United States Environmental Protection Agency
Research and Development

Water Engineering Research Laboratory
Cincinnati, OH 45268

EPA/600/S2-88/027 July 1988

EPA

Project Summary

Pilot Scale Evaluation of Sludge Landfilling: Four Years of Operation

J. W. Stamm and J. J. Walsh

A sludge landfill simulator program consisting of 28 lysimeters was used to evaluate sludge landfilling as a disposal option by assessing the environmental impacts on ground water, surface water, and air quality. The disposal scenarios investigated were codisposal, refuse-only, and sludge-only. All lysimeters were constructed in June 1982 and were housed at U.S. EPA's Test and Evaluation Facility in Cincinnati, OH. Thirty-four physical and chemical parameters were measured to document leachate and gas quality and quantity. In addition to the various environmental assessments, certain lysimeters were spiked with a priority pollutant solution to investigate the generation of potentially hazardous leachate.

This study presents the results of 4 yr of research, from July 1982 through June 1986. A complete tabulation of data collected over the 4-yr period is included in the report. The monitoring results indicate that codisposal of sludge and refuse accelerated the anaerobic decomposition processes relative to the other disposal scenarios. The experimental variables of infiltration rate, sludge loading rate, and sludge type produced definitive effects on the leachate and gas quality and quantity. A review of leachate and gas quality data suggests that the codisposal of sludge and refuse may be a superior means of disposal. This disposal scenario had the least detrimental effect on leachate quality and quantity while positively affecting the decomposition processes (as measured by methane generation). Gas chromatography/mass spectrometry (GC/MS) analysis of leachate samples showed several leaching trends exhibited by the priority pollutants from both the sludge-only and codisposal test cells.

This Project Summary was developed by EPA's Water Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Method and Objectives

To simulate sludge landfilling as it is commonly practiced, the program design included pilot-scale steel tanks (or cells) filled with municipal refuse and various loading rates of municipal wastewater sludges. Conceptually, each cell acts as an independent landfill (or section from a landfill) operated under anaerobic conditions and according to the initial experimental variables. For each cell, water is added on a monthly basis to reflect expected rainfall conditions. Leachate is drained monthly, and samples are collected and analyzed for standard chemical constituents as well as the presence of trace organic compounds. Additionally, gas is quantified and periodic samples collected for analysis. Lastly, temperature readings are routinely recorded to monitor changes due to decomposition processes or seasonal fluctuations. Under this general program design, the simulated landfills can be evaluated singularly or compared to one another under experimental conditions corresponding to actual field conditions.

The specific program design is outlined in Table 1. A total of 28 cells were filled with various sludge/refuse ratios. These ratios included 0% sludge (100% refuse), and 10%, 20%, 30% and 100% sludge loading rates. Other experimental variables included the use of two different sludge types, two infiltration rates, different cell heights and diameters, and the spiking of the sludge in eight cells with a priority pollutant stock solution. The project test cells were inside at the U.S. EPA Test and Evaluation (T&E) Facility in Cincinnati, OH. The codisposal and refuse-only cells (Nos. 1 through 20) were placed in a stacked arrangement of two lower rows of five and two upper rows of five. Reinforced concrete footers support the lower cells while the upper cells are supported on a structural steel framework. The sludge-only cells (Nos. 21 through 28) are smaller diameter tanks located in front of the codisposal cells at floor level.

The primary objective of this program is to monitor and evaluate leachate and gas release from sludge landfills constructed and/or operated under the following conditions:

1. Sludge landfills receiving anaerobically digested sludge versus those receiving lime treated sludge.
2. Sludge-only landfills versus refuse-only landfills versus codisposal landfills.
3. Codisposal landfills receiving various sludge loadings (10%, 20%, and 30% of the total sludge/refuse mass).
4. Landfills receiving low versus high infiltration rates.
5. Shallow versus deep landfills.
6. Landfills spiked with elevated levels of priority pollutant compounds, versus control landfills.

Procedures

The pilot-scale test cells were designed by SCS Engineers and constructed by a local fabricator. The purpose of the design was to provide a durable, gas-tight container of sufficient scale to promote the decomposition processes that occur in an actual refuse, sludge, or codisposal landfill. The cells are rolled steel tanks, double-welded at the seams, with two interior coatings of rustproof, high-build epoxy sealer. The codisposal and refuse-only cells (Nos. 1 through 20) are 1.8 m (6 ft) in diameter and 2.7 m (9 ft) in height. Due to the heterogeneous nature of municipal refuse, a greater waste volume was selected for the codisposal cells. The smaller sludge-only cells (Nos. 21 through 28) are 0.6 m (2 ft) in diameter; four are 2.7 m (9 ft) tall, and the remaining four are 1.5 m (5 ft) tall.

Required quantities of municipal refuse were obtained from City of Cincinnati collection vehicles and delivered to a specially prepared receiving area outside the T&E Facility. The purpose here was to obtain a waste medium that typified household refuse generated in the U.S. A quantity of over 45 metric tonnes (50 tons) of municipal refuse was delivered to the project site where it was manually mixed by a University of Cincinnati work crew. This manual mix consisted of breaking open all plastic bags, spreading materials, and removing non-representative refuse materials such as pianos, tires, and commercial items. After the mix was completed and prior to cell loading, a representative 3% sample was segregated from the waste mass and a refuse characterization procedure was performed. The refuse was manually sorted into 14 categories that included paper, plastic, metal, glass, and food waste. The refuse sorting procedure was performed to assure that the refuse sample was not biased and represented typical municipal refuse. In order to further assess the physical and chemical inputs to the cells from the refuse quantities, refuse grab samples were obtained for chemical composition and moisture content analyses.

Required quantities of municipal sludges were obtained from the Blue Plains Wastewater Treatment Plant in Washington, D.C. A total of about 12 metric tonnes (13 tons) of anaerobically digested (AD) and lime-treated (LT) sludges were loaded into 66 steel drums with lids and delivered by truck to the project site in Cincinnati. Samples of the incoming sludges were obtained and analyzed for a variety of chemical parameters. The sludges differed significantly in composition with notably higher levels for pH, alkalinity, and iron in the lime treated sludge. The two incoming sludges were also analyzed initially for organic priority pollutants by GC/MS.

Following the placement of the gravel drainage layers, quantities of refuse and sludges were weighed, loaded, and compacted in four 0.46 m (1.5 ft) high lifts in each test cell. In the codisposal and refuse-only cells (Nos. 1 through 20), refuse quantities were loaded first, followed by designated sludge types and quantities added atop each refuse layer. The cells were loaded on a lift-by-lift basis so that the first lift was completed in all cells before moving on to the second lift. Temperature probes were installed atop the second lift and the probe lines exited through temperature ports. Loading activities were conducted continuously for 4 days until the completion of the fourth lift in codisposal and refuse-only test cells. At that time gas ports and leachate drains were installed and an infiltration spray nozzle was placed on the interior of the test cell lids.

The sludge-only cells (Nos. 21 through 28) were loaded in a separate operation and received preweighed quantities of AD or LT sludges. Temperature probes, gas ports, and leachate drains were installed in the same manner. In designated codisposal and sludge-only cells, a solvent-based priority pollutant spike solution was added to individual sludge quantities at the time of loading. The spike solution contained the following 12 priority pollutant compounds in a methylene chloride carrier solvent:

Acenapthene	Ethylbenzene
Benzene	Naphthalene
Bis (2-Ethylhexyl) Phthalate	Phenol
1,4-Dichlorobenzene	Pyrene
Dimethyl Phthalate	Toluene
Di-n-butyl Phthalate	PCB (Arochlor 125

The last steps of the loading operations included placement of the test cell lids, final connection of gas and temperature probes and infiltration lines, welding of the steel lids, and pressure testing to ensure air and water-tight conditions.

Various operation and monitoring activities were performed on a continuous basis for this long-term experiment. Specifically, test cell temperatures (one probe per test cell) were recorded on a daily basis for the first 2 mo. Temperatures were then monitored bi-weekly or on an "as-appropriate" basis. In addition, leachate was drained from every cell each month. The volume of leachate drained was recorded to aid in the compilation of a moisture balance summary. Two representative samples were then collected from the leachate drained each month for each cell. The first sample was prepared for standard chemical analysis and transmitted to the University of Cincinnati. The second sample was collected for GC/MS quantitation of trace organics by analytical personnel at PEI Associates

Table 1. Program Design

Test Cell	Sludge Type*	Sludge Loading (%)†	Priority Pollutant Spike‡	Infiltration Rate**	Waste Height (m)
Codisposal and Refuse-Only:					
1	AD	10	--	Low	1.8
2	LT	10	--	Low	1.8
3	AD	10	--	High	1.8
4	LT	10	--	High	1.8
5	AD	20	--	Low	1.8
6	LT	20	--	Low	1.8
7	AD	20	--	High	1.8
8	LT	20	--	High	1.8
9	AD	30	--	Low	1.8
10	LT	30	--	Low	1.8
11	AD	30	--	High	1.8
12	LT	30	--	High	1.8
13	AD	20	Spiked	Low	1.8
14	LT	20	Spiked	Low	1.8
15	AD	20	Spiked	High	1.8
16	LT	20	Spiked	High	1.8
17	--	0	--	Low	1.8
18	--	0	--	High	1.8
19	--	0	--	Low	1.8
20	--	0	--	High	1.8
Sludge-Only:					
21	AD	100	--	Low	0.6
22	LT	100	--	Low	0.6
23	AD	100	--	Low	1.8
24	LT	100	--	Low	1.8
25	AD	100	Spiked	Low	0.6
26	LT	100	Spiked	Low	0.6
27	AD	100	Spiked	Low	1.8
28	LT	100	Spiked	Low	1.8

* AD = Anaerobically digested sludge (16 percent solids);
LT = Lime-treated sludge (16 percent solids).
† 10, 20, etc., = Percent (%) sludge addition by wet weight of sludge/refuse mixture.
‡ Spiked = Received solvent-based spike containing twelve priority pollutants.
** Low = Receives an annual water infiltration rate of 0.500 L/kg of cell waste (refuse and/or sludge) on a dry weight basis;
High = Receives an annual water infiltration rate of 1.000 L/kg of cell waste (refuse and/or sludge) on a dry weight basis.

During project start-up, changes in project scope and budget precluded the monitoring of three compounds. These compounds were benzene, ethyl benzene, and toluene.

Infiltration water was applied to every cell each month immediately after the leachate had been drained as described above. The volume added was based on an annual rate applied against the total quantity (dry weight) of wastes present in each cell. Cells received either the low infiltration rate (similar to Midwest U.S. percolation estimates) or the high infiltration rate (twice the low rate). The low infiltration rate was equivalent to 0.5 L of water/kg of waste/yr. The high infiltration rate was equal to 1.0 L of water/kg of waste/yr. Inspection and maintenance activities were also employed each month for general housekeeping purposes and to ensure air and water tightness in all cells.

Monitoring activities centered on providing physical/chemical descriptions of the in-place wastes, infiltration water, product gases, and generated leachates. Standard chemical analyses performed on leachate samples in the laboratory included pH, alkalinity, volatile acids, total and volatile solids, total organic carbon (TOC), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), total phosphate, chlorides, sulfide, seven metals, and trace priority pollutants. In conjunction with the above analyses, gases generated from the cells were sampled each month and analyzed by gas chromatography for methane, carbon dioxide, nitrogen, and oxygen contents.

Discussion of Results

The investigation has produced a great quantity of information on the behavior of the 34 parameters measured. An in-depth analysis of each of these parameters would have produced a report of unreasonable size. Consequently, the report presents general and obvious trends and includes all raw data in the Appendices. In this manner, major findings are made available as well as the total data set, allowing other investigators to explore specific aspects of the results in greater detail. The presentation and discussion of results below follow the outline of objectives presented earlier.

Sludge Type

The type of sludge that is placed in a landfill will have a direct effect on the generation of leachate. A comparison of the two sludge types showed that AD sludge posed less of a negative impact on leachate quality than LT sludge. These effects were more dramatic in the sludge-only than the codisposal cells.

A comparison of sludge types showed that the pH range among the codisposal cells was approximately 0.5 pH units through the first 2 yr. This range began to show signs of shrinking in the third year. Occasionally, higher pH values were detected as remaining pockets of lime were leached from the lime-treated codisposal cells. The two sludge types caused a dramatic difference in pH between the two types of sludge-only cells. The AD cells averaged a pH of 6 while the LT cells had a mean pH level above 9 with some values above 10 units. These trends generally continued throughout the rest of the monitoring period.

Table 2 presents a summary of leachate quality parameters for both codisposal and sludge-only cells. The parameters presented in this table are 4-yr mean values for selected AD and LT cells. Specific volume in this and subsequent tables is leachate quantity (L/kg/mo). All treatment conditions for the sets, except cell type, were the same. A review of this data reinforces the conclusion that AD sludge produces a leachate that is relatively more benign than LT sludge. The effect is larger for the sludge-only cells than for the codisposal cells.

In the sludge-only cells, the leaching of lime lowered the pH in the LT cells and allowed a resurgence of activity of microorganisms. This activity can be measured by many of the leachate parameters. This data showed an increase of volatile solids production in the LT cell while its anaerobic counterpart displayed a variable but normal decline in volatile solids levels. Over the 48-mo experiment, the average leachate composition for these 2 cells differed by over 3,000 mg/L of volatile solids. Also, these cells showed a sharp increase in volatile acid production during the close of the second year. An examination of COD levels for LT cells showed a steadily increasing level of COD in its leachate. By comparison, the anaerobic counterparts actually show a gradual decrease in COD levels. Over the 48-mo period, the average for the 2 sludge types differed by over 12,000 mg/L of COD.

A final point for consideration is the effect on microbiological activity as measured by methane generation. Though both sludges initially accelerated methane production, LT sludge tended to stall methane generation shortly thereafter. Initially, this appears to be a desirable effect, until one considers the following. Any organic matter (refuse or sludge) placed in anaerobic conditions (underground) will eventually undergo biological decomposition. This decomposition will result in the generation of methane. From the viewpoint of landfill planning and operations, it is desirable to encounter the bulk of methane generation in the early stages of operation. At this time, methane collection and disposal may be included in the landfill design and become a part of daily operations. If, however, the bulk of methane generation occurs in the final stages of operation, or after closure of the landfill, the problem may go unnoticed for some time. History has shown that uncontrolled methane generation and migration poses an environmental threat as great as ground-water contamination from leachate migration.

Based on these trends, the type of sludge stored in a landfill will have a definite effect on leachate strength and anaerobic decomposition as measured by methane generation. This study shows that AD sludge would be superior to LT sludge in either a codisposal or sludge-only landfill.

Landfill Type

The environmental impact of disposing of sludge in a landfill operation was the main thrust behind the research project. The experiment was designed to allow a comparison between three different types of landfills: codisposal, sludge-only, and refuse-only. An examination of the experimental data shows that the codisposal type landfill is superior to the other two types of landfills. The combination of sludge and refuse tends to enhance the rate of anaerobic decomposition. This is demonstrated in both leachate and gas quality.

Table 3 presents a cross-section of leachate parameters averaged over 4 yr. This table allows the direct comparison of codisposal vs refuse-only vs sludge-only. Other experimental variables were held constant between the three groupings of cells (see table legend). A review of COD levels for the three cell types revealed that the refuse-only cells produced a leachate with a COD higher than the other two cell types by an order of magnitude. How-ever, the codisposal cells were only 27% higher than the sludge-only cells.

Using COD as a measure of leachate strength, the codisposal cells show that a weaker leachate was generated relative to the other two cell types. More importantly, the bulk of this contamination was released sooner (approximately 1 yr) than either of the other two configurations. This second item is important when landfill designers are planning for leachate collection and disposal. Examining the other parameters in Table 3, similar leaching trends held true for TOC and volatile solids.

An examination of the gas composition data shows that the codisposal cells generated methane much sooner than the refuse-only cells. This signifies that decomposition of the waste had reached advanced stages in the codisposal cells sooner than in the refuse-only cells. As discussed earlier, methane collection and treatment is more effective in the early life of a landfill as opposed to after its closure.

Based on leachate quality and gas generation trends, codisposal landfills should prove less of an environmental hazard than refuse-only or sludge-only landfills.

Table 2. *Comparison of Leachate Parameters for Anaerobically Digested Sludge vs Lime-Treated Sludge*

Parameter	Codisposal Cells*		Sludge-Only Cells†	
	Anaerobically Digested Sludge	Lime-Treated Sludge	Anaerobically Digested Sludge	Lime-Treated Sludge
COD (mg/L)	2,496	7,455	2,159	14,961
TOC (mg/L)	904	2,599	734	5,566
pH	6.9	6.8	6.2	8.4
Volatile Acids (mg/L)	1,302	3,115	1,059	9,236
Volatile Solids (mg/L)	1,501	3,095	4,659	7,702
Specific Volume (L/kg)	0.07	0.08	0.07	0.09

* Cells 3 and 4.
† Cells 21 and 22.

Sludge Loading Rate

In this project, sewage sludge cake (16% dry solids) was codisposed with refuse at 10%, 20%, and 30% by weight ratios. Comparison of these codisposal ratios showed three distinct trends. First, as might be expected, the effect on a given parameter depended on the amount of the sludge present in the cell. This trend was quite prominent in the first year. A second trend showed all three loading ratios reaching a type of equivalence point early in the second year and showed little relative difference in release concentrations for the remainder of the monitoring period. The final relationship showed a significant increase in average leachate strength when sludge loading was increased from 20% to 30%.

Figure 1 shows the percentage of moisture in codisposal cells containing anaerobically digested sludge as a function of time. Throughout the first 12 mo of operation, all 3 cells exhibited an increase in percent moisture. By Month 12, the gap separating the 30% cell and the 10% cell had decreased from 6% to 4%. By Month 24, the gap separating the 3 cells was less than 3%. Generally, these trends continued through the end of the project. In addition, values of leachate generated per unit mass are presented in Table 4. These values show that on an average of over 4 yr, monthly leachate generation did not change as a function of sludge loading.

Table 4 presents the effects of the sludge loading ratio on the average of five other leachate characteristics over the 4-yr period. In every case except for pH, there was an increase in leachate strength as sludge loading was increased from 20% to 30%. For example, TOC levels in the AD cells increased from 879 mg/L (for 20% sludge) to 1,439 mg/L (for 30% sludge). This trend also was true for the LT cells. COD levels increased from 4,845 mg/L (20% sludge) to 12,581 mg/L (30% sludge).

In summary, sludge loading ratios produced two distinct effects in leachate strength. First, declines in a given leachate parameter during the first year were greater for cells with a smaller proportion of sludge. Second, increases in sludge loading between 20% and 30% had profound influence on the final 4-yr mean value for many leachate parameters.

Infiltration Rate

Infiltration rate was a controlled variable in the experiment. Consequently after the landfill was activated, leachate generation should have equalled infiltration rate. As Table 5 shows, leachate generation averaged over the entire 4 yr ranged from 0.03 to 0.07 L/kg/mo, while infiltration rates were 0.041 L/kg/mo and 0.083 L/kg/mo. The reason for the difference is the amount of water required to saturate the cell contents.

As expected, the high infiltration cells averaged roughly twice the leachate production that low infiltration cells experienced. This relationship was found for both codisposal and refuse-only cells.

Table 5 also contains a cross-section of other test cell parameters presented on the basis of infiltration rate. These mean values demonstrate differences in leachate strength and are not intended to serve as a basis for numerical extrapolation. An examination of this data shows that doubling the rate of infiltration did not substantially lower the strength of the leachate. Effects were not the same for the codisposal and sludge-only cells. An increased rate of

Table 3. *Various Average Leachate Values for Codisposal, Refuse Only, and Sludge-Only Test Cells*

Parameter	Codisposal *	Refuse-Only†	Sludge-Only ‡
COD (mg/L)	2,889	22,453	2,258
TOC (mg/L)	903	4,640	737
pH	7.1	6.4	6.2
Volatile Acids (mg/L)	868	7,434	1,213
Volatile Solids (mg/L)	2,171	7,659	5,555
Specific Volume (L/kg)	0.03	0.03	0.07

* Average of Cell 1, 5, and 9.
† Average of Cell 17 and 19.
‡ Average of Cell 21 and 23.

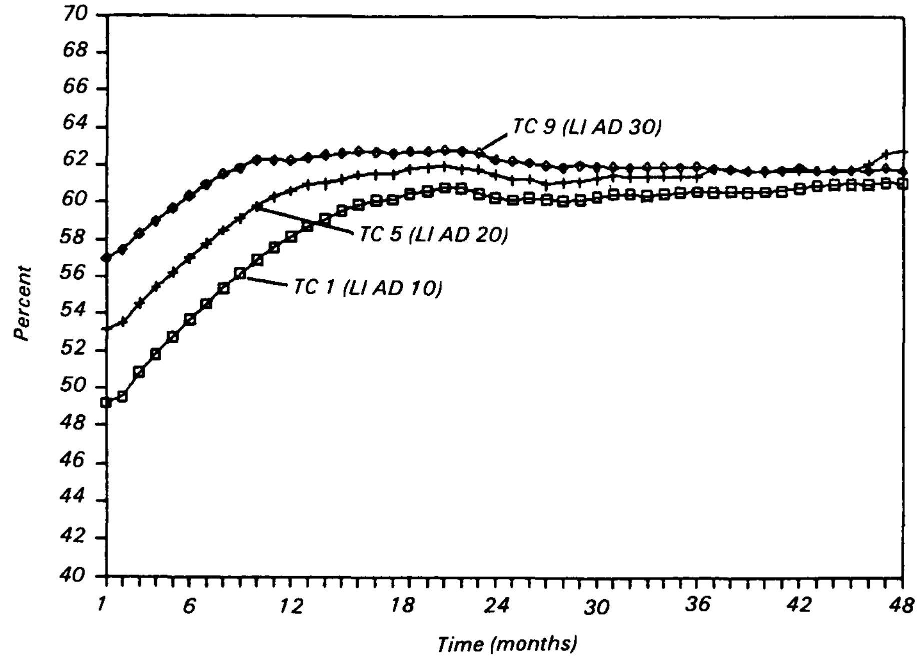

Figure 1. Percent moisture vs time.

Table 4. Comparison of Leachate Parameters by Sludge Loading Ratio and Sludge Type

	Anaerobically Digested Sludge*			Lime-Treated Sludge*		
Parameter	10%	20%	30%	10%	20%	30%
COD (mg/L)	2,601	2,447	3,477	6,585	4,845	12,581
TOC (mg/L)	761	879	1,439	2,361	1,691	4,127
pH	7.1	7.0	6.8	7.0	7 0	6 8
Volatile Acids (mg/L)	891	938	2,069	2,756	1,219	5,141
Volatile Solids (mg/L)	1,630	1,724	2,615	3,223	2,522	4,579
Specific Volume (L/kg)	0.05	0.05	0.06	0.06	0.06	0.06

*Values are average of LI and HI cells
Reported values are based on averaged monthly data values. Reported values are averaged over a 4-yr period.

Table 5. Comparison of Leachate Parameters as a Function of Infiltration Rate

	Codisposal Cells*		Refuse-Only Cells	
Parameter	Low Infiltration	High Infiltration	Low Infiltration	High Infiltration
COD (mg/L)	2,556	2,793	22,454	19,395
TOC (mg/L)	903	1,150	7,110	6,251
pH	7.1	6.8	6.4	6.0
Volatile Acids (mg/L)	868	1,730	7,434	7,234
Volatile Solids (mg/L)	2,171	1,808	7,659	6,297
Specific Volume (L/kg)	0.03	0.07	0.03	0.07

* Designates all codisposal cells at a similar state of infiltration.

infiltration generally increased leachate concentrations for the codisposal cells, but caused a slight decrease in leachate strength for the sludge-only cells.

Though increased infiltration rate did not produce a consistently stronger leachate, the higher rate of infiltration did increase the rate of decomposition in refuse-only cells. The high rate refuse-only cell generally reached 50% methane concentrations almost 12 mo earlier than the low rate cell. In this comparison, the levels of methane are used as an indirect measure of decomposition progress. This trend did not hold true for codisposal cells. It is hypothesized that the increased rate of infiltration brought the refuse-only cells to field capacity earlier, thus enhancing decomposition processes. Because the codisposal cells contained sludge with a high level of moisture, codisposal cells reached field capacity at roughly the same time regardless of infiltration rate. In conclusion, an increased rate of infiltration did increase leachate generation (as expected). However, it did not exert a substantial impact on leachate strength.

Waste Depth

The effects of disposal depth were studied for the sludge-only type of landfill in this project. The result showed that differences in cell heights produced only a secondary effect on certain leachate quality and gas production parameters.

Priority Pollutants

A review of the GC/MS data demonstrated three main points concerning the leaching of these target compounds. First, the release of these compounds from the cells was extremely erratic. This is not surprising from a mass transport point of view for several reasons. First, the heterogeneous nature of the municipal solid waste in the cells and the intermittent flow of infiltration water contribute to non-steady state conditions. Second, all of these compounds show a complex molecular structure, which can allow various chemical reactions once released within the heterogeneous environment of the test cell. Third, all of these compounds have extremely low solubilities in water. This leaves their dilution into the flow of leachate at the mercy of the quantity of organic solvents present in the leachate.

The second point was that the concentrations of the various compounds in the leachate from the spiked cells were not higher than their concentrations in the leachate from the non-spiked cells. The only exceptions to this rule were in the case of dimethyl phthalate and bis(2 ethyl hexyl) phthalate, and, in the sludge-only cells, 1,4 dichlorobenzene. A note of caution is included as to the significance of this statistic. The large standard deviations cast some doubt on the validity of comparing these two mean values.

The third point was that the bulk of the target compounds was released early in the life of the project. Though the erratic nature of the data makes conventional modeling efforts impossible, a review of the data showed that almost all of the target compounds reached peak leachate concentrations by the second year.

A comparison of the mean concentrations of all the target compounds in the leachate to the initial concentrations placed in the test cells (particularly for spiked cells) indicates that the cumulative amounts of compounds that leached out were less than the amounts charged. Either the materials were tightly bound in the cell contents or have been degraded. The ultimate fate of these pollutants cannot be determined until the cells are opened and their contents analyzed. The results clearly show that rapid transfer of these complex organic pollutants to leachate and potentially to ground water does not occur.

Conclusions

1. The codisposal of AD sludge should produce a lower leachate strength than codisposal with LT sludge.
2. The codisposal of sludge and refuse offers the optimum landfill setting because it has the least overall effect on leachate strength and enhances the overall rate of decomposition.
3. Over the life of a landfilling operation, variations in sludge cake loading ratios less than 20% will exert little effect on the strength of the leachate generated.
4. An increased rate of infiltration will not cause a corresponding increase in leachate strength. But an increased infiltration rate does increase the rate of decomposition in refuse-only cells.
5. The presence of elevated levels of certain priority pollutants did not cause significant increases in the concentration of these compounds in the resultant leachate.

The full report was submitted in fulfillment of U.S. EPA Contract No. 68-03-3220 by SCS Engineers under the sponsorship of the U.S. Environmental Protection Agency.

J.W. Stamm and J.J. Walsh are with SCS Engineers, Covington, KY 41017
***G.K. Dotson and J.B. Farrell** are the EPA Project Officers (see below).*
The complete report, entitled "Pilot Scale Evaluation of Sludge Landfilling: Four Years of Operation," (Order No. PB 88-208 434/AS; Cost: $25.95, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
*For further information, **J.B. Farrell** can be contacted at:*
Water Engineering Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

United States Environmental Protection Agency
Center for Environmental Research Information
Cincinnati OH 45268

BULK RATE
POSTAGE & FEES PAID
EPA
PERMIT No. G-35

Official Business
Penalty for Private Use $300

EPA/600/S2-88/027