene geotextile. As in the previous case study, the coefficient of friction between a geotextile and a smooth geomembrane typically ranges from 9-12 degrees. Thus the cap profile constructed on the design 3H:1V slopes would either be unstable or would rely on the tensile strength of the filter fabric and the geomembrane.

Just prior to letting bid documents, a geogrid was added to the cover profile. The geogrid was placed immediately above the filter fabric and was intended to carry the weight of the overlying cover soil. While incorporated into the project specifications, the engineer did not modify the drawings to indicate the proper placement of the geogrid. Fortunately, the small size of the cap, < 1/2 acre, allowed the geogrid to be run continuously across the breadth of the cap.

While no failure occurred in this cap, the success was due to the small size of the cap and not to the technical ability of the designer. No stability calculations had been performed and no geogrid installation guidelines were prepared. Interestingly, the EPA review process did not detect these omissions.

Summary

The rate of failures within waste containment systems is increasing. This increase rate can be directly traced to the following factors:

- The need for the design engineer to establish operational guidelines that ensure the stability of the facility as waste is being placed, and
- Sliding instabilities generated when two geosynthetic materials are used in contact on slopes.

Both designers and requlatory reviewers must ensure that stability calculations are prepared for construction profiles, operational conditions, and closure profiles. Such stability calculations should be used to establish operational guidelines for placement of waste within the waste containment system.

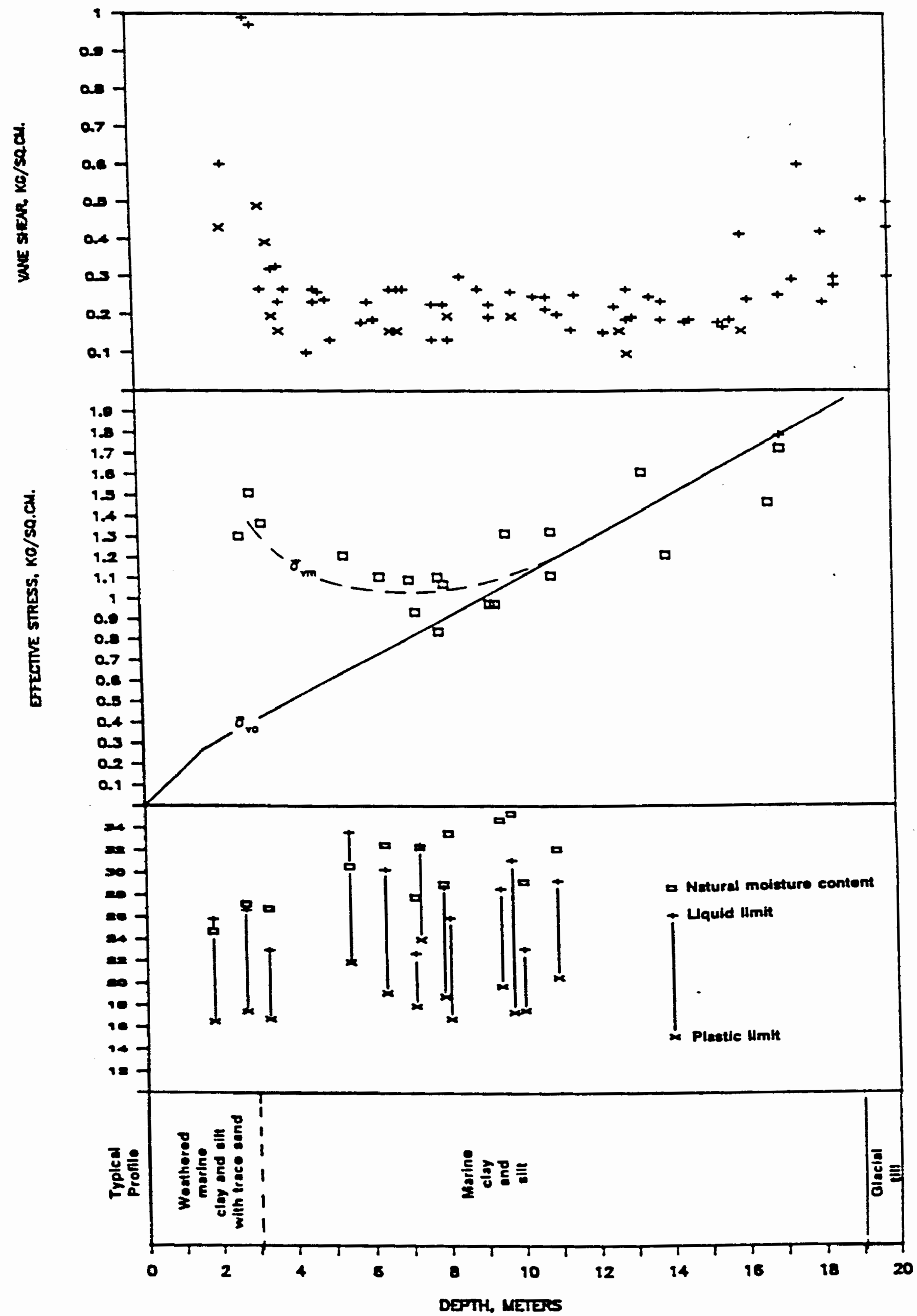

Figure 1 Case 1 Soil Properties Beneath Landfill

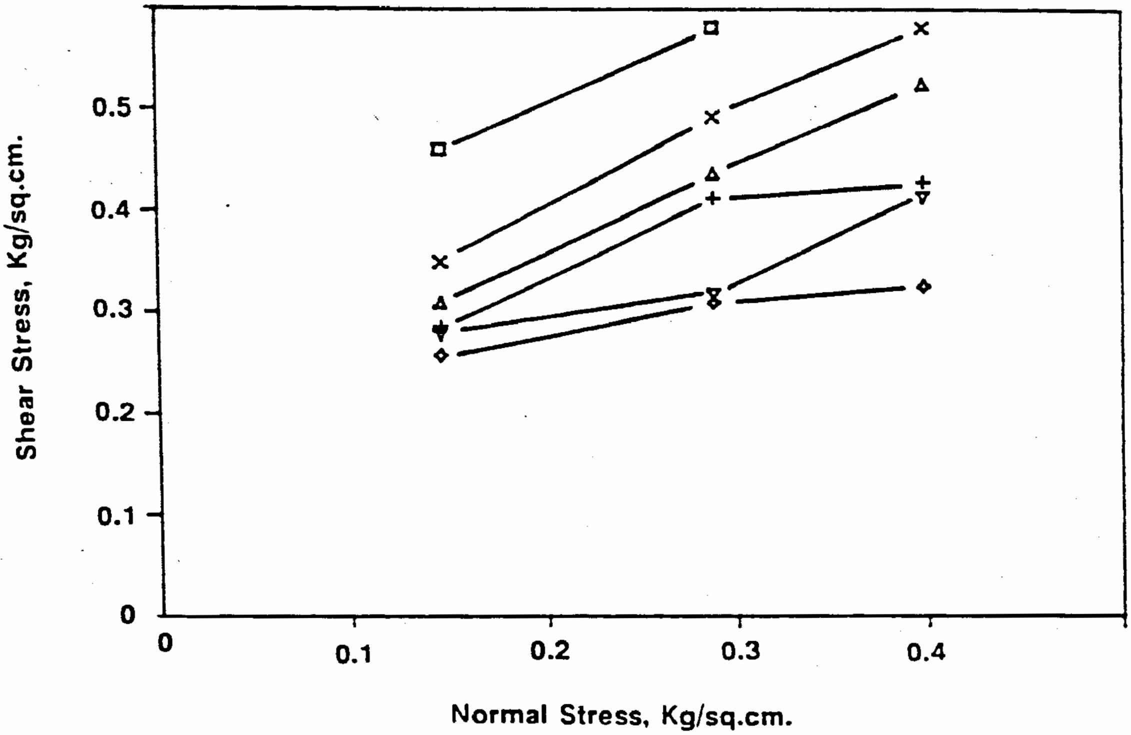

Figure 2 - MSW Direct Shear Test Results

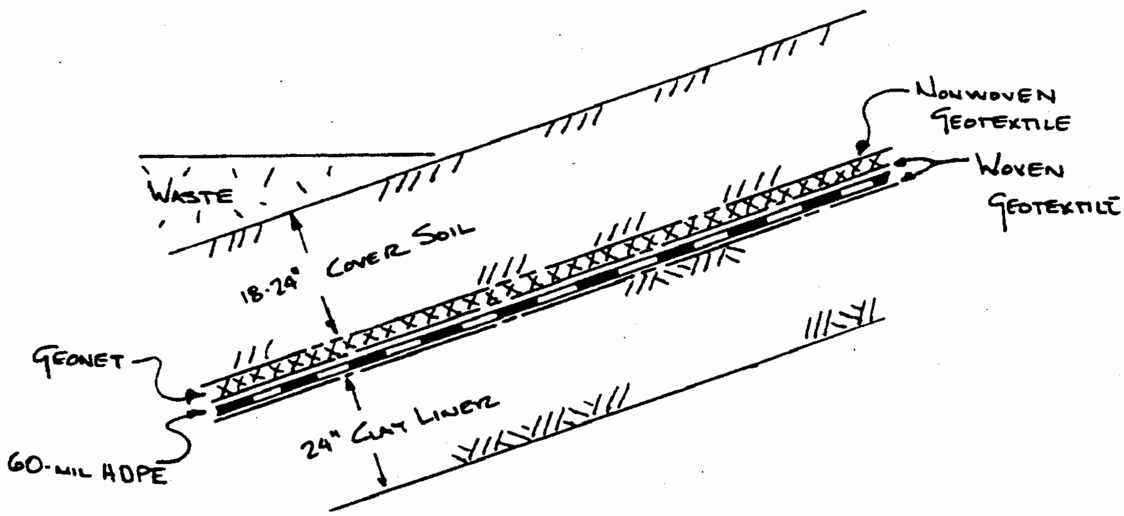

Figure 3 Failed CERCLA Liner System - Case 2

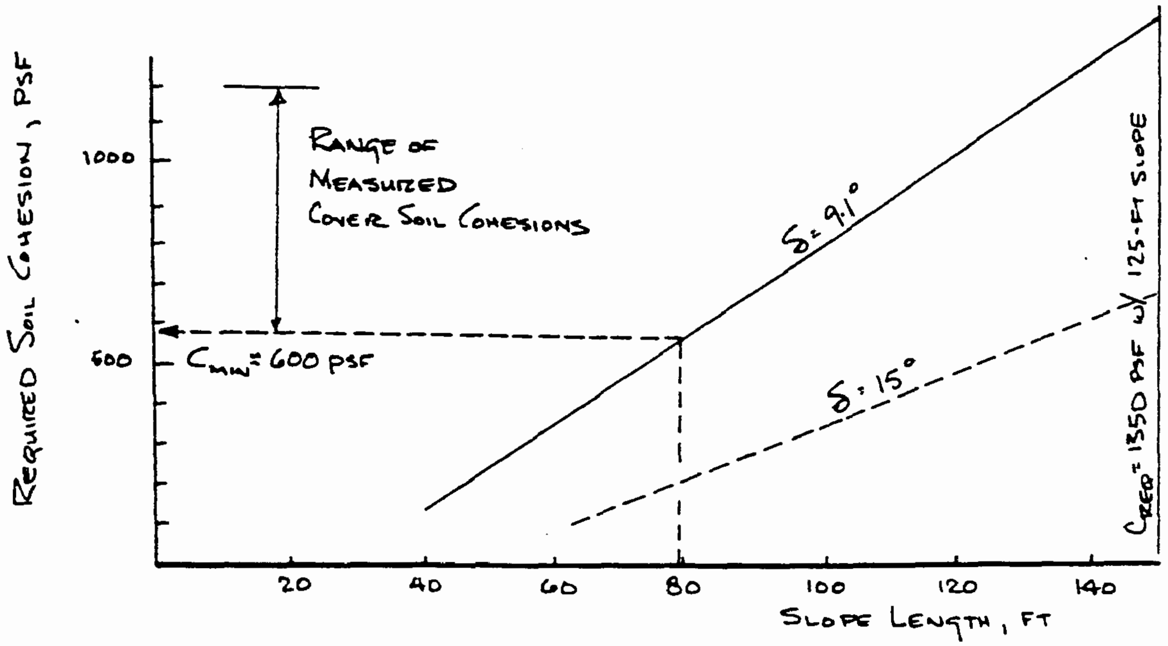

Figure 4 Cover Soil Shear Strength vs Stable Slope Length - Case 2

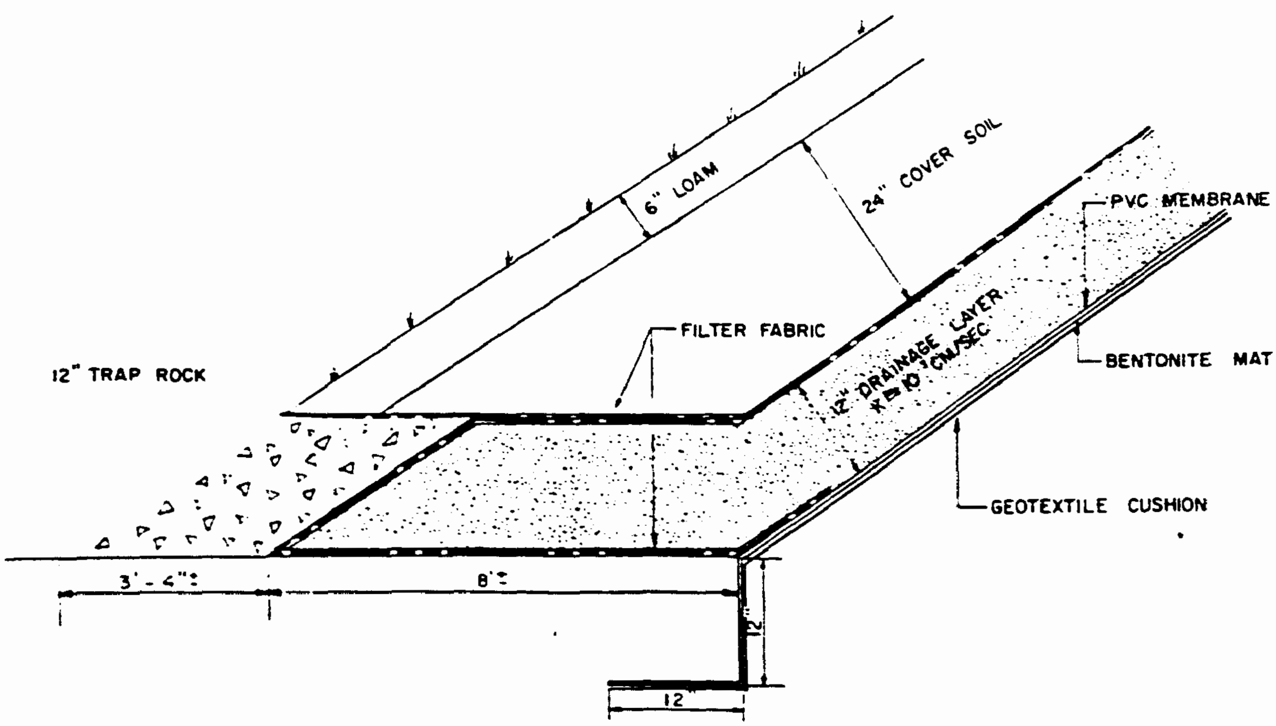

Figure 5 Initial CERCLA Cover System - Case 3

CASE STUDY:
LEACHATE CONTAINMENT IN AN OLD LANDFILL
SPRINGFIELD ROAD LANDFILL - HENRICO COUNTY, VIRGINIA

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Presented at the

First U. S. Conference on Municipal Solid Waste

June 13-16, 1990

SPRINGFIELD ROAD LANDFILL LEACHATE REMEDIATION PROJECT

INTRODUCTION

New regulations and new facilities have held our attention and much of the limelight in recent months and years. Many states, with their eyes set on the future, are implementing tougher regulations for a new generation of environmentally sound landfills. But what of the old facilities, the ones already in the ground. They have received little attention though many regulations require remedial action to control offsite leachate migration or documented groundwater pollution.

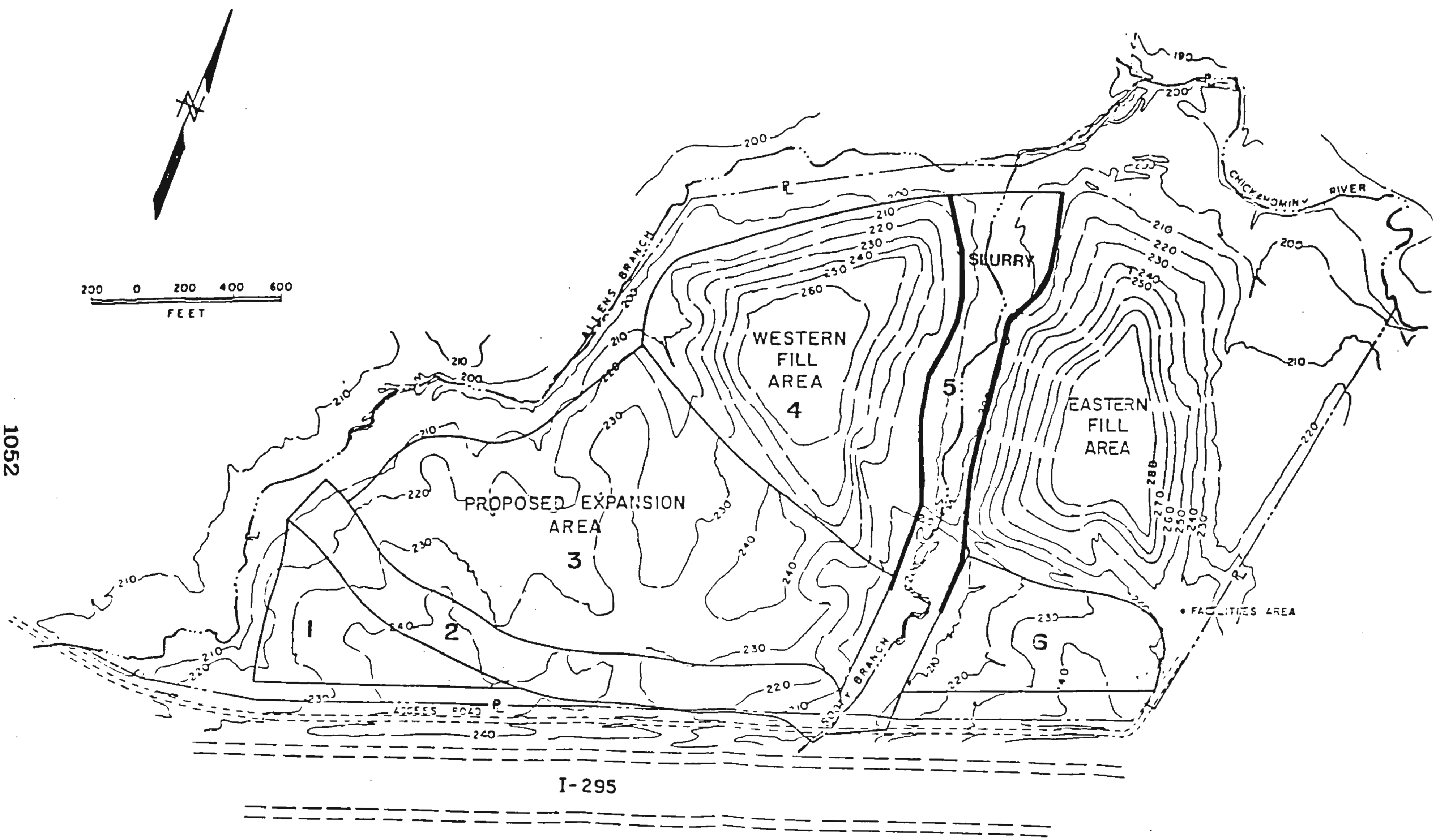
A great deal has been written and said about liner systems, leachate management systems and the other features of a modern landfill. But we hear little about how to deal with the older sites which are going to be with us for years to come.

This paper will explain how a corrective action project was planned, designed and implemented at an existing landfill in central Virginia. The landfill is a municipal solid waste landfill located in Henrico County Virginia, a suburban community of Richmond, Virginia.

In 1985, efforts began to plan for an expansion of the landfill. As part of that process, a detailed geotechnical investigation was made of the landfill. During that investigation it was discovered that there may have been problems with contamination of a major drainage feature, called Rooty Branch which flowed between the two main fill areas of the landfill. These indications caused concern that there might also be leachate entering Allens Branch and the Chickahominy River which form the west and north boundary of the site. (The general configuration of the site is shown on Figure 1).

With these concerns in mind, the first step was to review in detail the available data on the site ground water and surface water quality. In addition the depth and direction of groundwater flow and the surface of the bedrock underlying the site were mapped. This revealed that the landfill was situated on a thin soil overburden over a granitic bedrock. In some places, the depth to bedrock was as shallow as 5 feet.

Review of the data indicated that the flow of ground water was along the bedrock surface toward Rooty Branch. The flow ran under the existing landfill sections known as the



DRAPER-ADEN ASSOCIATES, INC. CONSULTING ENGINEERS BLACKSBURG, VIRGINIA	SPRINGFIELD ROAD LANDFILL MASTER PLAN - EXISTING SITE PLAN HENRICO COUNTY VIRGINIA	SCALE: 1" = 400'-0" PROJECT NO 8304	DRAWING 1

western and eastern fills. There was no flow toward Allens Branch or the Chickahominy River which bordered the site. Flow in the northeast and northwest direction was blocked by rock ridges. The slope of the bedrock was found to be toward Rooty Branch. this meant that the leachate flow could be confined and possibly intercepted at Rooty Branch.

Analysis of the ground water and surface water data confirmed the analysis of the hydrogeologic situation. The levels of indicator parameters in Rooty Branch were generally higher than in the other water courses. (Figures 3,4 and 5 illustrate selected readings for Chlorides, Iron and TDS in Rooty Branch). The initial indications led to the conclusion that leachate from the landfill was entering Rooty Branch.

Based on the results of the initial investigation the decision was made to find a way to prevent the contaminants from leaving the landfill and entering Rooty Branch. The next step in the process was the determination of the best method of achieving that goal.

The alternatives considered were (1) rerouting of Rooty Branch, (2) the lining of the creek and (3) the hydraulic isolation of the creek in its existing location. Relocation of the creek was eliminated from consideration first, due to its high cost, the amount of landfill space which would have been lost and the potential for creating pathways for leachate movement since significant blasting of the bedrock would have been required.

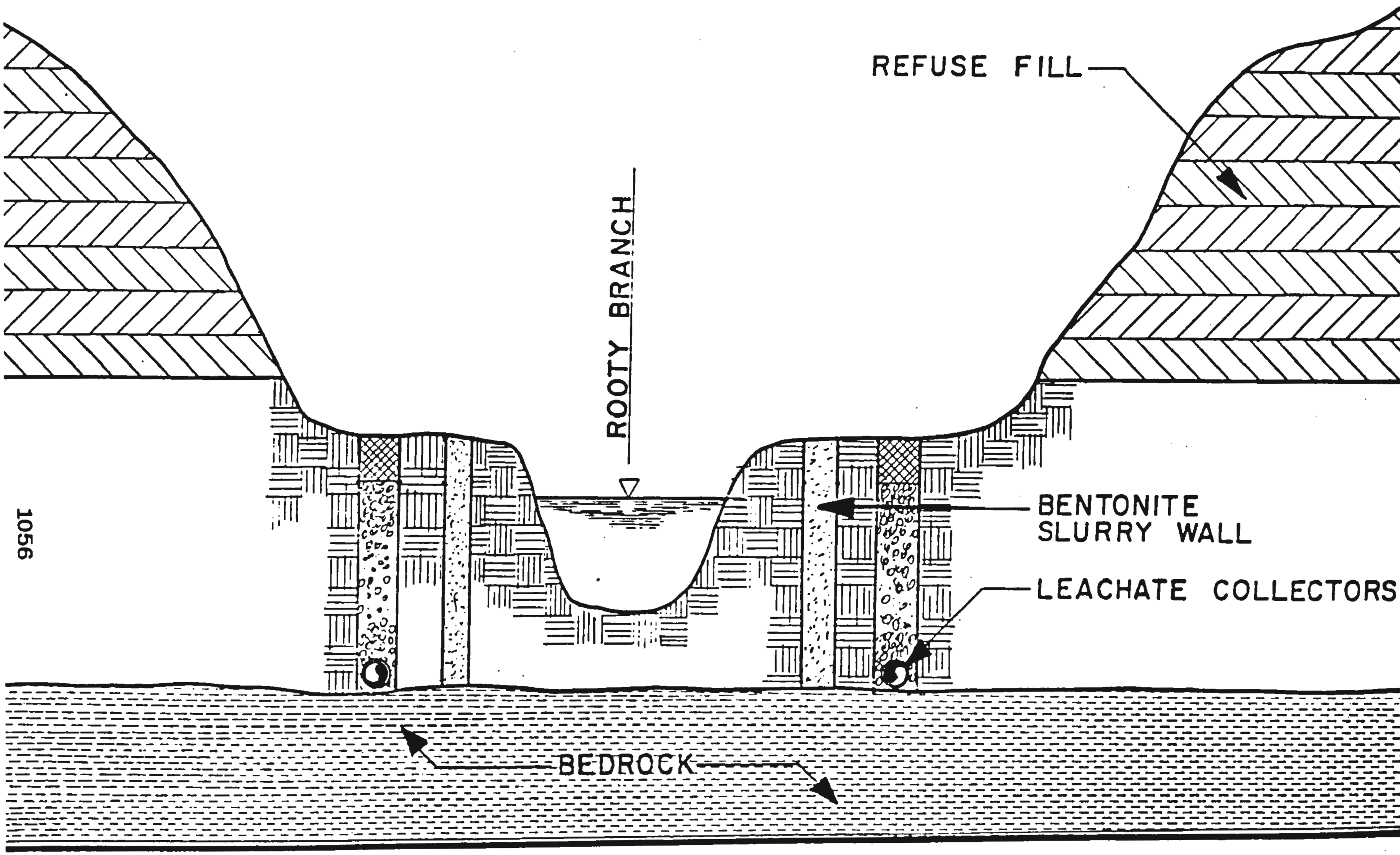
The second option, lining of the creek, would have separated the surface water from the ground water but would not have done anything to prevent movement into the groundwater. The alternative of hydraulically isolating the creek appeared to meet the goal of controlling release of contaminants into the Rooty Branch drainage course, with few negative effects.

Several methods were considered to achieve this isolation. They included the installation of concrete or sheetpiling walls down to bedrock; trench drains around the landfill and slurry walls. In the end, the alternative selected was to straighten the meandering course of Rooty Branch, install perforated drains along the toe of the existing landfill to intercept any leachate leaving the landfill and to install a soil bentonite slurry wall down to bedrock in the area between the creek and the perforated drains. In this way any leachate leaving the landfill and flowing toward the creek would be intercepted and diverted by the drains to a pump station which would pump the leachate to a regional wastewater treatment system. The slurry wall would act as a barrier to isolate the creek from the landfill. (Figure 2 illustrates the concept in schematic form).

SYSTEM DESIGN

Design of the features of this project presented several challenges. How could a bentonite slurry be installed in ground which was known to contain contaminants? Where were the limits of the landfill so the drains could be placed properly? How could the slurry wall be protected from the traffic and construction activities associated with landfills and how would it fit into the final closure configuration of the landfill? How could this system best fit into the overall landfill design? Could some elements of this system be used in conjunction with other parts of the leachate collection system for the existing and future landfill disposal areas?

The final configuration achieved answers to many of these questions. To reduce the effects of the known contaminants in the ground where the slurry wall was to be installed, the excavated soil was removed and not used for slurry backfill mix as is common practice. Clean soil was imported for use in the backfill mix. A bentonite which is listed as contaminant resistant was specified. The water source for the slurry



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HYDRAULIC ISOLATION OF ROOTY BRANCH

FIGURE 2

mixture was tested and approved. Use of the water in Rooty Branch itself was not permitted.

The configuration of the drain and slurry wall system was based on information gathered from the operating personnel who actually built the landfill and from test pits dug to confirm the limits of fill. The geotechnical mapping of the landfill gave information to guide decisions on the depth of the drains and slurry wall.

The slurry wall was designed to tie into the shallow bedrock on either side of Rooty Branch at both ends of the project. This was done to help achieve isolation by tying the slurry wall into the bedrock ridges which isolated the other parts of the site. Protection from desiccation, erosion and traffic was achieved by an 18 inch soil cap over the wall at the ground surface.

The trench drains are designed to be incorporated into the overall landfill leachate collection system. The trench drains act as the gravity connection between the leachate collection system on the eastern side of the landfill and the main pump station. The trench drains also connect the leachate collection system from the landfill expansion area to the main pump station. All collected leachate is pumped to a regional wastewater treatment facility.

The final phase in this project will come when the old fill areas have been finally capped out and closed. This measure will have the most dramatic affect on leachate reduction. The landfill is still in operation and final capping will not be in place for several years.

CONSTRUCTION

Construction of the improved channel of Rooty Branch, the trench drains and the slurry wall took place during the fall of 1987 and the spring of 1988. Though the construction went smoothly, there were two problems which were of particular note because they potentially could have affected the project goals.

The trench drains were to have been installed down to the rock surface. The rock surface was found to be more irregular than was expected. It became necessary to resort to some minor blasting to achieve the required grades to make the drains work properly. Rock was excavated as much as possible with heavy backhoes. Only blasting which was absolutely necessary was allowed and then only with light charges. This was done to minimize the chance of fracturing the rock and creating new pathways for leachate migration.

The installation of the slurry wall presented one problem which required field correction. Bench scale tests were performed to determine the appropriate bentonite content for the soil/bentonite backfill of the slurry wall when onsite soils were used for the mixture. Field mixtures revealed a problem with workability not found on the laboratory scale. The soil/bentonite mixture would not flow into the trench. In fact, the mixture acted much like a wet clay and was very cohesive. Additional lab tests found that the cohesive fines in the mixture were creating this situation. It was decided to add additional coarse material in the form of sand to the mixture to create the proper slump and flow characteristics.

SYSTEM EFFECTIVENESS

The effectiveness of the system is still being evaluated. The presence of contaminants in the soil between the slurry wall and the creek make evaluation by sampling the creek somewhat difficult. However there are some encouraging trends being observed. The level of contaminants in Rooty Branch has been steadily downward. (Figures 3,4 and 5 indicate the downward trend). Continued flushing of the soils between the creek and slurry wall will undoubtedly help in reducing the contaminant level.

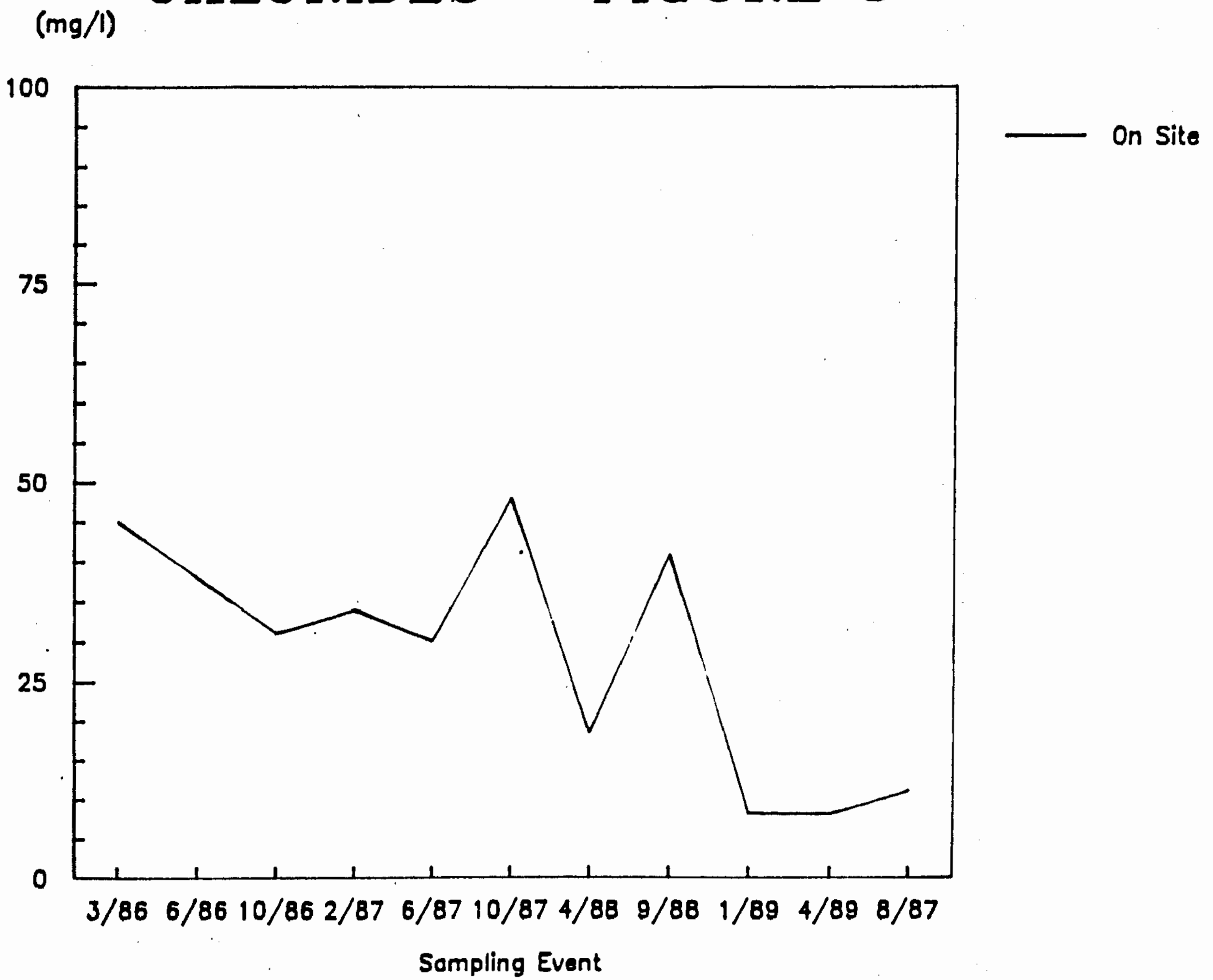
A reduction in contaminants began before the installation of the slurry wall. It is believed this can be attributed to several factors. One was the exceptionally dry year preceding the construction which limited leachate generation. A second was the temporary capping of the eastern fill when daily fill operations moved to an adjacent area. Finally, the removal of much of the contaminant laden soil from Rooty Branch as it was being straightened is considered to have contributed to the decrease.

One notable example of the effectiveness of the project has been detected in the landfill groundwater monitoring program. One of the site monitoring wells is located in the area which lies between the slurry wall and Rooty Branch. The well traditionally have contaminant levels similar to the creek. Since the installation of the project, the well has been dry, indicating no flow from the landfill to the creek.

CONCLUSIONS

The design of any project to isolate and control leachate from an old landfill requires a detailed understanding of the

ROOTY BRANCH SURFACE WATER DATA
CHLORIDES – FIGURE 3



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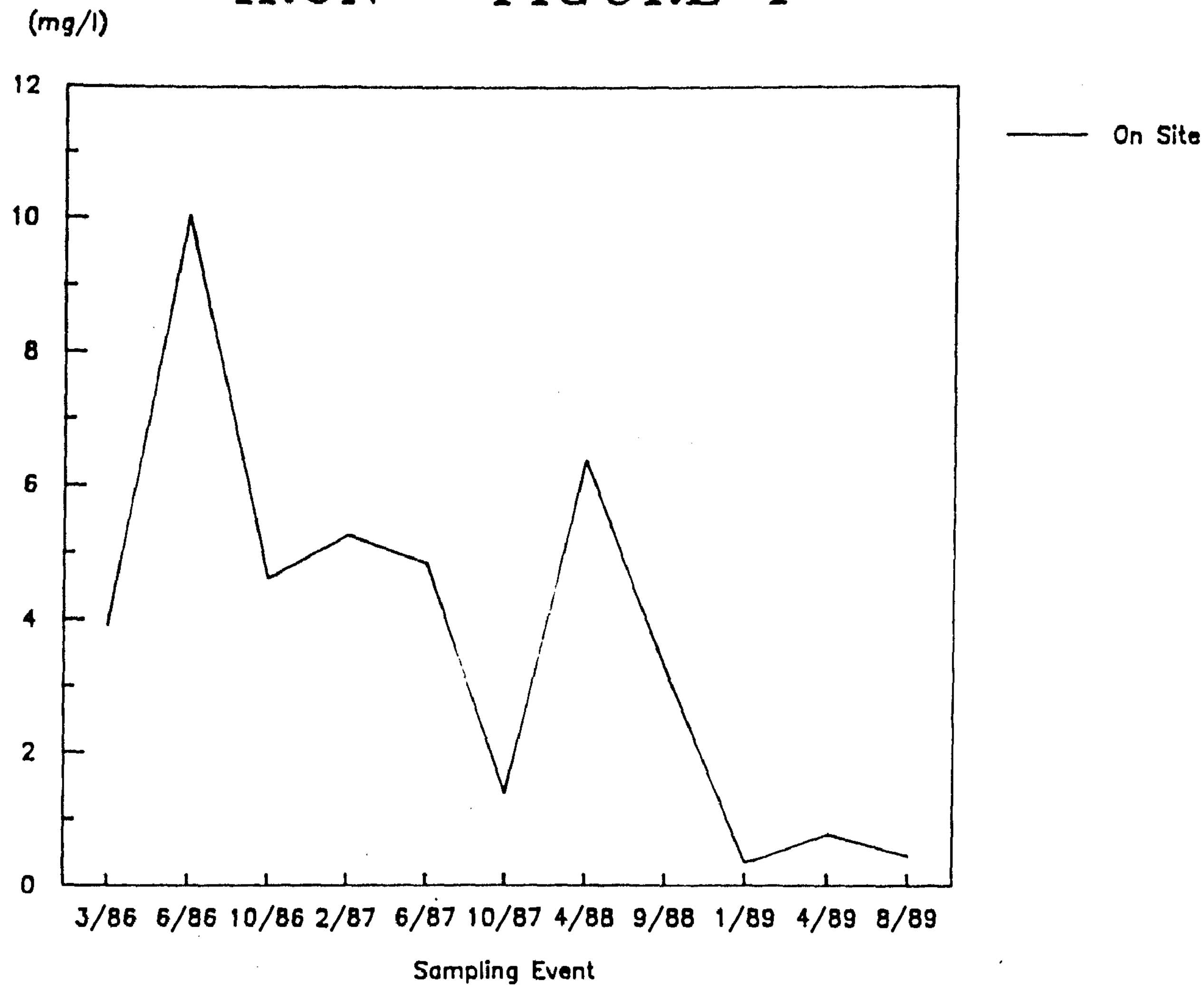
ROOTY BRANCH SURFACE WATER DATA
IRON - FIGURE 4



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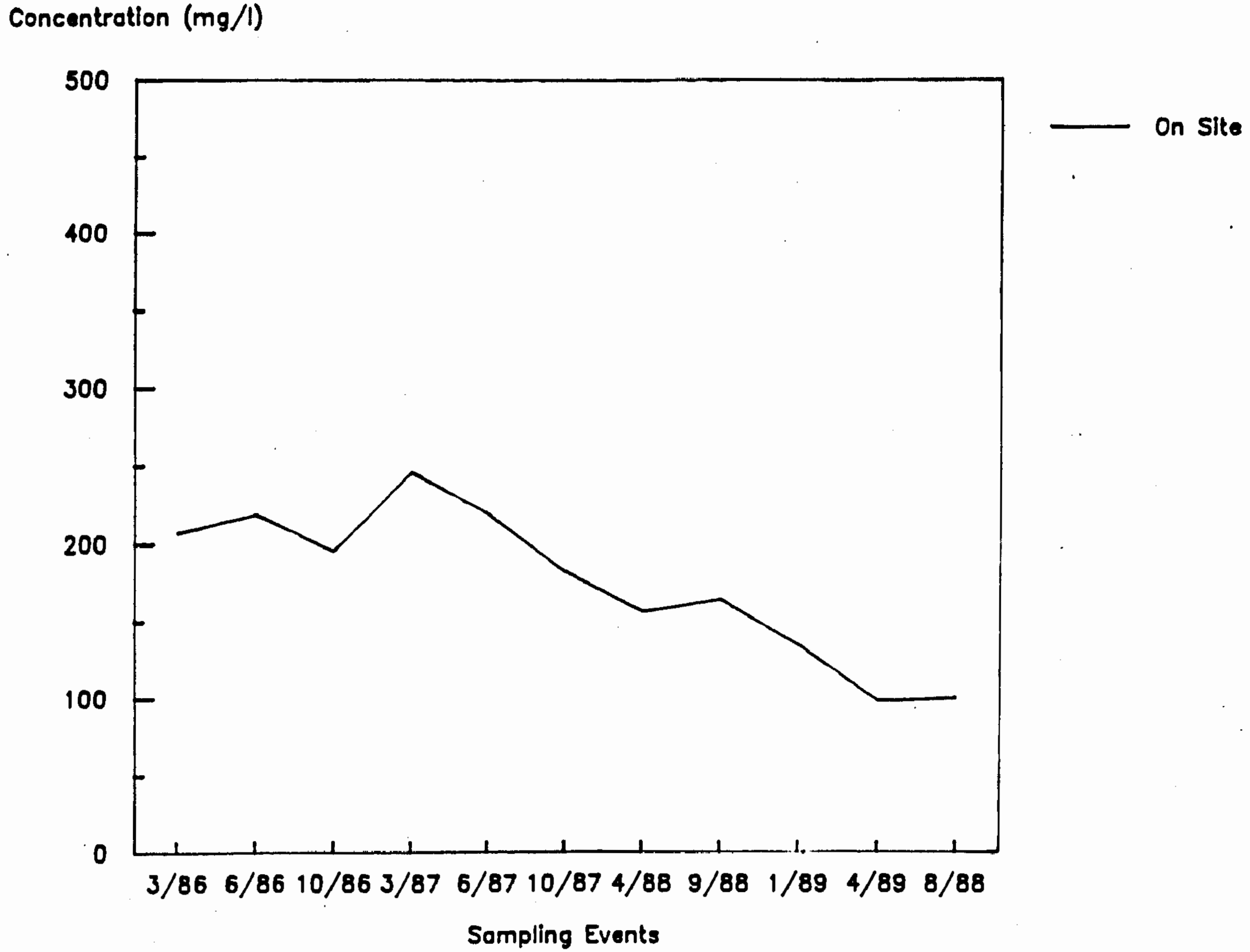
ROOTY BRANCH SURFACE WATER DATA
TDS - FIGURE 5



hydrologic and geologic setting of the entire site. Once such an understanding has been established, a variety of alternatives should be evaluated. the goals of the alternatives should be the isolation of the source of contaminants collection of the contaminants and reduction of leachate generation. This project has attempted to meet the first two goals. Final closure and capping of the site will address the final goal.

MANAGING OUR SOLID WASTES: DEVELOPING AN EFFECTIVE SITING FRAMEWORK

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Presented at the
First U.S. Conference on Municipal Solid Waste Management
June 13-16, 1990

Managing Our Solid Wastes: Developing an Effective Siting Framework

Introduction

The conflict over solid waste management continues to escalate in many parts of the country and is likely to be a pressing public policy issue throughout the 1990's. Even with increased source reduction, recycling, and composting, new waste disposal facilities will be needed to manage our growing waste stream. Finding new sites, however, promises to be extraordinarily difficult.

Efforts to site new landfills and waste-to-energy facilities, and even recycling transfer stations, have been met with mounting opposition from community groups. Much attention has been paid to the so-called NIMBY (not in my backyard) syndrome which portrays local residents as emotional opponents of new facilities while often ignoring the complexity of the underlying issues. In most cases there is a fundamental disagreement among different groups and individuals over whether the facility is needed, if it is safe, if the siting decision is fair, and/or who should make the decision.

Rethinking the Traditional Siting Process

In the traditional siting process—sometimes called the Decide, Announce, Defend model—decision-making power is concentrated in the hands of a few, key local government officials. Communication is often limited to legal requirements for technical information (such as environmental impact studies) and a mandatory public hearing. The general public is not confronted until key risk management decisions already have been made, at which time they are presented with a fait d'accompli. At this point, the level of public opposition becomes intense and both sides become polarized. Although the traditional siting process has been modified, the basic tenets of an exclusionary siting process persist to this day.

Each of the statements below highlight an important dimension of the facility siting problem and each presents public officials with a different set of challenges.

1) The siting problem is not simply a technical one—it is social, economic, and political. Public opposition to landfills or incinerators is not always generated by the same siting issue, nor is opposition limited to any single issue in a given case. For example, public officials might face conflict over estimates of public health risks, equity in site choices, property value impacts, and the distribution of benefits and burden among community residents. All of these concerns influence an individuals sense of risk from a new facility. The solution to the problem must reflect the nature of the problem—a technical solution simply will not work.

2) The public fears and mistrusts technical information and the people who communicate it. As with many risk management problems, the credibility of technical information has been a major battleground in siting disputes because of a history of inappropriate use, scientific uncertainty, and communication barriers. For example, a hydrogeological study might be legitimately disputed by an independent expert. In other cases, participants might manipulate the use of information in the communication process to achieve particular ends. Also, many lay people find technical studies incomprehensible because of technical jargon.

The role of technical information remains critical to making good public policy. But, members of the public are making decisions based on incomplete information or information that is difficult to process. Both citizens and officials need good, relevant information to make better decisions about the key controversial issues.

3) Many citizens have lost confidence in the decision-making process for solid waste management and now demand greater access and involvement. Citizens object to the process by which land use decisions have been made in the past. They are concerned about past facility mismanagement, the credibility of public officials, and the growing pressures on the environment from our society. Members of the public have demonstrated that they will not sit by while important waste management decisions are being made. An effective siting process must be able to incorporate public concerns into the siting decision.

A Comprehensive Siting Strategy

Each siting effort requires a strategy tailored to the specific needs and concerns of the community. Nevertheless, experience from other successful siting suggests that effective public involvement should be the centerpiece of a comprehensive siting strategy that also includes risk communication, mitigation, and evaluation activities. This siting strategy is presented in an EPA publication, *Sites for Our Solid Waste: A Guidebook for Effective Public Involvement* (1990).

Public Participation

Public participation can bring trust and credibility back to the siting process but is not a guarantee for success. Citizen advisory committees, public meetings, and workshops, among others, have proven successful in both resolving conflicts and producing effective waste management policies. Note, however, that the success of the program does not depend on the number of meetings held, rather the quality of the implementation. Public participation is not just window dressing—token participation often backfires by fueling fears and mistrust. Instead, effective public participation requires integrating public concerns and values at every stage of the siting process.

In particular, officials should take steps to understand the various groups and interests in the community as well as develop a public participation plan that outlines the activities that will be conducted, their sequence and timing, and responsibility for carrying out each activity. A comprehensive public participation program is a sizeable effort that requires careful planning and a significant commitment of time and staff. But the alternative may be to go through a prolonged, divisive, and expensive siting process and still find yourself at square one.

Risk Communication

The term risk communication has different meanings for different people, often depending on their individual or institutional goals. Many officials restrict its meaning to the dissemination of scientific information to the public by official sources. For example, the Department of Health might want to translate findings from hydrogeological studies into a fact sheet for homeowners.

The National Research Council (1989) recently noted that risk communication is more than simply designing and communicating risk messages to the public; it is a two-way *process* that provides government, industry, and individual decision makers with the information they need to make risk management decisions. For example, the siting proposal might win support from nearby residents if they take steps to mitigate negative impacts.

Public officials should be aware, however, that communication programs are complex endeavors with many pitfalls. For example, conflicting perceptions of risk among individuals make it difficult to develop effective risk messages. The news media have difficulty reporting scientific risk estimates. And, communicators must decide whether they will simply inform the public's judgment or attempt to manipulate behavior. Many resources exist to help officials understand the complexities of communicating about potential risks to public health.

Risk communicators should also establish a set of policies and procedures that ensure that risk messages are both accurate and credible, such as getting participation in the study plan, providing technical assistance to the public, and presenting technical information in understandable language. These steps will not remove all challenges, but by taking them you reduce the chances of opponents gaining political support by questioning the technical adequacy of studies.

Mitigating Negative Impacts

Some public policy issues in local communities, no matter how sensitive to the concerns of residents, are bound to have negative consequences for a few people. It is necessary, however, to find more immediate and direct means of mitigating these negative impacts. Mitigation might take any one of three forms: direct compensation, more advanced technical safeguards, or more extensive environmental monitoring. For example, a community in New England restricted the number of trips made by non-local haulers to a regional landfill. In a Florida community, a property value guarantee has been made to nearby homeowners.

It is important to note that people view health and safety in terms of safe and unsafe. If they perceive a facility is safe, then it is possible to talk about other issues. If they perceive a project poses a genuine risk to health or safety, then everything else is non-negotiable.

Evaluating Effectiveness

Evaluation can improve the management of the complex planning and implementation activities. Project leaders find themselves making important decisions throughout the siting process based on their judgment of the effectiveness of specific siting activities. This type of "intuitive" evaluation is often hindered by preconceived ideas about what people want, as well as the frantic pace of everyday life at the office.

By evaluating the effectiveness of your siting strategy, you are trying to learn which activities are working, which activities need improvement, and which siting issues have not been addressed. Evaluation tools can help provide important feedback to decision-makers in a timely, cost-effective way.

Conclusion

The trash problem in the United States has no easy answers, and the conflict surrounding the siting of solid waste facilities will be with us for many years. Just as the issues and challenges facing public officials and citizens have changed over the last two decades, we should also expect new issues and new challenges to emerge in the coming years.

The siting strategy presented in this paper is not a recipe for success. It tries to overcome some of the obvious deficiencies in the traditional siting process while providing a flexible framework for tailoring the strategy to the particular needs and issues of different communities. Experiences from around the country suggest that solutions to the waste management problem, and the siting impasse in particular, will require a cooperative effort among public officials, waste management professionals, environmental advocates, and private citizens.

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MIDWAY LANDFILL

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First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

MIDWAY LANDFILL

Background

The Midway Landfill, a 60-acre site approximately 15 miles south of Seattle, was used as a gravel pit from 1945 to 1966 (see figure 1). In 1966 the City of Seattle began using it as a landfill for nonputrescible waste (such as demolition debris, woody wastes, and yard clippings). The landfill is bounded on the east and west by major north-south highways (Interstate 5 and Pacific Highway South, respectively). Residential neighborhoods are clustered to the east and south of the landfill; commercial businesses and light industries are on the west, and a mobile home park, drive-in theater, and some undeveloped property are to the north. The City stopped disposing of waste at the landfill in 1983.

Landfill Gas Migration

The landfill was initially brought to public and regulatory attention in 1985 by the discovery of subsurface gas infiltrating nearby structures. Residents were evacuated from their homes in several cases due to concerns about the concentration of combustible gasses accumulating in the houses. This occurred in late 1985 and early 1986. The City of Seattle and the Washington Department of Ecology installed gas extraction wells in the affected neighborhoods and gas migration control wells on the perimeter of the landfill.

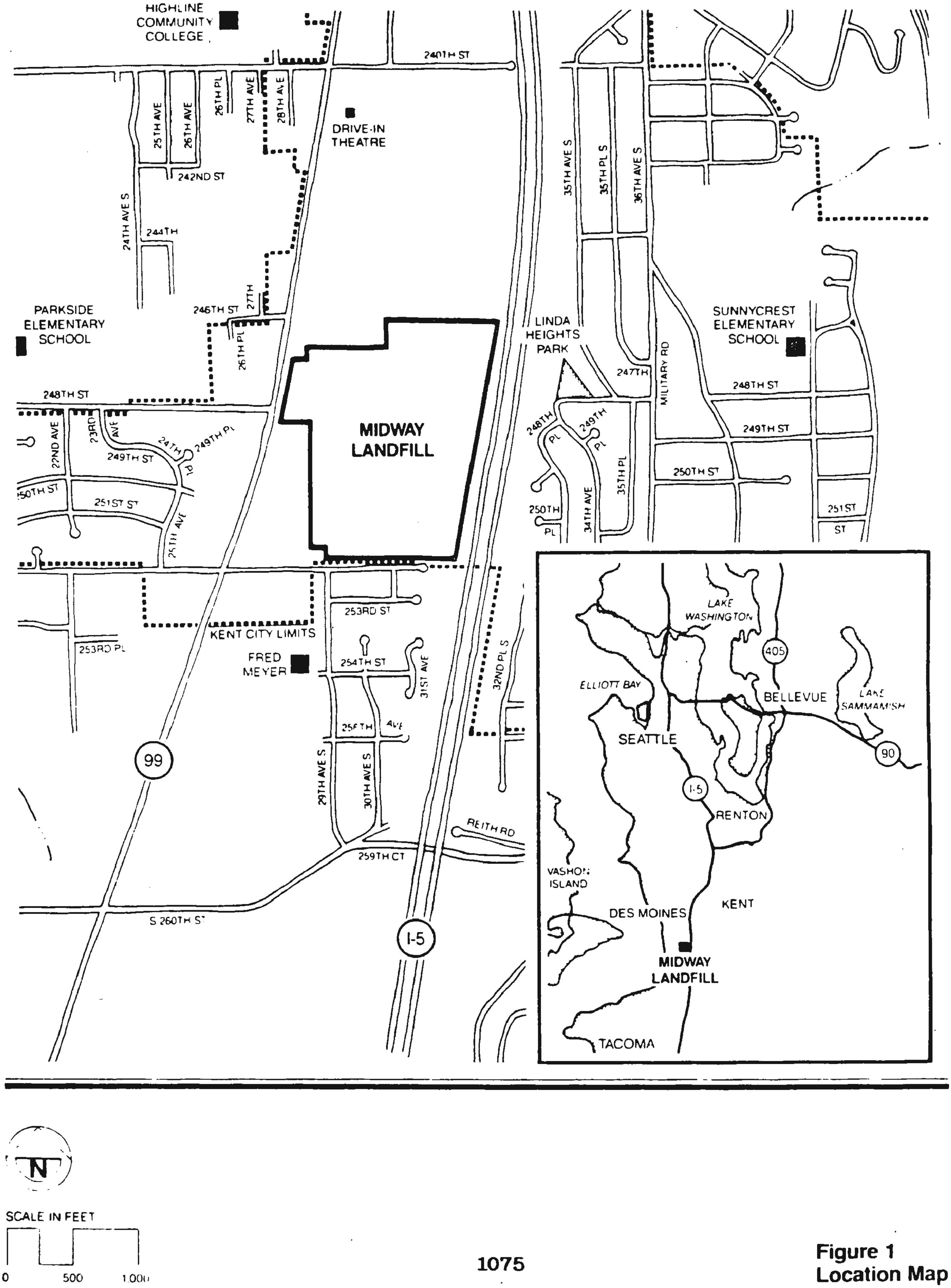


Figure 1
Location Map

In 1986, the Environmental Protection Agency placed the Midway Landfill on the National Priorities List. A Remedial Investigation/Feasibility Study (RI/FS) was begun and completion is expected late this year. The RI was an intensive effort by the City of Seattle to investigate the landfill's actual or potential impact on human health and the environment. The investigation covered surface water, ground water, soils, landfill gas and ambient air. The RI found that the gas extraction system stopped the off-site migration of gas, removed the gas from the structures and created a permanent system to prevent future gas migration.

Good Neighbor Program

During the period of time when gas migration was occurring and homes were being evacuated, property values were dropping drastically. While the City was working to control the gas migration, it established a Good Neighbor Program to maintain property values. The program allowed home owners to sell their home at a Fair Market Value established by the average of two appraisals. The homeowner and the City of Seattle each obtained an appraisal and the two were averaged to determine the Fair Market Value (FMV). The City could subsidize the purchase by another party to insure the seller received the FMV or the City could purchase the house for that amount and continue to market it. The program ended after 10 homes were sold at FMV which took about two years. During the program, 269 homes were sold through the program and the City purchased 165 of them.

After selling all but one of the homes, the net cost to the City for the program is approximately $5 million including all related management costs, real estate commissions, house repairs and price subsidies.

Ground and Surface Water

The next most serious concern of the RI was the potential for groundwater contamination by leachate from the landfill because of the large amounts of water known to enter the landfill by various means, including direct infiltration of precipitation, infiltration of runoff from surrounding property, and inflow from stormwater drains. During additional leachate sampling conducted as part of a treatability study for the FS, an oil was found floating on the aqueous phase leachate. The oil was found to be contaminated with polychlorinated biphenols (PCB's). A program was instituted to install 9 additional wells in the landfill to help determine the extent of the contaminated oil. Once the extent was determined to be isolated pockets, pumping began to remove the material before completion of all of the surface water management projects and the cap resulted in dewatering of the landfill. only a small amount of oil was recovered, approximately 100 gallons, and recharge of the wells with oil has been minimal.

A surface water management plan was prepared that would minimize the generation of leachate from surface water.

The plan included a pumping station to eliminate a stormwater discharge into the landfill, a 10 million gallon detention pond to store water from the pumping station, the landfill surface and some areas surrounding the landfill, and a pipeline to carry the stormwater to a creek approximately one mile to the west. No evidence was found during the RI of off-site transport of contaminants in surface water runoff from the landfill.

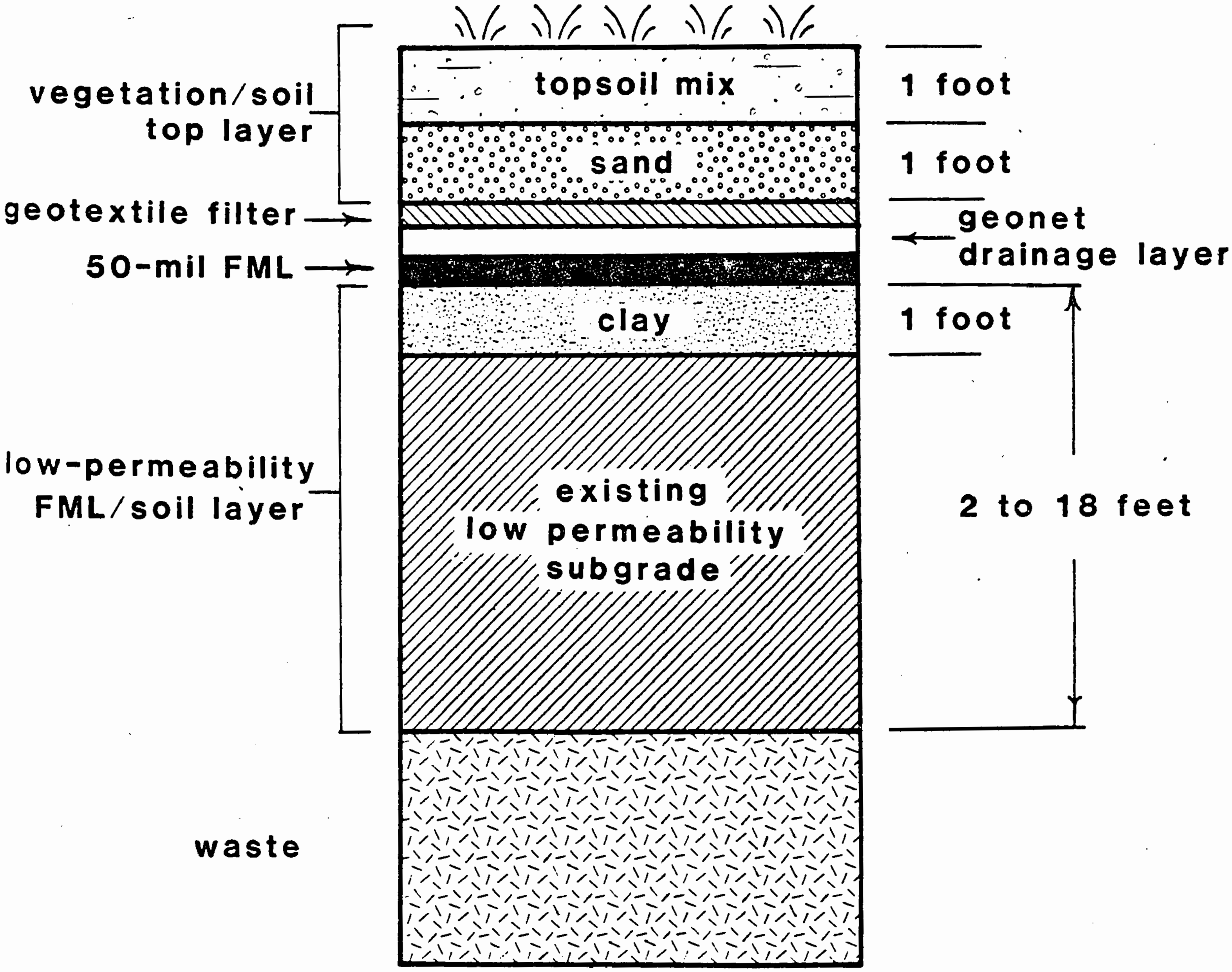
Ambient Air

Ambient air quality in the vicinity of the Midway Landfill was not found to be measurably different from typical urban air. The air moving across the site did not appear to show any consistent increase in contaminant concentrations that could be attributed to the landfill. Widespread low levels of contaminants in ambient air appear to be coming from off-site sources, including vehicle emissions from I-5 directly east of the landfill boundary.

Final Cover

Currently, the cap for the site is under construction (a cross-section of the cap design is shown in Figure 2). It includes a base cover of low permeability material placed during excavation of the detention pond in 1988. This material varies in depth from 2 to 20 feet and provides the general grade necessary to carry surface runoff to the detention pond. A foot of clay is being placed on top of the existing subgrade.

MIDWAY LANDFILL COVER



NOT TO SCALE

Figure 2

The next layer is a 50 mil layer of high density polyethylene. Then a synthetic geonet material is placed for a drainage layer and covered by a filter fabric. It is then covered with one foot of sand and one foot of topsoil and seeded.

Costs

The overall cost of all of the work at Midway is over $50 million. A breakdown of the costs is shown in Table 1.

TABLE 1

PROJECT ELEMENT	COST ESTIMATE (MILLIONS)
Preliminary Engineering Environmental Impact Statement	$ 3.1
Remedial Investigation/Feasibility Study	$ 5.7
Good Neighbor Program	$ 5.2
Claims/litigation	$ 12.3
Right-Of-Way	$ 1.3
Surface Water	$ 9.0
Gas Control	$ 6.0
Final Cover	$ 9.1
Staff Costs	$ 1.2
TOTAL	$ 52.9

CLOSURE OF THE CITY OF BOYNTON BEACH LANDFILL USING VERY LOW DENSITY POLYETHYLENE (VLDPE)

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13 - 16, 1990

CLOSURE OF THE CITY OF BOYNTON BEACH LANDFILL USING VERY LOW DENSITY POLYETHYLENE (VLDPE)

INTRODUCTION:

During the 1980's, Palm Beach County Solid Waste Authority has gradually taken over the responsibility from most municipalities within it's jurisdiction for the disposal of their solid waste. Previous to that period, each municipality within Palm Beach County was responsible for disposal of its own solid waste.

The City of Boynton Beach obtained a 40-acre site in 1958 from Palm Beach County for use as a landfill. This site was utilized through 1976 as an open landfill that accepted most types of waste, ranging from septic sludge to typical household refuse. It was a common practice in the past, for municipalities in this area to dispose of their waste in abandoned sand borrow or rock pits. It was believed that the City of Boynton Beach was no different in this aspect. Information contained in files retained by the City, the Palm Beach County Health Department (PBCHD), and the Florida Department of Environmental Regulation (FDER) alludes to this type of disposal of refuse below the water table in the southern end of the 40-acre site.

The southern and western boundaries of the 40-acre site are dilineated by canals: Equalizing Canal 3 (E-3) defines the western boundary and Lateral Canal 20 (L-20) defines the southern boundary (See Section 2.2). These canals are part of the local Lake Worth Drainage District (LWDD). The City of Boynton Beach Municipal Golf Course lies to the west of the site beyond the E-3. A residential development, called Le Chalet, has been constructed south of the site, and is serviced by a public water supply system. The land east of the site was a fish farm from the early 1960s until it was sold in early 1985. This land was bought by a developer who has cleared and

and developed it for a residential development called Arbor Glen, which is also on public water.

The area north and northeast of the old landfill site has, since the early 1960s, witnessed an increase in the number of private residences. The first residence was the Brandywine Horse Ranch, located on Palm Way. Today there are well over 50 private residences in the area north of the site and west of Haverhill Road Extension. No public water supply system or wastewater collection system serves this area. Therefore, each residence has its own private water supply well and septic tank.

The creation of Chapter 17-7 of the Florida Administrative Code (FAC) in October 1974 established a permitting process for the use of sanitary landfills in the State of Florida. To obtain enough time to conform with the rules and regulations of Chapter 17-7, the City of Boynton Beach applied in January 1975 for a temporary operating permit for the continued use of its sanitary landfill. On March 12, 1975, FDER issued a permit to the City, which was valid until March 7, 1976.

At the time, the staff of the City of Boynton Beach prepared a report including all of the information required by FDER for the operation of a sanitary landfill. This report was submitted to FDER in December 1975, and is believed to have been the first submitted under the new Chapter 17-7 rules and regulations. This report did not, however, fulfill the requirement for a hydrogeologic study of the strata underlying the site, and the City requested an extension of its temporary operating permit through July 1977. The FDER granted two extentions: the first, carried the City through from March 1976 to March 1977; the second overlapped the first and was only for the six-month period from January through June 1977. The disposal of sewage sludge at the site was discontinued in December 1976.

The City of Boynton Beach initially took steps to get the necessary hydrogeological data so it could still utilize its sanitary landfill. But, on May 19, 1977, the City notified the FDER by letter that the site was no longer going to be used as a sanitary landfill because the City could not comply with the regulation that disallowed the operation of a sanitary landfill within 1,000 feet of a water supply well. The City also expressed concern to FDER about the private residential wells located north of the site, if the sanitary landfill should continue operation. Thirteen private water supply wells already lay immediately north of the landfill, and this number was increasing as more homes were being built in that area.

The City continued using the site as an 8-acre trash-composting faciltiy on the northern half of the site and obtained permits for its operation until July 1, 1983. The remaining waste material that was not permitted at the trash composting facility was sent to the nearby Lantana Sanitary Landfill.

With the operating permit for the trash facility due to expire in July 1983, the PBSHD sent a letter to the City on February 27, 1983 outlining the reasons for performing a hydrogeologic investigation at the landfill site. These reasons were as follows:

- Past practices of disposing of putrescible waste into the water table
- Numerous depressional areas on top of the landfill
- Inadequate final cover material for the proper closure of the landfill
- An increase in the level of pesticides in the monitoring wells
- Groundwater sample analyses showing a general deterioration of water quality at the landfill, specifically for iron, chemical oxygen demand (COD), total dissolved solids (TDS) and chloride
- Numerous private homes to the east and north of the landfill, using private wells for potable water supply

The FDER requires that all inoperative landfills be properly closed to reduce potential pollution problems. Moreover, prior to the development of a closure plan, a hydrogeological investigation should be conducted, since the results of the investigation predicate the closure design for the landfill.

In early 1984, the City of Boynton Beach decided to close the old landfill at the site rather than reactivate the trash facility. It then requested proposals from engineering consultants to conduct a hydrogeologic survey of the site and develop a closure plan, with the intention of creating a 9-hole golf course that would eventually be connected to the City's Municipal Golf Course, west of the site.

HYDROGEOLOGICAL STUDY & CLOSURE PLAN:

Post, Buckley, Schuh and Jernigan, Inc. (PBS&J) was selected as consulting engineers by the City to conduct a hydrogeological investigation and to develop a closure plan for the old landfill. Jammal and Associates was selected to conduct the soil-boring program and drill the monitor wells installed in the first phase of the drilling program. The Testing Laboratory of the Palm Beaches was selected to drill the additional monitor wells that were installed in the second phase of the drilling program. This report was submitted to the City of Boynton Beach in May 1986, and then revised and resubmitted in November, 1986.

The purpose of the hydrogeological report was to gather into a single reference all the required and relevant data that will assist in the understanding of the local hydrogeology, to describe the field work conducted at the site, and to analyze the collected data and interpret the effect of the landfill on the surficial aquifer system and the nearby private water supply wells. The report presented all the information required to permit the design of a closure plan and, in so doing, described the existing hydrologic conditions at the site, the quality of the groundwater, and the potential threat, if any, of further contamination.

The results of the water quality analyses indicated that a leachate plume underlying the site is made up of two areas of high contamination: one in the northeast corner and the other in the central area of the site. For iron and lead, the contaminant center in the northeast corner was a horse manure pile. Dead and decaying vegetative matter in the marsh area and the organic matter from the horse manure pile together affected the water quality in the upper zone of the surficial aquifer system in the northeast corner and north of the site. The high levels of various metals, such as iron, lead, strontium, etc., identified in the central area of the site were not at the time considered to be a public health hazard, because of the semiconfining layer underlying the area in which they were found. The volatile organic compounds identified in various monitor wells at the site were also not considered to present a public health hazard. The high chloroform levels found in Monitor Well 13 were believed to be a localized occurrence resulting from an earlier well chlorination.

The monitor wells to the north of the landfill indicated that the contaminant plume had not expanded beyond the northern boundary of the site. Therefore, the report recommended that the City of Boynton Beach establish a quarterly water quality sampling program to monitor any movements in the contaminant plume. The water quality sampling program would monitor quarterly the leachate indicator parameters.

It was believed that the rainfall that recharged the upper zone of the surficial aquifer system in the area of the landfill leaches through the landfill mound and replenishes the piezometric mound. Although it moved slowly, the groundwater flow from this piezometric mound flowed away from the landfill site. Therefore, it was recommended that the City of Boynton Beach proceed with landfill closure to eliminate the infiltration of the rainfall through the landfill. The closure of the landfill would also greatly reduce, if not eliminate, the piezometric head differential between the upper and lower zones of the surficial aquifer system, which could induce contaminated water into the lower zone.

As directed by the City of Boynton Beach, PBS&J proceeded to develop closure plans for the 40-acre landfill site. As part of the closure plans, PBS&J had to meet three major objectives of the closure design:

- Meet FDER Closure Rules
- Meet South Florida Water Management District (SFWMD) Regulations
- Design the closure for the end use of a 9-hole golf course

The FDER Closure Rules require the landfill closure plan to develop a landfill gas management plan, a groundwater monitoring plan, a landfill cap design and a stormwater management plan. Since the landfill was nearly 30 years old and tests for methane presence proved negative, the landfill gas management plan required only the placement of landfill gas monitoring wells along the perimeter of the site and within the landfill mound itself. The Groundwater Monitoring Plan had utilized the previously submitted hydrogeological report to develop the monitoring plan for the site. The Stormwater Management Plan had to be developed and approved by the SFWMD. The ability to meet the SFWMD requirements and develop the required landfill closure design offered PBS&J's greatest challenge.

Like most old landfills, the City of Boynton Beach had utilized almost the entire 40-acre site for its landfill operation. The marsh area in the northeast corner of the site was the only area which was believed not to contain buried refuse. The SFWMD requires all stormwater runoff from a site to be retained in a ponding area before discharge into an open water way. This stormwater management rule required the construction of dry retention basins on the landfill site. The FDER requires that all buried waste must be covered by a clay or synthetic liner or removed from the ground in areas which are not covered. The need to meet the SFWMD and FDER rules and still design the site to be utilized as a golf course required close coordination of PBS&J's Solid Waste Division, PBS&J's Land Development Division and the golf course designer of Von Hagge & Devlin, Inc.

The closure plan was eventually developed which took into account all the design requirements. The plan required a contractor to excavate out buried refuse from various areas of the landfill in order for a dry retention area to be constructed of sufficient size to retain the rainfall volume from a 25-year storm effecting a 40-acre site. A berm was designed around the entire site to direct the stormwater to the dry retention areas. An outfall structure was also designed to allow a maximum discharge of 10 cfs. All excavated refuse was required to be placed on top of the mound and covered by either a 20-mil PVC or HDPE synthetic liner system. The closure design took into account the end-use of a 9-hole golf course to be developed at a later date by the City of Boynton Beach.

The Closure Plan was approved by FDER in late 1988 and construction started in mid-spring of 1989.

LANDFILL CLOSURE CONSTRUCTION:

The City of Boynton Beach awarded the closure construction contract to Ranger Construction of Boynton Beach with Gundle Lining Corporation as the subcontractor to install the synthetic liner. The contract had an additional requirement that stipulated that the contractor could not perform any work after dark. Since the landfill had become a sensitive issue over the years, it was hoped that this requirement would help relieve any new public relation problems. Before construction started, Gundle Lining Corporation requested that they be allowed to use their new 20-mil very low density polyethylene (VLDPE) instead of contracted 20-mil HDPE. Gundle Lining Corporation promoted the VLSPW's greater flexibility and percent elongation (900% @ break) as better product for landfill caps. Gundle also gave assurances that the VLDPE would meet contract specifications and not cause the City of Boynton Beach any additional cost. After a review of the material, PBS&J and the City of Boynton Beach approved the use of the VLDPE for the landfill closure.

Once the contractor started clearing and grubbing the, by now overgrown, 40-acre site, several problems became apparent. These problems encompassed not only assumptions of the closure design but also public relations with the residents of Arbor Glenn Estates. It appears that the residents of Arbor Glenn Estates, (especially the owners of properties which abut the landfill) had no idea that they lived next door to an old landfill. The property owners informed the City that they had been told that the neighboring property (the landfill site), was to be developed into a golf course, and they had paid a higher price for their land for that privilege. The City of Boynton Beach and PBS&J had to quickly arrange a meeting with the residents of Arbor Glenn to inform them of the history of the landfill site and to update them on present construction activities. Obviously, this public relations problem greatly sensitized the already sensitive issue which the landfill had become over the past years.

The clearing and grubbing of the site had also uncovered some problems which effected the design of the closure. To save the City of Boynton Beach the cost of clearing the landfill prior to the design phase of the project, PBS&J based the design on boring logs and an aerial topographical map. It was felt that this information was adequate to determine the depth of cover material and the extent of landfill mound. Once the landfill was cleared, it was quickly determined that very little on-site cover material was present and more than the estimated off-site clean fill would be required brought in to make up the difference. Also, not all the buried waste was in the mounded areas. It appears that pits had been dug where waste was placed up to the natural ground elevation.

Changes in design required the contractor to perform more excavation and backfilling and also stipulated that part of two dry retention areas needed to be lined. These design changes were coordinated with FDER and SFWMD and approval given before the installation of the liner began.

One area of the 40-acre landfill site which exemplifies the past procedures for disposing of waste, was along the L-20 canal in the very southern portion of the site. The Lake Worth Drainage District (LWDD) operates and maintains both the E-3 and L-20 canals which run along side the landfill. The LWDD maintains these canals through the use of 30-foot wide easements that run along the canals on the landfill property. Through the clearing of the landfill, it was discovered that waste was buried within the southern LWDD easement. The most cost effective method of handling this problem would have been to cover the area with a synthetic liner. But, the LWDD requested that all waste buried within their easement be removed and clean fill placed and compacted. The dimension of this excavation was approximately 1000 feet long by 20 feet wide and ranged from 4 to 6 feet deep. This problem area alone cost the City of Boynton Beach an estimated quarter million dollars or an additional twenty-five percent of the original contracted cost.

The last area which required additional earthwork was along the property line adjacent to Arbor Glenn Estates. Arbor Glenn was platted to allow drainage from the back of the properties to the road in front. However, the actual construction of Arbor Glenn allowed the backyards of these adjacent properties to drain onto the landfill site. To relieve this problem, the City of Boynton Beach and PBS&J met with the residents and submitted to them for their approval, a design to allow drainage along a former swale. Ranger Construction regraded the property owners backyards to produce a swale, seeded and mulched the regraded area and replaced a small drainage culvert to the L-20 canal at no additional cost to the client or residents of Arbor Glenn Estates. This cooperative effort between Ranger Construction, City of Boynton Beach and PBS&J helped many small public relation problems from developing into time consuming, troublesome headaches.

LINER INSTALLATION:

Gundle Lining Corporation had developed their new 20-mil VLDPE liner system in hopes of competing with the 20-mil PVC market. Unlike 20-mil high density polyethylene (HDPE), 20-mil VLDPE exhibits the flexibility of PVC liner without PVC's UV sensitivity and bio-degradability problems. This landfill closure was Gundle's first attempt to install VLDPE in the State of Florida and on a sandy sub-base. Due to construction schedule, Gundle had the additional misfortune of having to install the liner system during the very hot Florida summer. Liner installation was expected to have some problems since Gundle's 20-mil VLDPE was still considered to be product in the development stage. However, the scope and diversity of the problems encountered required Gundle Lining Corp., the City of Boynton Beach, and PBS&J to develop alternative installation and testing procedures to insure a quality synthetic cap. Problems which occurred in the VLDPE placement and their corresponding solutions are described in the following text:

VLDPE could not be welded using Gundle's double-wedge welding system. Because of the thickness and heat sensitivity of the VLDPE, any small misalignment of the liner through the double-wedge system caused a burn through the liner or the failure of one or both of the weld tracts to meet contract specifications. This problem was resolved by changing to a single wedge welding system.

The VLDPE also had a limited time span during the day in which it was possible to be welded. This was because the summer heat caused the liner material to be so flexible that it increased the potential for burn through. This initially limited Gundle to early morning and evening welding. Once the single wedge system was developed and produced the high quality seams required by PBS&J, the City of Boynton Beach released the contractor from the daylight work only requirement. Gundle was then able to weld the liner at a faster rate with fewer burn throughs during the cooler evenings.

The sand sub-base also created a temporary problem with the welding system. The VLDPE liner appeared to develop an oily surface when heated by the sun. This oily surface attracted sand and had a tendency to clog the lower rollers of the Gundle welding system. In the evening, the liner collected moisture underneath which also attracted sand. This problem was easily relieved by an extensive cleaning of the liner by Gundle's personnel and by keeping the liner off the ground with the use of a skid pad under the seam.

The most critical aspect of the VLDPE installation which required a reevaluation of the liner was the quality assurance testing of the seams. In short, Gundle's VLDPE could not meet the contract specifications for peel and shear testing using the standards established for either 20-mil HDPE or 20-mil PVC. It became apparent that the VLDPE really could not be compared to those standards because it was an entirely different type of material. At the time, no current ASTM test procedures or National Sanitation Foundation (NSF) No. 54 test standards existed for VLDPE. Through the combined efforts of Gundle Lining Corp., Richard Charron of GeoSyntec (geosynthetic testing laboratories) and PBS&J, new test standards were developed to adequately determine the seam quality. These standards are listed in the Table below:

Comparision of Testing Standards 20-mil Liner

	20-mil HDPE	20-mil PVC	20-mil VLDPE
Shear Test	36# (Yield)	36.8# (Break)	30# (Break)
Peel Test	FTB	10# or FTB	20# or FTB

FTB = Film Tearing Bond

Once the above described problems were resolved, the liner installation ran very smoothly. After completion of the liner installation, PBS&J felt the VLDPE system did meet the design and quality assurance requirements for this landfill closure. A great deal was learned about the properties and installation procedures for VLDPE by both Gundle Lining Corporation and PBS&J.

SUMMARY:

The City of Boynton Beach has a closed landfill facility designed for possible end-use as a golf course. Additional expenditures will be needed by the City to upgrade the final closure to an official golf course after any settlement occurs in the following years. This project was brought to its successful conslusion through the fore thought of the City officials. Unlike many communities, who wished the problems of their old landfill would go away, the City of Boynton Beach came to realize that a successful conclusion could be found only by taking the responsibility and working through all of the problems.

It could be said that the closure of the Boynton Beach Landfill exhibited many of the same problems in which many municipalities face in dealing with their old landfills. The City of Boynton Beach took on the responsibility for their landfill early in attempting to meet the Florida Regulations. In so doing, the City of Boynton Beach has become one of the few communities in the State of Florida to close their landfill without the need for FDER to issue a Consent Order requiring its closure. In addition, each aspect of the hydrogeological assessment and landfill closure took the public welfare into account. In order to keep public relation problems to a minimum, the City of Boynton Beach, at all times tried to keep the public informed of the progress and/or problems associated with the landfill closure. Be assured that further work at the Boynton Beach Landfill will still need to be done. Continued groundwater monitoring, general maintenance and repair to any eroded area's will be required by the City until an undetermined time in the future. But, finally, the potential risks to human health associated with this old landfill should be coming to an end.

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PUENTE HILLS ENERGY RECOVERY FROM GAS (PERG) FACILITY

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presented at the

First United States Conference on Municipal Solid Wastes
Solution for the 90's
Sponsored by the
United States Environmental Protection Agency

at

Washington, D.C.

June 13 - 16, 1990

Puente Hills Energy Recovery from Gas (PERG) Facility

by John Eppich, John Cosulich, and Hsin-Hsin Hsu Wong
Los Angeles County Sanitation Districts

Abstract

The Puente Hills Energy Recovery from Gas Facility (Facility) utilizes landfill gas as a fuel and is currently generating 50 MW gross of electricity. The Facility is located at the Puente Hills Landfill in Whittier, California. The landfill is owned and operated by the Los Angeles County Sanitation Districts. The Puente Hills Landfill has over 45 million tons in place and is currently receiving refuse at the rate of 72,000 tons per week. Because of the size and the extensive gas collection system in place, approximately 24,000 scfm of landfill gas is collected and burned at the PERG facility and the flaring station. The average heating value of the landfill gas is 420 BTU/scf.

The Facility, which has been operating since November, 1986, consists of two steam generators each firing 10,300 scfm of landfill gas. Each unit produces 210,000 lbs. of steam per hour at 1,350 psig and 1000°F. The steam is used to drive the turbine generator and produce approximately 50,000 kilowatts of electricity. Several technologies were investigated prior to selecting the rankine cycle, the most common technology used for power generation in the United States. The other technologies included reciprocating engines, gas turbines, and combined cycle gas turbines. The factors involved in the selection were air emissions, construction costs, ease of operation, and efficiency. A significant factor in the final decision was the large size of the facility.

Because of the financial and time constraints, the contractor for the Facility was required to bid a fixed price project based on preliminary design requirements and performance

specifications which were prepared by the Sanitation Districts. Payment to the contractor consists of 60 monthly lease payments which commenced 30 days after the project had completed construction and successfully passed the performance test requirements. In this manner, the Sanitation Districts was able to make payments for the Facility out of the revenues derived from the sale of electricity to the nearby utility, Southern California Edison.

The emissions from the Facility had to meet strict requirements from the South Coast Air Quality Management District. The emissions from the plant are well below those numbers required by the Air District due to several emission control strategies required of the equipment as part of the Performance Specifications.

This Facility has successfully demonstrated that landfill gas can be combusted in boilers, reduce air emissions, and provide significant economic advantages to the owner.

Introduction

The Los Angeles County Sanitation Districts (Districts) own and operate both the Puente Hills Landfill and the PERG Facility. The Districts are a special purpose organization created by the California State Legislature for the management of solid wastes and for water pollution control, and are governed by a Board of Directors consisting of elected representatives of the cities and unincorporated areas which the Districts serve. The Districts currently manage over 21,000 tons of solid waste per day at four major landfills and process a total of over 500 million gallons per day of wastewater at 11 major wastewater treatment and water reclamation plants.

The Puente Hills Energy Recovery from Gas (PERG) Facility, a 50 megawatt (gross) landfill gas to energy facility, commenced operation in November, 1986. PERG is currently generating its design capacity of 46 MW net. During the first three years of operation, the availability of the Facility exceeded 92%. This is to report the operational information on this Facility including availability, emissions, and landfill gas characteristics and collection. A schematic of the landfill gas collection system and PERG is shown in Figure 1.

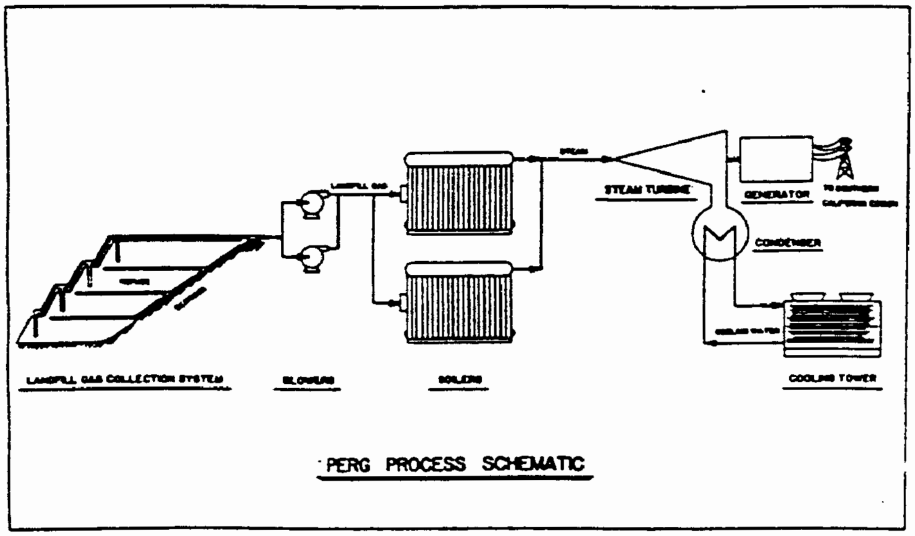

Figure 1 - Schematic of the Puente Hills Landfill Gas Collection System and the Energy Recovery from Gas Facility

Puente Hills Landfill

The Puente Hills Landfill, formerly a small private operation, was purchased by the Districts in 1970. The landfill is a California Class III site, permitted to accept non-hazardous solid wastes. Currently, 72,000 tons per week is landfilled at Puente Hills. Over 45 million tons have been placed at the Puente Hills Landfill.

The Puente Hills Landfill consists of 1,365 acres including both the active fill and buffer areas. The active area of the landfill is approximately 550 acres. The maximum depth of the landfill is approximately 500 feet.

Landfill Gas Generation

Landfill gas is produced by naturally occurring biological decomposition of the organic fraction of refuse. The current gas collection rate is approximately 24,000 standard cubic feet per minute of landfill gas.

When refuse is landfilled, much of the organic fraction of the refuse will be converted to landfill gas over a period of 10 to 40 years. The rate of conversion depends on many factors including moisture content, refuse composition, nutrients, buffer capacity, refuse compaction, and temperature.

The Districts project the landfill gas generation using a first order exponential decay model with a half life of approximately 20 years. Several other models for landfill gas generation are also used in the industry. The Districts estimate that approximately two cubic feet of methane is produced for every pound of refuse landfilled at the Puente Hills landfill.

Anaerobic production of landfill gas is approximately 60-65% methane and 35-40% carbon dioxide. If oxygen is drawn into the landfill by the gas collection system, aerobic decomposition of the refuse, or composting will occur. Composting produces carbon dioxide and water and raises the temperature of the landfill. However, it is necessary to draw limited quantities of air into the landfill for proper odor control. Accordingly, the landfill gas collection system is monitored to minimize the amount of composting and to control odors.

Landfill Gas Collection System

An extensive landfill gas collection system has been operated at Puente Hills Landfill since 1981. The gas collection system operation is optimized for odor control, power production is a secondary goal. The gas collection system consists of two major types of collection systems, vertical wells and horizontal trenches and includes over 40 miles of collection and header pipes. The primary purpose of the gas collection system is to control landfill gas and thus prevent odors and sub-surface migration.

Over 400 wells have been drilled in the front face of the landfill for odor control. The wells are monitored on a biweekly basis for temperature and methane content. A throttling valve on each well is used to control the tested parameters. A slight closure in the throttling valve results in decreasing the temperature and the oxygen, and increasing the methane content. A typical well detail is shown in Figure 2.

The trench system is constructed directly in the refuse on the operating deck of the landfill. The trenches are installed in four decks of the landfill with collection pipes approximately 260 feet apart. A new trench system is installed on the top of the landfill approximately 60 feet in elevation. The trench system installed to date consists of over 18 miles of landfill gas piping. A typical trench detail is shown in Figure 3.

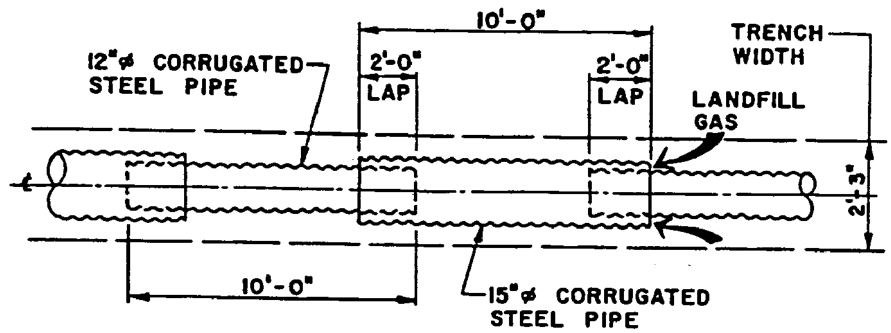

Figure 3 - Landfill Gas Trench Detail

Landfill gas delivered to the PERG Facility is approximately 42% methane, 35% CO_2, 3% O_2, 15% N_2, and 5% H_2O (all by volume). The landfill gas is normally at 100% relative humidity or saturated when it comes out of the landfill. Accordingly, condensate traps are located at all low points in the gas collection system.

The overall gas collection system at the Puente Hills Landfill is designed in a "loop" around the perimeter of the landfill. This allows the remainder of the collection system to be operational when part of the system is out of service for maintenance.

The entire landfill gas collection system is under a vacuum to insure odorous gases do not escape in case of leaks in the piping. Occasionally, expansion joints or other components of the landfill gas system will fail. The most common cause of failures is differential settlement.

The heating value of the landfill gas is monitored continuously by a calorimeter. Sharp decreases in methane content of the landfill gas generally indicate a breakage in the collection piping.

Technology Selection

Several technologies to convert the landfill gas to electricity were investigated by the Districts. These technologies include reciprocating engines, gas turbines (simple and combined cycle), and the rankine cycle. The study concluded that the most common technology used for electrical power generation in the United States, the rankine cycle was best suited for the Puente Hills Landfill. The selection criteria included energy conversion efficiency, air emissions ease of operation, and construction cost as shown in Table 1.

CRITERIA	RECIPROCATING ENGINES	GAS TURBINE	COMBINED CYCLE	STEAM TURBINE
AIR EMISSIONS	1	3	3	5
NET POWER	4	3	5	4
EASE OF OPERATION	2	3	2	3
B T U CONTENT	2	4	4	5
CONSTRUCTION COST	3	4	3	4
TOTAL POINTS	12	17	17	21

Table 1 Selection Criteria Used to Evaluate Alternative Landfill Gas to Energy Technologies for a 50 MW Project

The rankine cycle's gas fired boiler with multiple control strategies, offered the ability to achieve very low air emissions, lower than any other of the technologies. Reciprocating engines had the highest emissions.

The combined cycle offered the highest net power, but at increased complexity and cost, which outweighed the value of the added power.

The "BTU Content" criteria included the ability to effectively operate on a low BTU content fuel which is subject to sudden variations. The landfill is constantly settling. Differential settlement often results in line separations and sudden decreases in BTU content.

Two gas turbines are also currently operating at Puente Hills Landfill: a Solar Centaur (2650 kw) and a NATCO KG-2 (1250 kw). These gas turbines have been operated intermittently since 1983 when landfill gas is available. The gas turbines have operated successfully. The Districts consider gas turbines a viable technology for smaller landfills.

PERG Specifications

In order to assure a competitive bid and quality construction, the Districts prepared detailed Performance Specifications for bid to pre-qualified engineering contractors. The Performance Specifications included detailed specifications on major equipment and general construction specifications. Also, included in the Performance Specifications were the design, redundancy, and access requirements for all major equipment and systems. An equipment summary is provided in Appendix 1.

Bids were evaluated by calculating the net present worth of the 60 monthly payments and the residual value purchase to the bid opening using 1% per month discount rate. Net power from the Facility was included as an evaluated credit of $2,500 per kilowatt to encourage energy efficient designs. However, the Performance Specifications included limitations on the cycle complexity for ease of operation and reliability, and several mandatory emission control methods to achieve the stringent air emission limitations.

The Performance Specifications included redundancy requirements on most rotating equipment for reliability. The only mechanical equipment without redundancy are the boilers and steam turbine.

The successful bid by Schneider, Inc. included a steam turbine by Fuji Electric. The steam turbine heat rate is 8,545 BTU/kwhr (9.01 MJ/kwhr). The boiler efficiency is over 83% based on the higher heating value of the landfill gas. The parasitic load of the plant is approximately 8% of gross. The overall Facility's net heat rate based on the higher heating value is approximately 11,000 BTU/kwhr (11.6 MJ/kwhr).

Performance requirements included ASME performance test codes for steam turbines, boilers, and deaerator. The turnkey contractor was also required to demonstrate that the boiler could achieve the stringent limitations imposed on the project by the local air quality management district. Another requirements was to demonstrate the Facility could be operated reliably, which consisted of an 85% availability requirement for a 30 day period before the Districts accepted the Facility.

Project Schedule

A primary concern was to implement a project as quickly as possible to utilize the landfill gas. Project implementation, from conceptual design to commercial operation was accomplished in less than three years. Conceptual design was started in early 1984. Applications for air permits were filed in May, 1984 and final permits were received in April, 1985. The contract was awarded to the turnkey contractor in March, 1985. Commercial operation was achieved in November, 1986.

The turnkey method of procurement was selected since it offered considerable time savings over other procurement methods. The turnkey contractor was required to design and construct the Facility in 16 months. This tight schedule mandated a substantial overlap of the design and construction phases of the work.

Air Emissions

Air emissions are a critical issue in Los Angeles County. From a regulatory standpoint the South Coast Air Quality Management District (SCAQMD), requires that all landfill gas be collected and flared. When the permit was filed, the emissions from the flares provided the baseline emissions level.

The Performance Specifications included several requirements to assure the stringent emission levels could be achieved, including derating the boilers, flue gas recirculation, low NO_x burners, limiting the air preheat, and provisions for Thermal DeNO_x (a proprietary Exxon process). However, tests on Thermal DeNO_x demonstrated Thermal DeNO_x did not effectively reduce NO_x at the low inlet NO_x levels. Subsequently, the ammonia injection piping was removed. The air pollution control and NO_x reduction methods are shown in Figure 4.

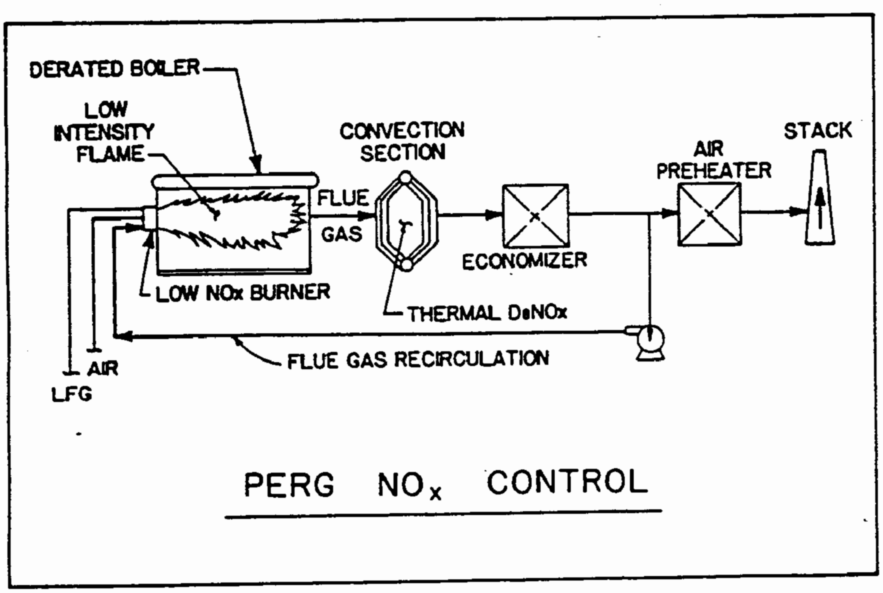

Figure 4 - Schematic of the PERG Boiler NO_x Reduction Methods

The boiler burners are low NO_x burners supplied by Coen. The burners, are the dual air zone type (Coen Model Number DAZ 42), with adjustable inner and outer scrolls which may be controlled to adjust the flame shape turbulence. The scrolls direct the gases in opposite rotating directions. Increasing the opposing spin increase turbulence and results in a shorter more turbulent flame.

The NO_x control strategies including the low NO_x burners, oversized boilers, and flue gas recirculation have resulted in very low emissions of less than 24 ppmv NO_x (3% O_2, dry) or approximately 0.03 lbs/10^6 BTU. Flue gas recirculation has proven to be an effective method of reducing NO_x emissions by approximately 60%.

A comparison of the PERG boiler emissions to the flare emissions is given in Figure 5. This figure shows the boilers provide substantially lower NO_x, HC, and CO emissions.

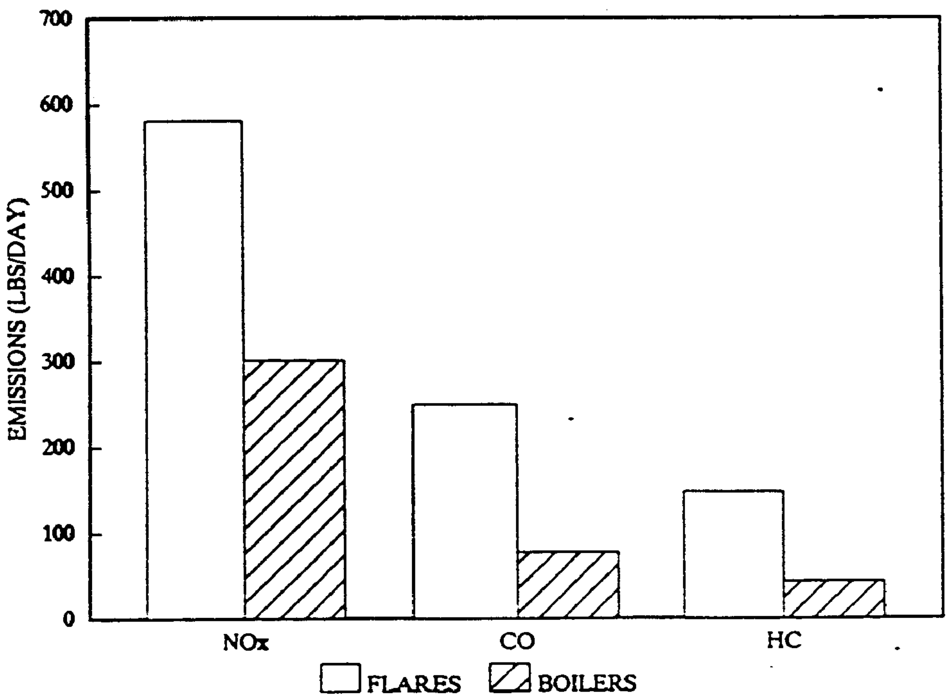

Figure 5 - Emission Comparison between the Flares and Boilers at the Puente Hills Landfill

Using Landfill Gas as a Fuel

The operations problems at PERG have for the most part been the result of failures with equipment common with a natural gas fired power plant. The availability to date has been 92% for the first three years of operation.

Any operational problems which could be attributed to landfill gas may be caused by the moisture, or by the chlorine and sulfur compounds in the landfill gas, or by the variability in the landfill gas quality. The landfill gas is essentially saturated when it is collected from the landfill.

Landfill gas is a relatively clean fuel. The landfill gas from the Puente Hills landfill contains 30 to 80 ppmv each of chlorinated and sulfur compounds. This compares favorably with coal which may contain between 100 and 1,000 times more sulfur and chlorine.

The landfill gas collection at the Puente Hills Landfill includes more than 40 miles of collection and header piping. The piping, being located in a landfill is subject to both differential settlement and vehicle damage. Differential settlement within the landfill is the most prevalent cause of failure. Differential settlement causes failures by over stressing flexible joints in the landfill gas piping. Periodic inspection of the landfill piping has limited major failures caused by differential settlement.

Normally there is a slight diurnal variation in the landfill gas with the landfill gas quality causing the BTU content to be lower at night. This may be the result of thermal expansion of the PVC collection piping during the day resulting in lower air infiltration into the above ground piping. The air infiltration may occur at cracks in the flexible joints.

The problem that arises from the power plant standpoint is the variability in the BTU content of the landfill gas. Normally the Puente Hills landfill gas varies from 410 to 440 BTU/scf. However, in the case of a piping failure, the BTU content may drop to below 200 BTU/scf. This may result in flame stability problems in the boiler.

Flame stability in the boilers is a potential problem, especially using a high flue gas recirculation rate. The pilot flame for startup is fueled by propane. Prior to successfully completing lightoff on landfill gas, the minimum fire settings had to increase in terms of firing rate and excess air had to be decreased. This is due to the nature of the landfill gas fuel. Since landfill gas has less than half the BTU content of natural gas, the flame burns cooler. This results in occasional burner safety management trips when the flame scanner (Fireye) fails to sense the flame.

The chlorine and sulfur in the landfill gas make the gas and its condensate corrosive. Since the landfill gas is saturated and the ambient temperature is below the dewpoint of the landfill gas, moisture condenses along the pipe walls. This condensation, or condensate has a pH between 2 and 3. Carbon steel corrodes quickly at this pH. Accordingly, the Districts use 304 stainless steel for both landfill gas and condensate piping.

Landfill gas is generally low in particulate matter. However, when new collection piping is placed in service or in upset conditions a large amount of particulate matter or moisture can be passed through the landfill gas piping. Witch hat strainers are located at the inlet of the landfill gas blowers to protect the blowers from particulate matter. A knockout drum protects the blowers from slugs of water.

Occasionally a condensate trap which normally removes the condensate from low points in the landfill gas collection system fails. This results in the partial or complete plugging of the associated piping until the water condensate is removed. Partial plugging of the landfill gas pipe in the collection system is detected at the energy station by oscillating landfill gas pressures. When all the condensate traps are functioning properly, the landfill gas pressure is very stable.

Availability

A summary of factors affecting availability during the first three years of operation is given in Table 2. The most trouble prone pieces of equipment during the first three years of operation were boilers. The largest factor was the forced draft fan motors which both failed during rainstorms. Enclosures around the motors have precluded subsequent failures. The other factors which significantly affected boiler availability were: a faulty electronics board in the burner management system; binding of the forced draft fan dampers; bearing failures at the air preheater rotor (hot end) and the forced draft fan; and the flue gas recirculation fan related problems. A boiler feed pump suction bypass from the fifth heater feedwater line was installed to reduce the NPSH transient due to a sudden load decrease. The original forced draft fan damper was replaced with an external greased ball bearing inlet vane damper.

Item	Number of Outages	Total Downtime (hrs)
Boiler	67	768
Steam Turbine	6	35
Landfill Gas System	10	59
Electrical	12	135
Instrumentation	13	83
Utilities	17	118
Other Mechanical Equipment	5	23
Annual Maintenance Outage	3	1,051
Total	133	2,272

Table 2 - PERG Outage Summary for 1987, 1988, and 1989

The Fuji steam turbine proved to be a reliable piece of equipment during the first three years of operation. However, during the scheduled warranty inspection at the end of the three year warranty period, the following items were discovered and repaired:

1. Erosion/corrosion noted at the trailing edge of the 33rd stage of stationary blades.
2. Severe seal fin damages (both moving and stationary blades).
3. Erosion/corrosion noted at the stationary blade seal fin bases at 31st and 32nd stage.

The scheduled maintenance outage was extended for these unexpected repairs by approximately three weeks.

The landfill gas collection system caused 10 outages in the first three years of operation. Five outages were the result of sharp drops in the landfill gas methane content. There were two scheduled outages for landfill gas piping modifications. Two outages were caused by landfill gas blower failures. One outage was caused by air preheater fouling which required water washing due to an excessive pressure drop. The deposits were analyzed and determined to be silica, iron, chlorine, and sulfur in descending order of concentration.

There were 12 electrical failures in the first three years of operation. Three electrical failures were in the uninterruptible power supply system. Three main breaker trips resulted from electrical fault in the circulating water pump motor. Three outages were resulted from trips in the 4160 volts transformer. Three scheduled outages totaling 70 hours were resulted from correcting the overheating in the Southern California Edison metering (12KV) cubicle.

Seven instrumentation trips occurred due primarily to faulty vibration signals. Subsequently, the vibration switches were changes to alarms rather than trip. Six outages resulted from faulty instrumentation signals. Water leaks through connecting conduit to one of the outdoor process control unit cabinets resulted in 24 hours of down time.

Two different utility power sources are required for the operation of PERG. One electrical service provides the electric power for the landfill gas collection blowers and the water booster station. The other electrical service provides both the generated and parasitic power for PERG. Seventeen outages resulted from interruptions in service or disturbances resulting in the opening of the main breaker by protective relays for a total of 118 hours of downtime.

Outages due to other mechanical equipment such as pumps and compressors were limited to 23 hours due to redundancies and automatic standby controls.

Annual maintenances were typically scheduled in May approximately one month before the four summer months when power sold at a higher rate.

Economics

The project capital costs, including design, construction, and interest during construction was approximately $33,000,000 for the entire Facility. On a unit cost basis this is equivalent to $650 per kilowatt of installed capacity. The District structured the project financing to allow the electrical revenues from the project to pay for the project capital costs.

Project revenues are derived from the sale of electricity to Southern California Edison. The gross revenues were $90,688,900 for the first three years of operation in accordance with the power purchase agreement with Southern California Edison. Each of the 60 monthly lease payments is $726,000, and the average routine monthly operations and maintenance expenses were $319,000. The cost for the FGR fan modification and a major turbine and boiler overhaul was $1,200,000.

Operating Costs

The operating costs for PERG were estimated at $300,000 per month. The average operating costs for the first three years of operation was $319,000 per month. A breakdown of the operating expenses is provided in Table 3.

Expenses	$/Month
Payroll	138,000
Materials	49,000
Chemicals	13,000
Water	16,000
Electricity	35,000
Services	20,000
Insurance	18,000
Other	30,000
Total	319,000

Table 3 - PERG Operating Expenses

Conclusion

The PERG Facility demonstrates that a large scale landfill gas to energy facility can combust landfill gas (a waste product), reduce air emissions, and provide significant economic benefits.

Appendix 1
PERG FACT SHEET

Owner and Operator	Los Angeles County Sanitation Districts
Turnkey Contractor	Schneider, Inc.
Engineer (Detailed Design)	Energy Systems Associates
Boilers	
Number	2
Manufacturer	Zurn
Steam Capacity (each), lbs/hr (kg/hr)	264,000 (120,000)
Steam Pressure, PSIG (MPa)	1350 (9.4)
Steam Temperature, °F (°C)	1000 (538)
Configuration	"O" Type
Erection	Field
Burners	Coen
Air Preheater (Ljungstrom type)	Combustion Engineering
Stack Gas Temperature, °F (°C)	260 (127)
Efficiency (as bid)	83%
Steam Turbine/Generator	
Manufacturer	Fuji
Capacity	50,000 kw
Blading	Reaction
Number of Stages	35
Extractions	6
Condensing Pressure, "Hg"(kPa)	2 (6.8)
Heat Rate (as bid)	8545 BTU/kwhr (9.01 MJ/kwhr)
Condenser	
Manufacturer	Graham
Surface Area, $ft^2(m^2)$	38,000 (3532)
Feedwater Heaters	
Manufacturer	Struther-Wells
Stages	5
Cooling Tower	
Manufacturer	BAC-Pritchard
Heat Rejection, 10^6BTU/hr (MJ/hr)	272 (286)
Superstructure	Concrete
Fill Material	PVC
Fans	150 hp, 2 speed
Control System	
Supplier	Bailey Control
Type	Distributed
Model	Network 90

STABILIZED FOAM AS LANDFILL DAILY COVER

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13 - 16, 1990

Abstract:

This paper is concerned with the use of stabilized foam to provide daily cover in sanitary waste landfills. The paper will discuss the problems faced by landfill operators in using soil and other materials as daily cover and the inherent advantages and needs associated with the use of stabilized foam. In addition the paper will discuss the experiences of 3M as a material and equipment supplier of stabilized foam synthetic daily cover. The paper will highlight the equipment and foam technology used to produce the the foam cover and also the experiences of 3M and its customers in getting the product approved for use in various localities. The paper will discuss the facilities required on the site to use the product efficiently and also some of the training and service provided to landfill operators to take advantage of this technology.

3M-WMA Presentation text (ref. slides)

I. Introduction

A. Problem Statement

The generation of waste in the U.S. is accelerating and the available technologies to deal with the problem are limited. In particular, landfills have been the traditional approach to disposing of municipal waste but they are filling up at an alarming rate and the siting of new landfills is very difficult. There has been a decrease of about 8000 permitted landfills from 1987 to 1990 in the United States. One of the factors leading to the limited life of existing landfills is the use of soil as daily cover material. When soil is used as daily cover there are several associated problems:

1 - Soil consumes valuable air space.

2 - The availability of soil to a local site may be poor and if that is the case, soil cover may be costly.

3 - Application of soil cover is quite labor intensive and can be susceptible to adverse weather conditions.

4 - Soil may cause unwanted lateral movement of leachate and gas.

B. Need:

Performance criteria for daily cover:

1 - Control litter

2 - Control odors on the workface

3- Control Vectors

4 - Provide a fire barrier against hot loads, spontaneous combustion and surface ignition

5 - Provide a disincentive to scavenging and

other undesired activity on the landfill

6 - Provide a barrier to excessive water infiltration which could create excessive leachate.

7 - Provide a degree of acceptible esthetics for the landfill relative to neighbors and passersby.

C. Non - Soil Alternative Daily Cover material:

There have been a variety of materials which have been used as alternative daily cover material to soil. Generally all have had deficiencies.

Flyash, incinerator ash and bottom ash have been tried in some locals as daily cover material. These all are considered unacceptable from the standpoint of heavy metal content and dust problems.

Industrial and municipal waste streams such as waste water sludge, paper sludge, tire chips, foundry sand, wood chips and shredder fluff have all been used occasionally as daily cover material. Contamination of by heavy metals, PCBs together with materials which cause bad air emissions are generally associated with materials of this type. An additional problem with sludges is that they can inhibit the maneuverability of landfill equipment.

There have been several attempts at using geotextiles as daily cover material. Although they appear to satisfy some of the basic criteria for cover such as litter control and esthetics, the geotextiles in use suffer from several important aspects relative to daily cover requirements. They can be very difficult to install especially in windy conditions and inclement weather. They are porous to rain and therefore can create significant problems with leachate. The geotextiles are flammable and if they are reused they can cause problems with air emissions and exposure of workers to refuse residues.

D. Solution:
An excellent approach has been to use stabilized foams which are designed as daily cover material. These materials are engineered to meet the basic performance requirements of daily cover in conserving valuable air space while providing increased revenue to the landfill operator.

Two such materials sold by the 3M Company will be discussed further.

II. Description of foam materials

3M produces two types of foam materials for use as synthetic daily cover (SDC) on municipal landfills. The materials are: 3M Foamat™ SDC and 3M SaniFoam™ SDC. Each type of foam can substitute for soil cover in daily applications. In both cases, foam is produced by combining water, air, an aqueous surfactant solution and a stabilizing resin. This combination of materials exits from a spray nozzle to give the desired foam material on the landfill surface. Equipment has been developed to apply the materials in an efficient and effective manner through either pull-behind spray bar units or hand-held spray devices.

While both foam systems are effective replacements for soil as daily cover, they are based on different polymeric resin systems and have different physical appearance. They also require different equipment and handling procedures. We will describe the systems one at a time.

3M Foamat SDC -- There are two components (in addition to water and air) which make up this system. FC-9400 polyurethane resin and FC-9401, the surfactant/catalyst solution. This system has been designed for use with the Foamat foam Cart. The resin is provided in a closed-head 55 gal drum and material is pumped directly from the container. The FC-9401 is provided as a concentrate in closed-head 5 gal. pails and is diluted with water for use.

The gellation rate of the foam is controlled by the concentration of foamer used. The recommended range of foamer solution per hundred gallons of water may range from 10 to 16 gal. depending on such things as temperature and water hardness. FC-9400 will react with ambient moisture on prolonged exposure, but has greater than 1 year shelf-life when stored in its original container in relatively dry conditions at temperatures less than 100°F.

The FC-9401 foamer is a concentrated solution of the active ingredients in water. When the Foamat™ system is used, the foam is dispensed from each of the six nozzles at a rate of 10 gal/min. The foam expansion is typically 20-25. The six nozzles will give a spray width of 12-15 ft. and when the cart is pulled over the workface at 1.0 to 1.5 ft./sec. , the foam depth is about 3-4 inches. This foam depth is adequate to cover moderate to well-compacted refuse.

Environmental Information:

Extensive environmental testing has been done to review the potential impact of the foam products on the landfill and surrounding environment as well as to monitor the effectiveness of the product for its intended use. Leachate testing has shown that very little material leaches from cured foam and that which does has no adverse environmental impact. Animal testing has also shown the material to be non-hazardous. The results of this testing are available to interested persons. With regard to product utility, tests have shown the product to be effective in controlling litter, odors and vectors. Other tests have shown that the material provides protection against the infiltration of rainwater into the refuse and that this synthetic daily cover is non-flammable and does not add to the inherent fire hazard of the landfill. These are very important considerations when using a daily cover material. Again, specific information on methods and results can be made available.

The Foamat™ Cart is designed to be towed with normal landfill equipment such as a D-6 to D-8 Caterpillar. In daily operation, the unit is filled and prepped in the morning and foaming is done in the afternoon. Experience has shown that a properly maintained cart requires about 1-2 hrs./day for filling, cleaning and general maintenance. The equipment has several built-in features for ease of use. These include a drum hoist to change barrels of FC-9400, an hydraulic jack to aid in moving and handling the cart and a bottom-fill system to mix in FC-9401. Foaming and flushing are controlled by the driver of the tow vehicle and in many cases the operation involves only one person. Experience has shown that it takes about 20-30 min. to cover a workface of 15,000 sq.ft. This is normally quicker than it would take to cover a similar area with soil at the end of each workday.The foam cover does not require removal the next morning and compacts under the next day's waste, thus saving valuable landfill air space.

The major difference between Foamat™ and SaniFoam™ SDC from the standpoint of the user tends to be esthetics. The Foamat® material forms a dense transparent membrane as the water in the foam evaporates. Although this membrane continues to function effectively as daily cover, some landfill operators and inspectors prefer a higher level of opacity of the foam cover. For those operators the SaniFoam™ SDC is the preferred product.

The following information describes the 3M SaniFoam™ SDC system including materials and equipment. There are many similarities between the foam systems particularly in terms of their use. The major differences are related to the type of polymeric resin employed to produce the foam and also some differences in the type of equipment used to apply the foam. The main components of the SaniFoam™ SDC system are FC-4200 resin and the FC-4201 foamer solution.

FC-4200 is a solution of a urea-formaldehyde prepolymer. This material is a very low viscosity, water-soluble resin which when combined with FC-4201 forms a highly crosslinked matrix which provides the foam stabilization. FC-4200 is supplied normally in 55 gal. closed head drums which is pumped from the drum into the resin tank on the application equipment without dilution. At large user sites, the FC-4200 is supplied and stored in bulk containers. The resin is pumped directly from the storage container into the foam trailer. The FC-4200 has a shelf life of approximately 90 days.

FC-4201 is a foamer solution for FC-4200. This material generates the foam structure and is acidic and catalyzes the FC-4200 crosslinking process. The FC-4201 is normally supplied in 55 gal drums and is diluted at the rate of twenty to one one with water in the foamer tank.

A "drum set" which is one drum of resin and 2.5 gal of foamer will cover about 2000 sq.ft. with 1-2 inches of foam. The strength and opacity of the SaniFoam™ SDC system provides for very effective cover.

Many tests have been done to verify the environmental compatibility of the SaniFoam system. Levels of free formaldehyde, are extremely low in the cured resin solution and the foam. The extraction tests show that there is almost no detectable level of any of the SaniFoam resin components present in the leachate. The foamer material which is a special surfactant, is very biodegradable and compatible with the landfill environment. Tests for system efficacy have shown that the SaniFoam blanket provides excellent protection as daily cover on the landfill. As the material dries, it maintains its original appearance and this feature is desired by many of the landfill operators. Details of the test methods and results on this product to determine environmental suitability can be made available to interested parties.

There is a wide choice of equipment available to users of the 3M SaniFoam™ SDC system. The equipment ranges from relatively small and portable handline units to large, pull-behind spray bar trailers for high-volume landfills. All of the units work on the same principle to produce stabilized foam. The aqueous FC-4201 foamer solution is pumped or forced by compressed air through a bead chamber where it is combined with air to produce foam. The foam is then delivered to the nozzle where it is mixed with the stabilizing resin before ejection to the surface. The material begins to cure to produce the stabilized foam immediately and its stabilization is normally complete within 10 min. The stabilized foam is a fluffy white material which is flexible and has good adhesion to all surfaces on the landfill including vertical surfaces. In a typical landfill application when a pull behind unit is used, touchup is done if necessary by using a hand line available on all SaniFoam™ SDC equipment. Many users find it advantageous to use the hand line simultaneously with the spray bar. All application units have a hot water flush system to clean the nozzles after use. They also have enclosures for the resin and foamer tanks in order to allow use of the equipment in cold weather. 3M provides technical service assistance to users of all equipment from startup through normal application.

III. Regulatory concerns:

The use of foam for daily cover falls under the jurisdiction of regulatory agencies at the state and local level. The specific regulations differ from locality to locality. Normally, approval to evaluate and/or use foam as synthetic daily cover comes only after negotiations with several agencies. Typically, the local agencies have required a testing period in order to evaluate the product for efficacy and environmental impact and equivalency to soil in meeting the performance criteria.

It is extremely important that regulatory agencies be apprised by the suppliers of the daily cover alternate products about the benefits and disadvantages of their cover material relative to traditional soil. This is true because there are occasions where landfill economics and operational practices might compel an operator to use an inappropriate material such as a fabric or sludge simply because there is a perception that the workface is covered adequately with little thought given to the long range engineering implications such as impact on leachate quality and quantity and air emissions upon removal together with the inherent fire hazards on the landfill.

Reputable providers of cover material should have the same concerns that are expressed by regulators.

Regulators should expect that providers of alternative cover materials have the type of documentation that indicates the efficacy of the product to meet or exceed the requirements of daily cover for landfills while having overall environmental acceptance for landfill use.

IV. Landfill Requirements

The landfill is required to have certain facilities in order to effectively use the stabilized foam systems. Normally a landfill will already have these facilities in place. Occasionally, a landfill is required to invest in additional facilities. The major requirements are:

- Adequate water supply to fill the unit efficiently– about 10 gpm minimum
- Inside storage of foam materials and equipment in cold weather to prevent freezing.
- An area suitable for daily preparation and routine maintenance of the unit.

As indicated, 3M provides all training ,materials and service to assure high quality, dependable daily cover for the applicator.

V. Actual landfill experience

The use of stabilized foam as alternative daily cover has been studied and approved on landfills both in this country and in Europe. Several slides demonstrating the use of the stabilized foam materials will be shown at the time this paper is presented.

In the majority of cases, evaluation of the installation and performance of the stabilized foam cover was done by an independent consulting engineering firm. Their reports will be highlighted in this section of the presentation.

A STUDY ON LEACHATE TREATMENT BY MEANS OF FENTON METHOD

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

A STUDY ON LEACHATE TREATMENT BY MEANS OF FENTON METHOD

ABSTRACT

During the sanitary landfill period, the COD value of leachate can usually exceed 10,000 or 20,000 mg/l. After aerobic or anaerobic biological treatment, however, the residual COD is still up to thousands and the effluent remains dark brown. In convention, COD and color are removed by chemical coagulation followed by carbon adsorption. But, even if a huge coagulant dosage is used, the COD removal efficiency is very low and there will be a lot of sludge to be handled.

The Fenton method, a chemical oxidation, applies hydrogen peroxide as an oxidizing agent whose reaction is accelerated by ferrous sulfate. It has been proved that the Fenton method can break some recalcitrant organics effectively. This method is thus employed to treat the leachate after the activated sludge treatment, in order to find out the proper chemical dosage and operation conditions.

The results are: (1) It achieves lower COD and clearer supernatant than the coagulation method does. (2) The best ratio of H_2O_2 to FeSO is between 0.5 and 0.8. (3) To reach 70% COD removal efficiency (the final COD value 400-500 mg/l), it needs 0.3-0.5 g H_2O_2/g COD removed, and the more H_2O_2 dosage is added, the better COD can be removed. (4) The proper final pH is between 3 and 4.

1. Introduction

Nowadays the landfill of a considerably large quantity of refuse entails problems of leachate. Generally, biological treatment is utilized to lower the concentration of organics in refuse leachate. But the ability of biological treatment is limited, especially when confronted with the low biodegradable organics. After the phase of biological treatment, it is thus necessary to proceed to chemical coagulation in addition to the operation of filtration and/or adsorption, so that the treated water quality may reach the effluent standards. However, chemical coagulation is not good enough for dissolved COD removal; it will produce a great deal of chemical sludge to be handled.[1] This study employs the Fenton method to solve the problems of refuse leachate that has undergone activated sludge treatment, such as the low biodegradable organics which caused high COD and color.

The Fenton method, a chemical oxidation, uses hydrogen peroxide as an oxidizing agent whose reaction is accelereated by Fe^{2+}. In 1860, Schonbein found that the oxidation of iodide ion by means of hydrogen peroxide is markedly accelerated by iron salts. And, in 1894, Fenton discovered that a mixture of a ferrous salt and hydrogen peroxide could oxidize many hydroxylic organic compounds, and that the mixture possessed potent oxidizing properties not present in the separate reagents.[2] Hereafter the Fenton method has been explored on and off.

2. Background

Hydrogen peroxide was found by Thenard in 1818 and manufactured for industry at the end of the nineteenth century. During World War II, because it became the liquid fuel to promote equipment, its production was rapidly increased. The melting point of hydrogen peroxide is at -0.41℃, liquid at normal temperature, and its boiling-point at 150.2℃. At 25℃, it becomes viscous liquid with density of 1.4425 g/ml, and can be mixed up with water. On the market, its mixing rate is from 3% to 90%, weak acid, and the specific conductivity is 5×10^{-7} $ohm^{-1}cm^{-1}$. The reaction of hydrogen peroxide itself is very slow. To accelerate the ability of hydrogen peroxide, it needs metal ions such as Fe, Cu, V, Cr and Mn, or materials with rough surface such as zeolite and activated carbon, high pH and radiation (short-wave ultraviolet rays). [3] The common oxidizing agents used for chemical treatment of refuse leachate include ozone, chlorine, hypochlorite, hydrogen peroxide, and so on. The installation of ozone costs much and cannot remove COD in an efficient way. Both chlorine and hypochlorite have weak oxidation and may bring forth halogenated compounds. By contrast, hydrogen peroxide is cheaper, safe, and without bad consequences. When combined with Fe^{2+}, the oxidation of hydrogen peroxide will be strengthened. Some experiments have indicated that the Fenton method is effective on the decomposition of ABS, phenol, etc.[4] Besides, in Japan

the study of various organic compounds applies the Fenton method under the following conditions:
$H_2O_2/COD = 1.0$, $H_2O_2/FeSO_4 = 5.0$ (mole rate), pH = 4, and one hour's reacting time. COD removal efficiency for alcohols, acids, aldehydes, and ketones are 30-40%, 30-50%, 30-50%, and 10-40%, respectively. As for dicarboxylic acid, COD removal is around 60%, for some unsaturated compounds up to 90%, and for the decomposition of aromatic compounds is from 70% to 90%.[5] Some documents have proved that through the Fenton method TOC removal can be more than 75% for low biodegradable organics, such as Urea resin, dibromsalicil, POENPE (n = 15).[6] Further, Takashi Korenaga employs the Fenton method to treat the photographic wastewater, whose COD removal is decreased from 62,300 mg/l to 291 mg/l and treatment efficiency is as high as 99.5%.[7]
The mechanism of the Fenton method is as follows:[8]

$$Fe^{2+} + H_2O_2 \rightarrow (FeOH)^{2+} + \cdot OH \rightarrow Fe^{3+} + \cdot OH + OH^- \quad (1)$$

$$\cdot OH + Fe^{2+} \rightarrow (FeOH)^{2+} \rightarrow Fe^{3+} + OH^- \quad (2)$$

$$\cdot OH + H_2O_2 \rightarrow H_2O + \cdot O_2H \quad (3)$$

$$\cdot O_2H \leftrightarrow \cdot O_2^- + H^+ \quad (4)$$

$$\cdot O_2^- + H_2O_2 \rightarrow O_2 + \cdot OH + OH^- \quad (5)$$

$$Fe^{3+} + H_2O_2 \rightarrow Fe^{2+} + \cdot O_2H + H^+ \quad (6)$$

$$Fe^{3+} + \cdot O_2^- \rightarrow Fe^{2+} + O_2 \quad (7)$$

(i) When $H_2O_2 < 10^{-4}$M and the initial concentration of Fe^{2+} is low, the main reaction formulas are (1) and (2).

(ii) With the increasing proportion of H_2O_2 to Fe^{2+}, $\cdot OH$ radical will strengthen its competence to lay aside Formula (2). It results in $\cdot O_2H$ radical, that is, the reaction of (4), (5) and (7).

$$\cdot O_2H \rightarrow \cdot O_2^- + H^+ \quad (4)$$

$$\cdot O_2^- + H_2O_2 \rightarrow O_2 + \cdot OH + OH^- \quad (5)$$

$$Fe^{3+} + \cdot O_2^- \rightarrow Fe^{2+} + O_2 \quad (7)$$

The above reaction will release Oxygen to increase the dissolved oxygen in wastewater.

(iii) When the organic monomers exist,

$\cdot OH + CH_2{=}CHX \rightarrow HO\cdot CH_2\text{-}CHX$ --- polymers

or $\cdot OH + RH \rightarrow H_2O + R\cdot$

$R\cdot + CH_2{=}CHX \rightarrow R\cdot CH_2\text{-}CHX$

$R\cdot CH_2\text{-}CHX + CH_2{=}CHX \rightarrow R\cdot CH_2\cdot CHX\text{-}CH_2.CHX$ --- polymers

the polymerization occurs.

(iv) When there exist the organics, the reaction is as the following:

$H_2A + \cdot OH \rightarrow HA\cdot + H_2O$

$HA\cdot + Fe^{3+} \rightarrow HA^+ + Fe^{2+}$

$HA^+ + OH^- \rightarrow HAOH$ (primary product)

$HAOH + \cdot OH \rightarrow HOA\cdot + H_2O$

$HOA\cdot + Fe^{3+} \rightarrow Fe^{2+} + H^+ + AO$ (secondary product)

(v) When oxygen exists, the reaction of the organics is as follows:

$H_2A + \cdot OH \rightarrow HA\cdot + H_2O$

$HA\cdot + O_2 \rightarrow HAO_2$

$HAO_2 + Fe^{2+} + H^+ \rightarrow HAO_2H + Fe^{3+}$

$HAO_2 + H_2A \rightarrow HAO_2H + HA\cdot$

$HAO_2H + Fe^{2+} \rightarrow HOA\cdot + Fe^{3+} + OH^-$

$HOA\cdot + H_2A \rightarrow HAOH + HA\cdot$

$HOA\cdot + H^+ + Fe^{2+} \rightarrow HAOH + Fe^{3+}$

In the reaction process, the free radicals of $\cdot OH$ consisting of unpaired electrons are full of activating and oxidizing ability. The oxidation is even stronger than that of ozone, and can decompose high molecualr weight organics into low molecules. Thus, as has been confirmed, after applying the Fenton method, BOD is increased and the proportion of BOD to COD raises.[9] Such a decomposition can remove the color and COD of the low biodegradable organics. Besides the free radicals of $\cdot OH$ and $\cdot O_2H$, Fe^{2+} is oxidized into Fe^{3+} and $Fe(OH)^{2+}$, which results in coagulation and, plus the organic monomers, polymerization. To sum up, the Fenton method retains the double effect of oxidation and coagulation.

Judging from the above functioning structure, in the reaction process the Fenton method will not produce troublesome matters. With the adding of reagents, this method does not increase the total solids and chemical sludge, while chemical coagulants $Al_2(SO_4)_3$ and $Ca(OH)_2$ do. Neither does it encounter such problems as the hardness of $Ca(OH)_2$ may augment and the chloride of $FeCl_3$ increases.[1] According to these contrasts, the Fenton method can avoid producing troublesome matters in effluent. Though the adding of Fe^{2+} can increase the amount of iron ion in the system, during the reaction process the ferrous ion is gradually oxidized into Fe^{3+}, coagulated and removed as precipitate. Moreover, the sedimentary sludge containing a great deal of iron ion may be recovered and utilized again by acidification,[9] and the remaining hydrogen peroxide will react little by little to increase dissolved oxygen in wastewater. From these viewpoints, the Fenton method is economical as well as efficient.

3. Methods

The sample for our experiment is the leachate from the sanitary landfill site of Futekeng in Taipei City, which was opened on August 29, 1985. A semi-aerobic method was designed as the disposing means but, after a short period, it turned out to be anaerobic. The landfill area is 37 hectares, and its capacity is estimated to be 8 million cu metres. The site is paved with HDPE liners and has a leachate-collecting system. Up to now, it has practised landfill for five years. The waste organics are decomposed by micro-organism within the landfill layers. Of the leachate, COD is lowered from the highest amount 45,700 mg/l to the present amount between 3,000 and 4,000 mg/l; BOD decreases from 39,520 to 1,000 or so; the concentration of ammonia nitrogen is raised from 550 mg/l to 2,500mg/l; pH rises above 8.0; and a great quantity of methane gas is produced. It shows that the acid fermentation stage is transformed into the methane generation stage. The way of treating leachate is an extended activated sludge process, followed by chemical coagulation. Nevertheless, as the landfill period lengthens, the color matters of the recalcitrant organics in the leachate can not be effectively removed by activated sludge process. Though BOD of effluent may decrease to be below 100 mg/l, COD is still as high as 2,000 mg/l and visibility is bad, between 4 and 7 cm. When $FeCl_3$ is used as a coagulant, it needs reagents of 1,200 mg/l to reach the visibility of 37 cm, sludge volume 300 ml/l, COD removal efficiency 50% (1,273mg/l). If the amount of $FeCl_3$ is increased, visibility will be worse and COD cannot be improved.[10] Contrasting the advantages of the Fenton method with the defects of the usual coagulatns in chemical coagulation, this study has carried out some preliminary experiments and proved the distinguished efficiency of the Fenton method.[11] Thus, we continued to explore further the wastewater with COD and color that cannot be removed by biological treatment.

The above-mentioned preliminary experiments have studied the operating conditions of pH, the mixing time, the sedimentation time, and the relationship between visibility and transmittance, and found out the proper scope of operation. The management conditions adopted by this paper are as follows:

(1) pH control is at 6.0.

When $FeSO_4$ = 1,000 mg/l and H_2O_2 = 750 mg/l, the treated water will be under perfect control if pH < 7.7 or pH > 12. when the concentration of FeSO is lowered, in the beginning pH control must be under 6. Therefore this study decides the initial pH control to be 6.0.

(2) Transmittance testing adopted wave length is 656 nm.

Use Spectrophotometer to detect the absorbance of samples and treated water from 400 nm to 700 nm. A peak appears around 656 nm, so the wave is fixed at 656 nm.

(3) The rapid mixing time of the experiment is 10 min.

Compare COD of the experiment during the rapid mixing time from 10 min to 60 min. After the reacting time lasts for 10 minutes, COD of the treating solution does not show much change. Thus the reaction is fixed at 10 min.

(4) Substitute transmittance for visibility.

To analyze visibility needs the treated sample more than 200 ml, while transmittance analysis takes only 10 ml. To save the sample, the relationship between transmittance and visibility should be first examined. When transmittance is over 80%, visibility can reach above 15 cm; if over 90%, more than 25 cm.

4. Results and Discussions

(1) Effects of the concentration of $FeSO_4$:

According to Figure 1, when the dosage of H_2O_2 is fixed at 500 mg/l, that of FeSO is increased ($H_2O_2/FeSO_4$ decreased) and COD removal rises. When $H_2O_2/FeSO_4$ = 0.59, COD removal is at its best. When $H_2O_2/FeSO_4$ is lowered to less than 0.45, that is, the adding of $FeSO_4$ reashes more than 1,100 mg/l, COD removal decreases and remains in a stable state. Then the adding of $FeSO_4$ should be confined in a proper scope. If exceeding the range, the treatment effect will be worse. Judging from the above reaction control, when the concentration of Fe^{3+} is too high the chain reaction will be restrained, and that is similar to the phenomenon of chemical coagulation.

(2) Effects of the dosage of H_2O_2:

Fix the dosage of FeSO at 750 mg/l. According to Figure 2, COD removal is raised as the dosage of H_2O_2 is increased. It shows that the oxidation of organics is in direct proportion to the dosage of H_2O_2.

(3) The dosage of H_2O_2 and FeSO4 and their effects on COD removal:

According to Figures 1 and 2, the suitable proportions are 0.59 and 0.73, by which the dosage of H_2O_2 and $FeSO_4$ is changed. In figures 3 and 4, when $H_2O_2/FeSO_4$ = 0.59, it needs at least 0.23 g H_2O_2/g COD removed; hereupon, COD removal reaches only 45%. If the dosage is added up to 0.367 g H_2O_2/g COD removed, COD removal can reach 70.5%. But, afterwards COD removal does not speed up with the adding of H_2O_2. This point may be named the most economical point of adding reagents. When $H_2O_2/FeSO_4$ = 0.73, at the most economical point the needed amount of H_2O_2 is 0.522 g.

According to the most economical point of adding reagents, the dosage of FeSO has great effect on COD removal. When $H_2O_2/FeSO_4$ = 0.59, it needs only 0.367 g H_2O_2/g COD removed; if $H_2O_2/FeSO_4$ = 0.73, it needs 0.522 g. Therefore, the more dosage of $FeSO_4$ is added, the less amount of H_2O_2 is needed. The Fenton method becomes more economical.

(4) Effects of oxidation reduction potential:

Compare the ORP curve with COD removal. When the rising of COD removal becomes slow and even, so does the ORP, as shown in Figures 5 and 6. The testing of ORP may be regarded as the guide of treatment. As for this point, it needs further survey.

(5) The dosage effects of the final pH value:

As the dosage of $FeSO_4$ and H_2O_2 is increased, pH is decreased. The more dosage of $FeSO_4$ is added, the more quickly pH drops. In Figures 5 and 6, the test of pH stops when the dosage of H_2O_2 is up to more than 1,500 mg/l, because the high concentration of dissolved oxygen reveals the violent reaction. To protect the pH electrodes from damage, the test of pH is ommitted.

(6) Effects of dissolved oxygen:

When the dosage of H_2O_2 is under 1,000 mg/l, there is not much change in dissolved oxygen (less than 10 mg/l). When the adding of H_2O_2 is up to 3,000 mg/l, the dissolved oxygen will rapidly increase and reach 40 mg/l. It is discovered that when the dissolved oxygen begins to drop, the most economical point of COD removal is obtained. In other words, when COD removal becomes most effective, H_2O_2 is exhausted by organics and cannot be transformed into DO. But, when COD removal efficiency is not high, the remaining H_2O_2 is transformed into DO and becomes a waste. The DO value can thus be used to judge the treating efficiency. Then, the DO , ORP and pH values are guides for the Fenton method.

(7) The effects of H_2O_2 on COD:

H_2O_2 is an oxidizing agent, whose remaining dosage, if much, will interfere COD and makes the COD testing value higher than the actual. It is reported that H_2O_2 can be removed by $KMnO_4$,[8] but the equivalent point is hard to recognize and the organics will be oxidized by the overdosed oxidant simultaneously. So, it is not a reasonable method. The interference caused by H_2O_2 is not yet solved. However, it is understood that COD value of the sample is less than the tested one.

(8) Effects on transmittance:

The Fenton method is good at color removal. When the dosage of H_2O_2 is 300 mg/l and that of $FeSO_4$ is 508 mg/l or 411 mg/l, transmittance is above 90%. When using $FeCl_3$ and alum, though their high concentration can achieve the wonderful effect of decolorization, they cannot remove COD effectively. The Fenton method, due to its double effect of coagulation and chemical oxidation, can reach the COD removal efficiency more than 70%.

(9) Effects of the final pH control on the Fenton method:

Figure 7 shows the initial pH fixed at 6, and the relationship between the final pH and the transmittance of supernantent obtained when the concentration of H_2O_2 and $FeSO_4$ is changed. From the Figure, it is discovered that when the final pH is below 4.5, transmittance can reach above 92%. Figure 8 indicateds the effect of the final pH on COD removal. When the final pH is less than 4, COD removal can be more than 60%; if lowered to 3.33, COD removal can be above 70%. According to these two figures, suppose the initial pH control is adjusted by acid to be 6, and the final pH, decreased by the Fenton agent , reaches 3.33, COD removal will be more than 70%, and transmittance above 92%. The actual experiment has proved the effect, shown in Figure 9. In Figure 9, the management conditions are: initial pH is 6, the concentration of $FeSO_4$ is 600 mg/l and 800 mg/l, respectively, that of H_2O_2 is changed, and the reacting time is 10 minutes, in order that the final pH is less than 4. Under these conditions, the transmittance of the treated water can reach above 92%. As for the COD removal, if $FeSO_4$ = 600 mg/l, the final pH = 3.42, and H_2O_2 = 900 mg/l, it can exceed 71.4%; if $FeSO_4$ = 800 mg/l, the final pH = 3.33, and H_2O_2 = 780 mg/l, it can be 70.6%. In this experiment, the final pH control can make sure the definite COD removal efficiency. (It should be noticed as well that the initial pH is fixed at 6. If it is 5, 4, or 3, the effect of COD removal will not be certain; as Table 1 shows.) It is clear that though the final pH is important, the adding of $FeSO_4$ and H_2O_2 is also a pivotal point.

5. Conclusion

(1) When the Fenton method is employed to treat the leachate that contains low biodegradable organics after biological treatment, the concentration of $FeSO_4$ plays an important role on COD removal. When the concentration of $FeSO_4$ is too low, even if that of H_2O_2 is high, the COD removal effect is not good. Besides, the cost of H_2O_2 is higher than that of $FeSO_4$. To be economical, the proper dosage of $FeSO_4$ should be first tested with the small amount of H_2O_2, and later add the dosage of H_2O_2 according to the COD removal rate.

(2) When $H_2O_2/FeSO_4$ = 0.59, the amount of H_2O_2 required to remove COD per g is between 0.3 g and 0.5 g; if $H_2O_2/FeSO_4$ = 0.73, the required amount is from 0.4 g to 0.6 g.

(3) In search of the most suitable dosage, ORP and dissolved oxygen can be the references.

(4) The initial pH control is very important. For our study of the leachate, the initial pH control is from 6 to 4, and the final pH is between 3 and 4.

(5) The quantity of sludge resulting from the Fenton method is related to the dosage of H_2O_2. In general, the sludge is 1/4 of the total volume. If the dosage of H_2O_2 is

increased, the sludge decreases. Nevertheless, if the dosage of H_2O_2 is too high and the retention time of sludge is too long, the reaction within the sludge will accumulate a lot of bubbles to make the sludge float.

6. Acknowledgments:

The author is grateful to the National Science Council of the Republic of China for the grants to this study. The author also wishes to thank his student Fang-Shu Chang, a candidate for MS, for her executing the experiments of this study.

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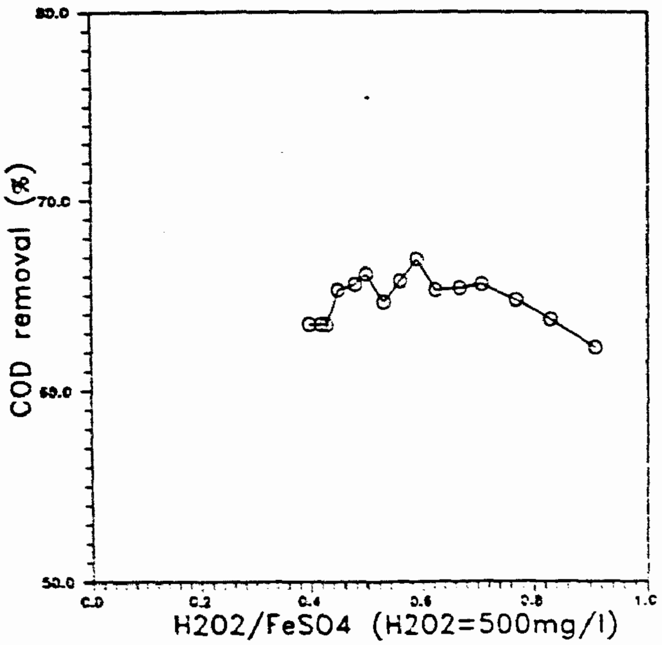

Figure 1. Diverse dosage of $FeSO_4$ VS COD removal.

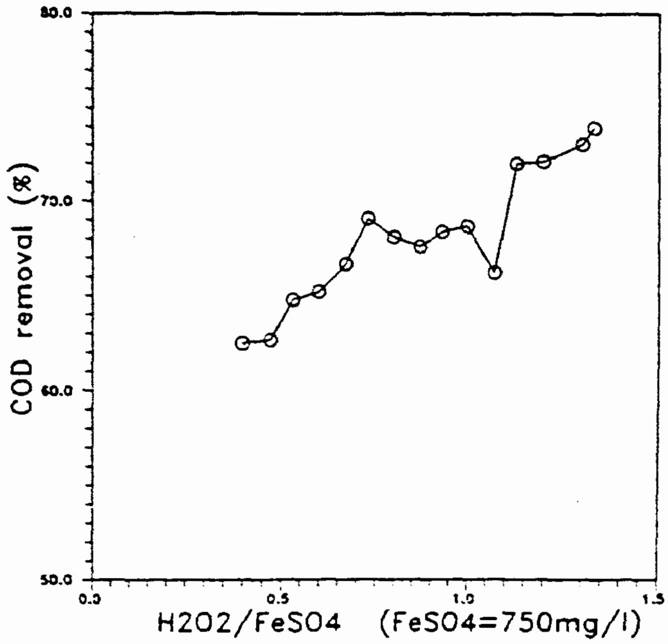

Figure 2. Diverse dosage of H_2O_2 VS COD removal.

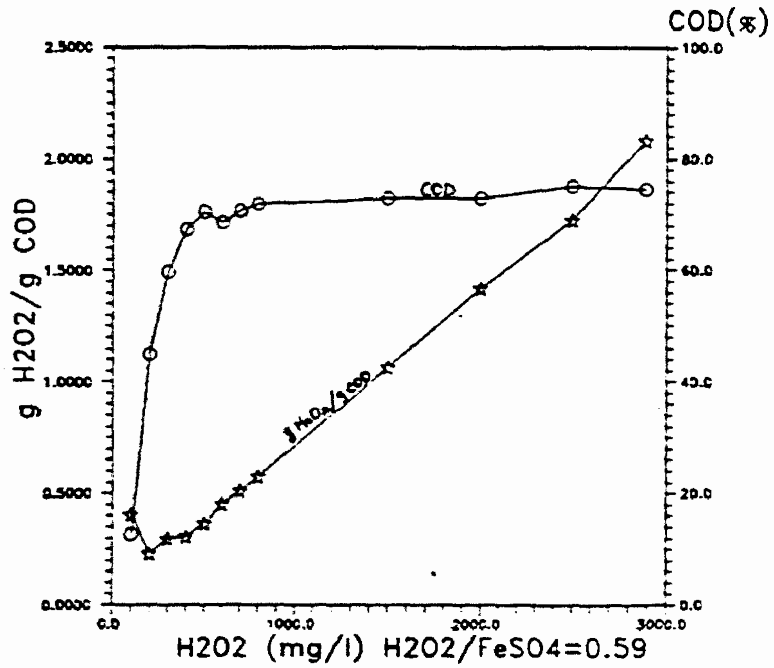

Figure 3. Under the condition $H_2O_2/FeSO_4$ = 0.59 the required dosage of H_2O_2 to remove COD per g and COD removal efficiency.

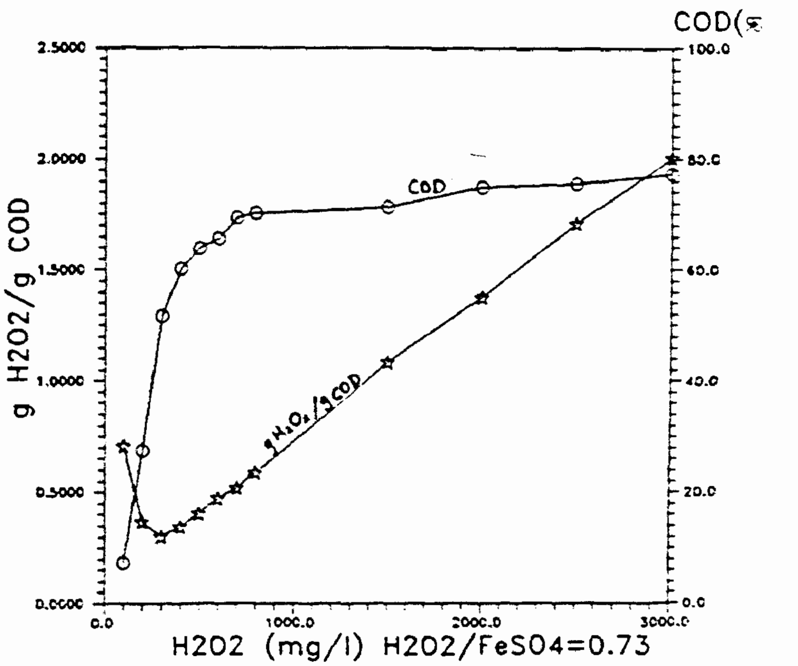

Figure 4. Under the condition $H_2O_2/FeSO_4$ = 0.73 the required dosage of H_2O_2 to remove COD per g and COD removal efficiency.

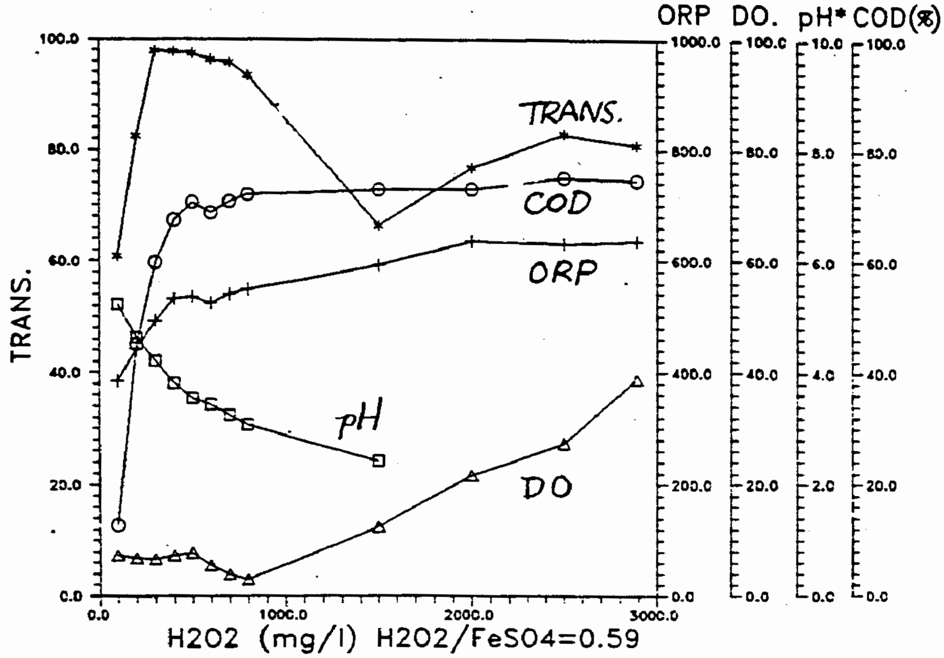

Figure 5. With the chang of dosage, the relationship between COD and TRANS., ORP, DO., and the final pH value, respectivly.

($H_2O_2/FeSO_4$ = 0.59)

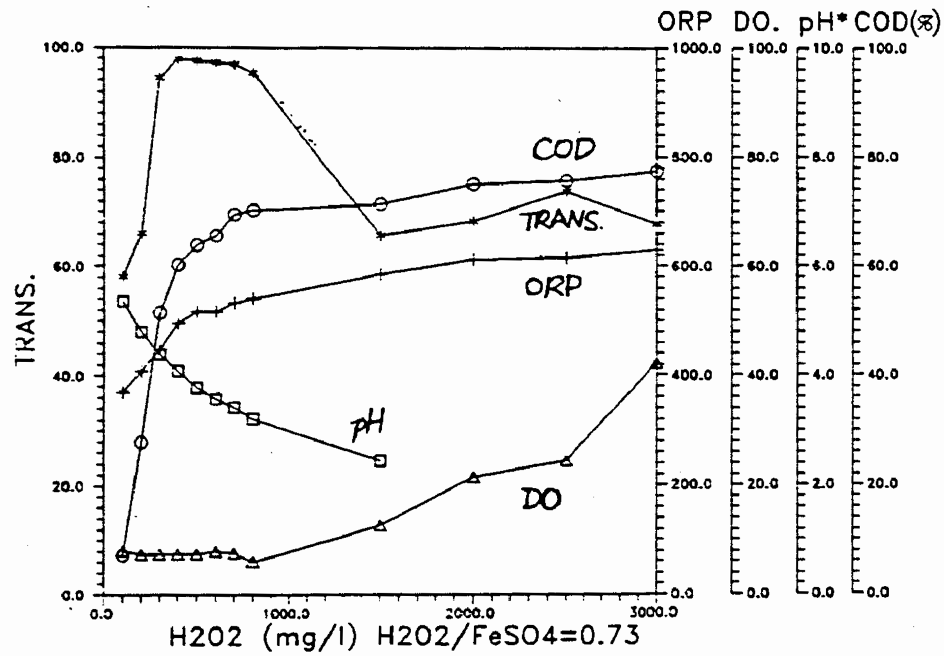

Figure 6. With the chang of dosage, the relationship between COD and TRANS., ORP, DO., and the final pH value, respectivly.

($H_2O_2/FeSO_4$ = 0.73)

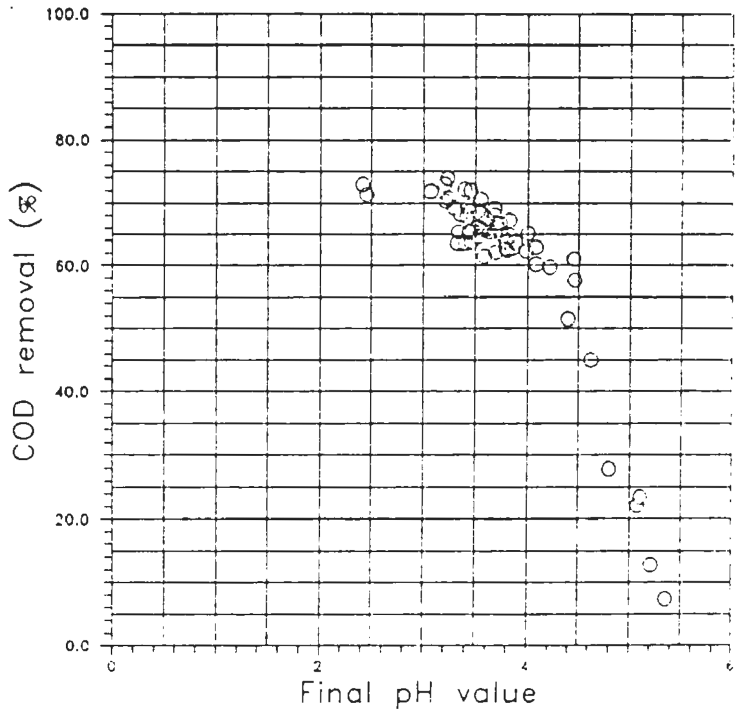

Figure 7. The final pH value VS transmittance.

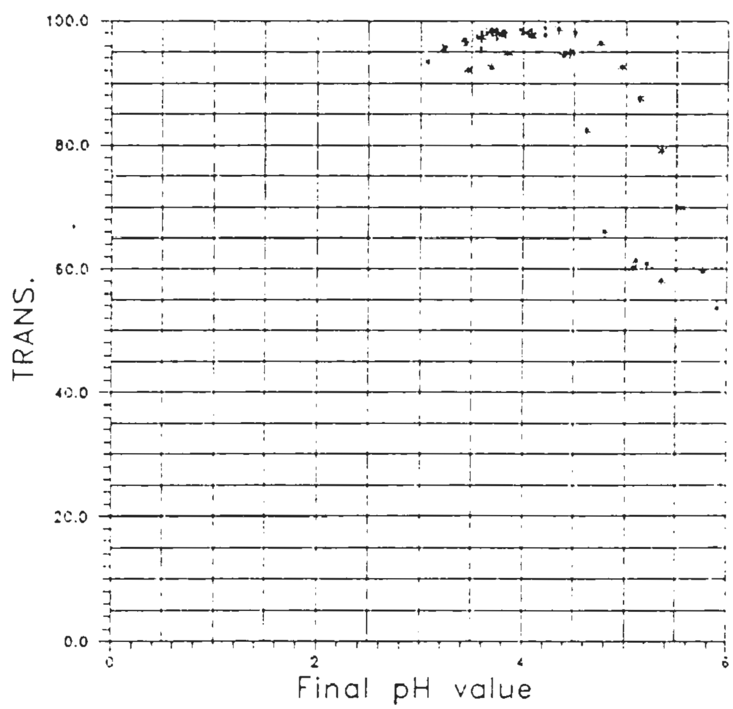

Figure 8. The final pH VS COD removal.

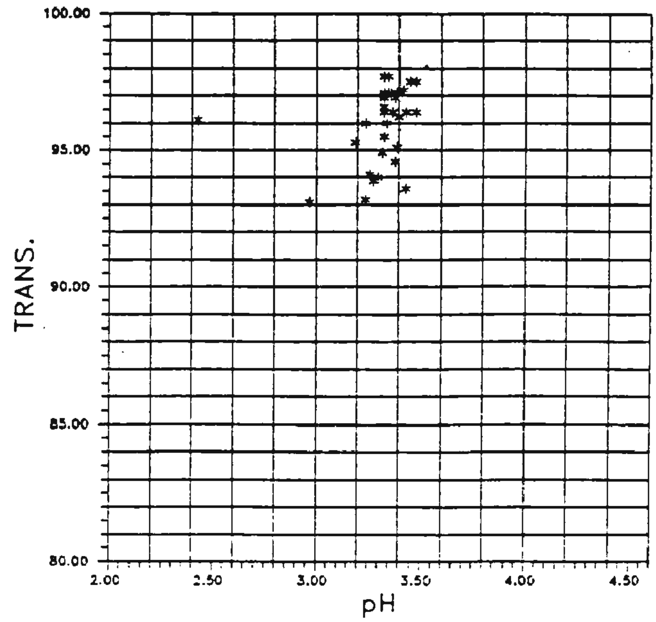

Figure 9. Under the control of the final pH, pH value VS transmittance.

Table 1. The control of initial and final pH values influences COD removal and transmittance.

H_2O_2 6mg/1)	$FeSO_4$ (mg/1)	inital pH	final pH	TRANS. %	COD removal
450	600	4	3.26	94.1	63.7
600	600	4.5	3.33	96.4	67.8
705	600	5	3.36	97.1	70.2
750	600	5	3.33	97.0	70.3
825	600	5.5	3.35	97.1	68.7
900	600	6	3.42	97.2	71.4
345	800	4	3.30	94.0	55.5
510	800	4.5	3.33	95.5	59.7
645	800	5	3.33	96.9	68.5
705	800	5.5	3.33	97.1	68.0
780	800	6	3.33	97.7	70.6

URBAN LANDFILL SITING STUDIES: A CASE HISTORY

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13 - 16, 1990

Otto von Bismarck, the 19th Century "Iron Chancellor" of Germany, said there are two things people should never have to see being made: sausages and laws. A third, and current, "never" could also be added: deciding a landfill site for a metropolitan area. As Bismarck suggested for the first two, none of these processes are "picture pretty." And in the case of landfill siting, there probably isn't a less attractive but critically key issue facing urbanized areas.

Montgomery County (Maryland) needs a new landfill to serve its 700,000 plus residents. The county completed a 15 month, $525,000 landfill site study that led to selection of one site by the County Council in April. The site will undergo detailed engineering studies and work leading to a sanitary landfill permit. The Council also chose one backup site if significant problems arise at the selected site during the permit application phase - the county can quickly switch to developing the backup site. The earliest projected opening for the new landfill is autumn 1993.

We faced a number of challenges during the study - some conventional, others not so. These challenges included:

- o landfill siting in a high growth county
- o land use limitations
- o public opposition
- o relative scarcity of sites

As with any challenge, there were opportunties, including:

- o involvement by elected officials
- o mitigation of land use limitations
- o public participation
- o a balanced approach to the study

WASTE MANAGEMENT PROGRAM

If this conference were held 199 years ago, we'd be sitting in Montgomery County. The Maryland legislature ceded 36 square miles of the county for the new nation's capital in 1791. The county's population, as well as its geographic area, has changed over time. While I was writing this paper, the nation observed the 125th anniversary of the end of the War between the States. Since several skirmishes were fought in Montgomery, I was curious about the county's population then. Montgomery had about 20,000 residents in 1865 - in 1965, there were about 420,000 residents. From 1965 to present, the county has grown to about 715,000 residents. A recent report by the Greater Washington Research Center showed the Washington area to be the second fastest population growth area in the country. Montgomery led all local jurisdictions in the area, adding about 23,000 residents between 1987 and 1988. From its current population of 715,000, Montgomery is projected to grow to 820,000 residents in the year 2000.

All of these people generate appreciable amounts of municipal solid waste - about 650,000 tons of it in 1989. Using normal compaction rates, this yearly waste, spread over a football field, would rise more than 700 feet. As a comparative reference, the Washington Monument is 555 feet high. Estimates suggest that even at modest growth rates, the County will top one million tons of municipal waste produced in the year 2000.

How to manage this waste becomes the crux. Montgomery has an ambitious integrated solid waste management plan consisting of

- source reduction and recycling,
- combustion, and
- landfilling,

in that order of preference.

The county's mandated goal is to recycle 27% of its waste stream by 1992; we currently recycle about 13%. Recycling progress is evidenced by the county's successful newspaper recycling program; pilot programs for commingled recyclables and yard wastes, leading to phased countywide curbside pickup of recyclables starting this summer; construction of a Materials Processing Facility for recyclables, expected to begin operation in spring 1991; and a nationally recognized program for composting leaves, grass clippings and sludge.

The county and its agent have selected a vendor to construct an 1800 ton per day resource recovery facility. The facility is slated to produce about 40 MW of electricity while reducing the amount of landfill waste by over 70%. We received our approval of a Prevention of Significant Deterioration Source for the facility in April, 1990.

None of these accomplishments, however, dispels the need for landfilling. Landfills are necessary for the disposal of non-recyclables and for disposal of recovery facility ash. In fact, having a landfill is a key element to help secure financing for the recovery facility.

The county currently has one municipal landfill, which began operations in 1982. It had a projected life of 15 years, but reached original estimated capacity in 1989. We got a permit modification to serve disposal needs until August 1990; we then got a permit for a long-term expansion, relying on vertical growth capacity at the site, in February 1990. The projected 23 year expansion hinges on successful recycling and an on-line resource recovery facility; if these elements don't fall in place, we're facing only six or seven useful years.

STUDY HISTORY

When the County Executive and County Council hammered out the integrated waste management plan I noted, they indicated that county government must conduct an urgent site search, land acquisition and site development program to find and prepare a new landfill site. The goal of this program was to open a new landfill as soon as possible so that the current landfill could close. Part of this stemmed from a political commitment elected officials made; part of it stemmed from good planning practices seeking a disposal site in a non-crisis atmosphere; and part of it stemmed to avoid past history. The current study marks the county's third effort in the last 15 years to site a landfill. Each effort met typical siting constraints - costs, technical and environmental issues, and public concerns - but each effort became more difficult because the county was rapidly losing sites large enough and environmentally suitable for a landfill given our rapid urbanization. Between

1978, when the study began leading to the existing landfill, and 1985, 13 of the 22 potential sanitary landfill sites identified in the 1978 study were developed.

Similar circumstances occurred during the current study. One of the sites considered is pegged for residential development; another site is adjacent to a high density development. Even within county government, there were competing interests for the candidate sites. A county agency proposed a golf course on one site. Another agency plans to locate a new detention center on a study site.

Sites for the current study were chosen from those identified in previous county landfill studies. We chose this approach to save time, money, and to hone in on those areas that had been identified as environmentally suitable for a landfill. This process provided a stock of possible sites, resulting in 16 sites for study. In addition, 26 criteria to rate the sites were developed. For practical purposes, these criteria fell into categories assessing costs, environmental and community impact factors. There were 11 cost criteria, and 15 criteria fell in the environmental/community impact category. To produce a few finalist sites, this was the idea - present costs for the appropriate criteria, develop an evaluation matrix for the environmental/community criteria, analyze the data, and make recommendations to the elected officials. Each criterion had equal weight; costs were treated as a lump sum, and environmental/community impact criteria were equal to each other.

The structure of Maryland's solid waste laws is such that each county must have a Comprehensive Solid Waste Management Plan; the structure of the county's solid waste laws is such that the plan and any amendments must originate from the Executive and then be decided by the Council. This occurred for the sites' selection and the rating criteria to evaluate the sites. Having elected officials determine study sites and criteria proved helpful throughout the study. There were two public hearings before sites and criteria were voted on and approved in 1988.

Additionally, most of the candidate sites were in the county's agricultural reserve area. This area, primarily in the western region of the county, consists of about 89,000 acres - approximately 28% of the county's total area. While public facilities can be sited in this reserve, citizen perception seemed to be that public use of this land should be restricted to school or park development only. Site selection in this area was predicated, in part, because the county has a limited amount of industrially zoned land and land zoned for manufacturing use, which are preferable categories for landfill sites. Additionally, several of the sixteen sites ultimately selected for study were on or near rail lines. This was an important consideration, since we plan to rail haul waste in an effort to reduce community impacts.

The study began in January 1989 with a design to winnow the 16 selected sites over at least two study stages, using the defined criteria. The winnowing process was fueled by increasingly detailed data as the study stages progressed. The first study stage used existing data to compare study sites. These data were typically maps, reports, documents from preceding landfill studies and population data, to name a few information sources. Actual on-site investigation and analysis were limited in this stage. The goal was to identify, through sufficient initial analysis, the sites that were obviously less preferable. The remaining sites would undergo more detailed analyses. This stage concluded in May 1989, with six of the 16 sites found unsatisfactory for continued study. Consultants provided a report of their methodology and findings.

The study's second stage occurred between June and December, 1989. Work included on-site or near site hydrogeologic analyses with installation of observation wells, soil permeability analyses and characterization of soil types. Work also included field reconnaissance, detailing environmental features such as presence of historical resources, screening and buffer capabilities, and transportation routes for rail haul, where possible, and for road haul. Costs were produced for applicable criteria; an appraiser prepared preliminary site acquisition costs. Additional published materials were also used in this study stage. Consultants published their findings in a January 1990 report, without site preference recommendations. We wanted the flexibility to make our own recommendations, based on the information provided. From our analyses, two sites seemed to emerge as much stronger candidates than the other eight. Study information was sufficiently detailed to prompt us to recommend one site for the landfill permitting process and the other of the two clear choices as a backup if insurmountable problems arose with the first choice. Recommendations at this stage also had the effect of saving further study costs and mitigating further concerns for a number of affected communities.

The precept of comparing a large set of candidate sites against the same criteria is rooted in a fair approach to siting. Issues like land use and adjacent population are considered, but are equal elements among many and all criteria received equal weight. This approach caused much consternation among the affected communities with significant outpouring of emotion. But to paraphrase Churchill's observaton on democracy, this siting method is the worst possible unless measured against all other methods.

The study did cause a lot of consternation among communities near the sites. There was understandable reluctance on communities' parts to accept the idea a landfill would be sited in their area. Added to that, there were true emotional issues associated with sites. A farm owned within the same family for over 150 years was part of a site. Another site had about 90% of its area dedicated to an environmental land trust. Yet another site was basically comprised of two working farms whose owners recently entered their lands into the county's agricultural preservation program.

There were literally hundreds of letters sent to us during the 15 month study, with what seemed to be an equal number of phone calls. We felt it was important to prove we were listening - we responded to all calls and answered vitually every letter.

We also met with civic and community associations, in the affected communities. The meetings were often emotionally charged. The upside of these meetings was there was an opportunity to talk with community members. The downside was that, because of the nature of the meetings, there was little informational exchange - we didn't take away much information that would help in the study. To remedy this, we formed a landfill working group, consisting of representatives from these community associations and members of some citizen advisory groups. There were 12 members of the working group, which met approximately once a month during summer and autumn, 1989. Members represented communities where study sites were located, as well as members of other county government citizen advisory groups. The working group focused on study criteria and methodology, looking at ways to assure environmental safeguards and mitigate community impacts that a landfill might cause.

The working group was effective - the approaches they suggested for evaluating a number of criteria were incorporated in the study report; members, along with property owners, accompanied staff and consultants during on-site investigations, sharing their knowledge of the sites; and members were liaisons to their community groups, providing assessments of the study.

To offer a concrete example of the group's effectiveness, they suggested a reexamination of the study's land use criterion. This reexamination included provisions for land dedicated to agricultural preservation programs. We agreed this was an important element and used it in our review. This, in part, led to the rejection of the three farming sites just mentioned.

In addition to these elements, we sponsored two public information meetings prior to the County Council public hearings on final site selection. The information meetings allowed citizens to question us about the study report's findings and our recommendations.

The County Executive and County Council maintained an active role in the study. There were numerous discussions with the Executive during the study's progress; he also viewed the sites from the ground and from the air. He met with citizens on the issue and participated in the public hearing process. The Council, in addition to approving candidate sites and rating criteria, held public hearings on the recommended finalist sites and subsequently, a day-long work session, where they decided upon one site for permitting activity, with a backup site if problems occurred with their first choice.

Currently, we're preparing the report required in the first phase of Maryland's landfill permitting process for the selected site. Field work for the next permitting phase has already begun. A successor landfill working group, consisting of citizens near the selected site and members of County advisory groups, will work with us on the project.

The problems encountered in this study will be typical in the future for urbanizing areas. Growth areas face a loss of lands suitable for a landfill; remaining land occurs in areas that the public believes a jurisdiction has committed solely for open space or similar purpose. Public antipathy arises from this perceived incompatibility.

Selection of a study process can also be nettlesome. Our approach to select a relatively large set of candidate sites and narrow them to a few finalist sites through increasingly demanding stages seemed fairest. Admittedly, this approach also disturbs more communities during its process. Despite this, our selected method afforded the best method to choose sites of merit.

THE USE OF GEOSYNTHETICS IN MUNICIPAL SOLID WASTE DISPOSAL FACILITIES

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Presented at the

First U.S. Conference on Municipal Solid Waste Management

June 13-16, 1990

The Use of Geosynthetics in Municipal Solid Waste Disposal Facilities

The use of geosynthetics is increasing in all types of waste management facilities. Their use has been brought about by their ability to outperform soils as barrier, drainage, and filter media; by consistency of material properties over the entire facility; their adaptability to innovative designs; ease of construction; and low cost. Their relative newness in waste management applications, i.e. only 10-20 years field experience, has led to certain technical issues that require additional discussions and perhaps additional research. Two issues receiving recent attention will be briefly discussed in this paper: (1) chemical resistance of the materials and (2) the biological/particulate clogging potential of geosynthetics used in leachate collection systems. For more detail the reader should consult the cited references.

CHEMICAL RESISTANCE

Chemical resistance of geosynthetic materials is essential if they are to perform over the active and post-closure periods of the facility and even beyond. Geosynthetics are being used extensively in hazardous waste management applications. One criterion for approval of geosynthetic use in hazardous waste is passage of EPA Method 9090 chemical compatibility test (1,2). Method 9090 requires that samples of the geosynthetic be evaluated after immersion for periods of 30, 60, 90 and 120 days in the leachate from the waste management facility. Leachate temperatures should be 20°C and 50°C. The immersion vessel should not be made of the same material as the geosynthetic being tested and should not compete with the geosynthetic for potentially aggressive leachate constituents. The vessel should be sealed with no free air space in order to prevent the loss of volatile constituents from the leachate.

An alternative immersion procedure is being developed by ASTM D-35 Committee on Geosynthetics. This ASTM procedure closely follows the procedure of Method 9090 but adds details regarding test conditions and the immersion vessel. This ASTM procedure is under review by the U.S. EPA for acceptance in lieu of portions of Method 9090.

The materials used in constructing municipal solid waste (MSW) disposal facilities must be resistant to generated leachate. However, several technical issues need to be addressed including representative leachate, potentially aggressive constituents in the leachate, and the test method itself.

Representative Leachate

The intent of requiring a representative leachate in a chemical resistance test is to assure that the geosynthetic is exposed to all potentially aggressive constituents that could affect its long-term performance. The leachate samples may be taken from the sump areas for existing landfills. The concern with this approach is whether these samples represent the worst case. It is well known that leachate aggressiveness toward FMLs is the strongest (represents the worst case) early in the life of a landfill (3). Over the life of the landfill the contaminants will be washed out of the landfill and the leachate quality will improve. If the "representative" sample of leachate is removed for compatibility testing from the landfill late in its life there is a good chance that it will not represent the worst case. On the other hand, if the "representative" sample of leachate is removed early in the life of the landfill, it may be several years before the geosynthetics tested for compatibility are actually installed. Due to the rapid improvements in geosynthetic quality there is a good chance that the geosynthetic tested will not be of the same composition as the material to be installed. The latter problem faces many owner/operators. The Agency has taken the position that the "fingerprint" or chemical makeup of the geosynthetic evaluated for chemical resistance should be essentially the same as the material installed (2).

Since we generally know (3) what the chemical make-up of the leachate is, why don't we make a synthetic leachate? Ham (4) investigated the development of a synthetic MSW leachate. Difficulties were encountered, such as the changing of the leachate quality with time, the development of a proper carrier medium for the synthetic leachate, and the impact of the biological constituents. It was apparent that more questions were raised than answered. Therefore, synthetic leachates have not been recommended, because they cannot completely and accurately represent the fluids that geosynthetics may encounter in service.

Potentially Aggressive Constituents

A review of the literature (3) to determine the chemicals found in municipal solid waste leachate suggests that almost any chemical or combination might be found. Haxo (5) performed a study to determine if solubility parameters of geosynthetics could be used for determining chemical resistance. This study evaluated 28 polymeric compositions against 30 organics and deionized water. The 28 polymers included basic polymers and compound variations, such as type, level of crystallinity, crosslink density, filler, and amount and type of plasticizers. The 30 organics covered a wide range of Hildebrand solubility parameters as well as the component solubility parameters, i.e. dispersive polarity and hydrogen-bonding components. The conclusions indicate that this technique may have value for chemical resistance evaluations.

Haxo (6) has more recently reviewed the issue of aggressive agents in MSW leachate. His study indicates that recent reported analyses of leachates show the presence of priority pollutants, aromatic hydrocarbons, and other constituents which may be absorbed by geosynthetics. He further states that, in view of the distribution coefficients, or ratios of chemical concentrations between aqueous solution and a geosynthetic, the absorption of a given organic from an aqueous solution would be less at low concentrations compared with that at higher concentrations. Because concentrations are ordinarily very low in MSW leachates, the absorption of organics by geosynthetics may be so low that it will not significantly affect the properties of the geosynthetics. Also, as the landfill ages, the leachate will probably become less concentrated, so that there will not be any further increase in absorbed organics in the geosynthetic, and lower amounts of organics in the geosynthetic will be at equilibrium with the leachate. This also suggests that small-generator waste may not influence the amount of organics ultimately absorbed by the geosynthetic.

Test Method 9090

Haxo (6) also assessed the feasibility of performing EPA Method 9090 using MSW leachates. The study expectedly found that MSW leachate is a highly complex mixture of inorganics, organics and bacteriological constituents usually generated in anaerobic environments. The leachate has a high oxidation potential and is unstable and subject to rapid changes in quality upon removal from the environment in which it was generated. Even sealing in refrigerated bottles will not prevent the changes.

Method 9090 requires that the testing be performed at room and elevated temperatures and that samples be removed at selected time intervals for analysis. Due to the instability of MSW leachate, these requirements do not readily lend themselves to conducting chemical resistance testing of geosynthetics by this method. If not this method then what procedure, if any, should be used? Again, a review of the literature may point us in the right direction.

In the late 70's and early 80's the U.S. EPA conducted laboratory experiments to determine the chemical resistance of polymeric membranes and other materials to MSW leachate (7). These exposure tests involved placing liner samples in landfill simulators containing 8 feet of compacted, shredded urban refuse, and in immersion tanks containing MSW leachate and water. A third test involved placing leachate inside a bag made of the liner material and then placing that bag inside a polybutylene bag containing deionized water. Materials tested included 4 admixed materials, 2 asphaltic membranes, 50 commercial polymeric membranes, and 9 miscellaneous materials. Exposing the wide range of polymeric membranes to a typical MSW leachate in the landfill simulators for up to 56 months produced only limited changes in material properties. It should be noted that the composition of the membranes was similar to that of the geosynthetic products used in today's applications. With some reservations (e.g., the simulators represented one batch loading of waste rather than continuous addition of new wastes), the tests indicated that geosynthetics would withstand exposure to MSW leachate.

We can conclude from the above discussion on chemical resistance that:

- chemical resistance of geosynthetics in waste management applications is an appropriate issue for concern;
- the presently designed EPA Method 9090 should probably not be used for assessing the compatibility of geosynthetics with MSW leachate unless the concentrations of the aggressive organics, e.g. the aromatics and chlorinated hydrocarbons in the leachate appear sufficiently high to pose problems; and
- commercially available geosynthetics are probably appropriate for use in MSW waste management facilities where industrial waste disposal is relatively small.

BIOLOGICAL/PARTICULATE CLOGGING

Surveys and studies have been performed to identify the potential for clogging of leachate collection systems (8,9). Although these surveys did not excavate leachate drainage systems, there was some evidence that clogging would be a concern, especially in municipal solid waste (MSW) leachate collection systems. It is well known that the leachate from MSW landfills has a high biological component (3). The fine particles in MSW also can intrude into those collection systems and reduce their ability to perform as they were designed.

A study of geosynthetics was undertaken to evaluate the potential for clogging, determine if the clogging was biological or particulate, determine whether biological clogging was detrimental to the geosynthetic, and to develop appropriate controls to mitigate clogging (10).

The first phase of the study evaluated both aerobic and anaerobic conditions at six landfills over a twelve-month time frame (11). Ten geotextiles were used for this initial work. The aerobic phase results indicated that:

- flow was reduced 40% to 100%
- geotextile opening size played a key role, with larger sizes allowing for the passage of clogging sediment and/or dormant biologicals;
- the type of geosynthetic polymer is of no significance;
- soil clogging could not be separated from geosynthetic clogging; and
- particulate clogging could not be distinguished from biological clogging.

The anaerobic incubated samples indicated:

- smaller flow reductions, 10% to 40%;
- that biological build-up was cumulative as confirmed by

photo-micrographs which showed progressively greater biological accumulation over the 12-month evaluation period;
- there was no physical attachment to the geosynthetics; and
- there was no strength loss of the geosynthetics over the 12-month period.

The second phase, which is underway now, was redesigned to provide additional answers not obtained in the first phase. The objectives of phase II are:

- to compare and distinguish the sand filter clogging from the geotextile filter clogging;
- to distinguish the particulate clogging from the biological clogging;
- to distinguish aerobic clogging from anaerobic clogging.

The testing apparatus was designed to:

- operate with continuous or periodic flow;
- operate under variable head or constant head conditions;
- be backflushed with leachate and results assessed; and
- be backflushed from either side with biocide and the results assessed.

The initial results of the second phase indicate:

- a stabilization of the flow under continuous flow conditions, suggesting that the near-term filtration characteristics of the soil/geotextile perform as designed;
- aerobic and anaerobic clogging is similar;
- flow changes are more distinguishable when geotextiles are not covered with sand; and
- long-term clogging still occurs (69 of 96 test columns had $\geq$ 50% clogging).

Initial leachate backflushing experiments were encouraging; a 51% flow rate increase for the sand/geotextile combination and 63% for the geotextile alone. The study is expected to be completed in September 1991. It is anticipated that recommendations on designs and corrective additions for leachate collecting systems will be part of the final report.

SUMMARY

Two concerns that face the Agency in the use of geosynthetics in municipal solid waste land disposal facilities have been discussed. Chemical resistance of membranes has traditionally been evaluated, for hazardous waste, by Method 9090. This method may be unsuitable for chemical resistance evaluation when using MSW leachate, unless there appears to be a high concentration of organics (aeromatics and/or chlorinated hydrocarbons). Long-term studies conducted by the Agency suggest that commercially available geosynthetics may be used for urban refuse land disposal facilities without deterioration by exposure to the leachate.

Biological/particulate clogging of geosynthetic drainage materials continues to be researched. Preliminary results indicate biological clogging does not degrade the geosynthetic and that backflushing may be a partial corrective action for clogged systems.

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