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Project Summary

Evaluation and Disposal of Waste Materials Within 19 Test Lysimeters at Center Hill

Riley N. Kinman, Janet Rickabaugh, Jean Donnelly, David Nutini, and Martha Lambert

A study was conducted to evaluate the physical, microbiological, and chemical conditions of 19 experimental landfills after the completion of a ten-year-long municipal refuse/industrial sludge codisposal project. The simulated landfills were constructed in 1974 and 1975 and operated until September 1983. Data collected during this termination study (June 1984) included observations of overall test cell conditions; chemical analysis of final leachate, refuse, and bottom gravel; physical analysis of refuse, gravel, and clay conditions; microbiological analysis of the refuse; and in-place permeability and specific yield of the refuse. Comparisons between municipal refuse-only cells and municipal refuse/industrial sludge codisposal cells were made in order to evaluate the effect the industrial sludges had on the decomposition process.

The codisposal cells did not appear to be different from the municipal refuse-only cells in terms of any of the parameters analyzed. Large numbers of aerobic, anaerobic, and facultative microorganisms, many of which were pathogens, were found in both types of cells. It appeared that the decomposition process was more inhibited by the presence of intact plastic or paper bags and other protective wrappings than by the presence of sludges from battery production, plating operations, water softening, paint pigments, solvent-based paints, petroleum processing or municipal wastewater treatment. Identifiable food wastes and other readily biodegradable materials, including fecal matter in disposable diapers, were found protected from decomposition by such wrappings.

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

Introduction

Long-term experimental landfill studies commonly produce vast quantities of data on characterization of the refuse prior to cell loading and leachate and gas analysis over the life of the study. However, relatively little data are available on the characterization of the waste upon completion of the study. The termination of this codisposal lysimeter project provided an opportunity to investigate the physical, microbiological, and chemical components of refuse in its in situ state after 10 years. Nineteen experimental lysimeters 12 feet high and 6 feet in diameter were packed with 6000 to 10,000 pounds of refuse and refuse/industrial sludge combinations. Table 1 describes the contents of each test lysimeter. The lysimeters were located at the Center Hill Solid and Hazardous Waste Research Facility in Cincinnati, Ohio. Fifteen of the cells (designated cells 1 through 15) were located in a cleared area behind the facility. They were buried in the ground to within 6 inches of their tops. The other test cells (designated cells 16 through

Table 1. *Cell Contents*

Test Cell	*Contents*
1	*Municipal Refuse*
2	*Municipal Refuse*
3	*Municipal Refuse*
4	*Municipal Refuse*
5	*Municipal Refuse* *Sewage Sludge*
6	*Municipal Refuse* *Sewage Sludge*
7	*Municipal Refuse* *Sewage Sludge*
8	*Municipal Refuse* *Calcium Carbonate*
9	*Municipal Refuse* *Petroleum Sludge*
10	*Municipal Refuse* *Battery Production Waste*
11	*Municipal Refuse* *Prewetted with Water*
12	*Municipal Refuse* *Electroplating Waste*
13	*Municipal Refuse* *Inorganic Pigment Waste*
14	*Municipal Refuse* *Chlorine Production Brine Sludge*
15	*Municipal Refuse* *Polio Virus*
16	*Municipal Refuse*
17	*Municipal Refuse* *Solvent Based Paint Sludge*
18	*Municipal Refuse*
19	*Municipal Refuse*

19) were located in the high bay of the facility.

The following objectives were established in order to fully evaluate the condition of the ten-year-old refuse and lysimeters: 1) Perform an in-depth microbiological analysis of the refuse, including routine indicator analyses and characterization of a certain percentage of the total number isolated, examination for fungi, methane-producing bacteria, *Clostridium*, and, finally, total plate counts distinguishing between aerobic and anaerobic bacteria, 2) Determine the in-place permeability and specific yield of the refuse, 3) Perform observations on channeling that may have occurred through the refuse, 4) Evaluate the coal tar epoxy used to line the inside of the lysimeters, 5) Evaluate the seals around probes and infiltration lines on the lysimeters, 6) Observe any layering of the refuse, and 7) Analyze the chemical components of the refuse, gravel and the final leachate from the cells.

Not all tasks were performed on all 19 test cells. Rather, representative subgroups were selected for the various tasks.

Procedures

All refuse removal was performed by hand by a team of three researchers. Three separate 50-pound samples were composited for chemical analysis from across the surface of three distinct locations in each cell sampled (top, middle, bottom). The bulk chemical analysis samples were dried at 75°C in the as-sampled condition until the sample reached constant weight. Each sample was coarsely ground, then finely ground. A well-mixed subsample was dried at 75°C to drive off any remaining moisture. All chemical analyses were performed on subsamples of finely ground refuse. Standard methods were selected for all chemical analyses.

The microbiological samples consisted of five grab samples composited to a total of about one kilogram at each of the same three sampling locations. Large items such as bottles, plastic toys, cans, etc., were intentionally avoided in the microbiological samples. During the sampling procedures, numerous disposable diapers were encountered containing fecal matter. In order to evaluate the impact of the diapers on the overall microbiology of the refuse, a composite diaper sample replaced the composite refuse sample at six of the microbiological sample locations. All microbiological analyses were standard methods with the exception of the methane bacteria analysis. This was essentially a qualitative analysis in which the gas produced by the bacteria was analyzed for methane, indicating the presence or absence of methane-producing bacteria.

Visual observations on the condition and appearance of the refuse, including any channeling or layering, were recorded in field notebooks as well as through extensive photographs.

Results and Discussion

The test cells themselves withstood the rigors of the ten-year study with varying success. All cells were coated on the inside with a coal tar epoxy lining to prevent corrosion. The linings were in excellent condition in all cells. Most of the seals around the lysimeter lids, water infiltration lines, and gas and temperature probes were cracked and therefore not gastight. Many of the cells had a fiberglass coating on the inside bottom of the tank. Four of the 15 cells with the fiberglass seal showed splitting or some breakdown of the fiberglass. The remaining 11 cells with fiberglass seals were in good condition. Three of the four inside lysimeters had white-painted bottoms that were in excellent condition, and the remaining cell had a coal tar epoxy bottom that was also in excellent condition.

In general the cell contents were very damp and appeared as a black tar-like mass with some easily recognizable items (i.e., cans). There were many paper and plastic bags with refuse intact. A number of organic products were protected from degradation in this manner and were readily identifiable. Some of the organic products found included green grass clippings, potatoes, chicken, hot dogs, cheese, chocolate candy, bacon, and carrots. After the refuse was sorted and the tar-like mass was cleaned off, many other readily identifiable items were found. Among these were plastic items, stainless steel flatware, legible books and magazines, cloth (both synthetic and natural) with fibers still strong, coins, wooden toys, rubber tires, and a ten-dollar bill.

There were no clear layers of waste within the cells except in cell 18, even though the industrial sludges had been added in distinct layers. The paint sludge in cell 18 did not appear to undergo any decomposition and was still clearly visible as a distinct layer. The chlorine production brine sludge in cell 14 was still in the original plastic bags. Although there were distinct pockets or layers of the sludge, the behavior of the sludge was not considered conclusive, since it was not available for decomposition.

There was no evidence of channeling through the refuse in the lysimeters except in test cell 9, where the petroleum sludge was codisposed. Refuse coated with the sludge was relatively dry. Water was clearly channeled around the petroleum sludge.

Microbiology

The microbiology was designed to determine the ability of pathogenic organisms to survive long-term exposure in a landfill and to determine which organisms were actively stabilizing the waste. Microbiological enumerations showed no clear trends from sample level to sample level, nor were there any clear differences in relative numbers of microorganisms found in refuse-only cells and codisposal cells. Diaper samples were found to contain levels of microorganisms similar to non-diaper samples. Relatively high numbers of all organisms analyzed were found in all samples. Figures 1 and 2 indicate the results from the total aerobic plate counts and fungi levels using Rose Bengal agar. Relative levels were similar for all analyses performed. The cell number is included by the results to emphasize the lack of any recurring trends in any of the cells. These results also show no significant difference between codisposal cells and refuse-only cells.

An attempt was made to isolate and identify all of the anaerobes, gram negative rods, and fungi found in the samples. Some difficulties were encountered with organism survival; therefore, additional species were undoubtedly present. A total of 13 different species of *Clostridium*, 34 different species of fungi, and 23 different species of gram negative rods were identified in the waste. Identified microbes included known pathogens which can be seen in Table 2.

Permeability and Specific Yield

In-place permeabilities and specific yield were determined on four of the 19 test cells. These four cells included test cell 2, the primary control cell; test cell 1, which had the least moisture added throughout the project; test cell 4, with the most moisture added; and test cell 16, which was located in the high bay rather than outside, as were the other three cells. Results of these two tests are shown in Table 3.

The permeability measurements were determined with a constant head of from 2.3 to 3.6 feet, depending on the cell. Permeabilities were essentially the same for the four cells tested. Permeabilities of this absolute magnitude are commonly found in sands and gravels. These tests indicated that under the conditions stated, leachate would move through the landfill rather quickly. Although this estimate of permeability would tend to be more similar to a full-scale landfill than laboratory measurements, care should still be exercised when extrapolating to full-scale conditions, since several test conditions would probably differ from those created in the lysimeters.

Specific yield varied from 6.37 ft^3/yd^3 in test cell 1 to 3.20 ft^3/yd^3 in test cell 4. It appears that the higher moisture rate accelerated decomposition and produced a finer particle size mass that could retain more water or leachate than those receiving less moisture.

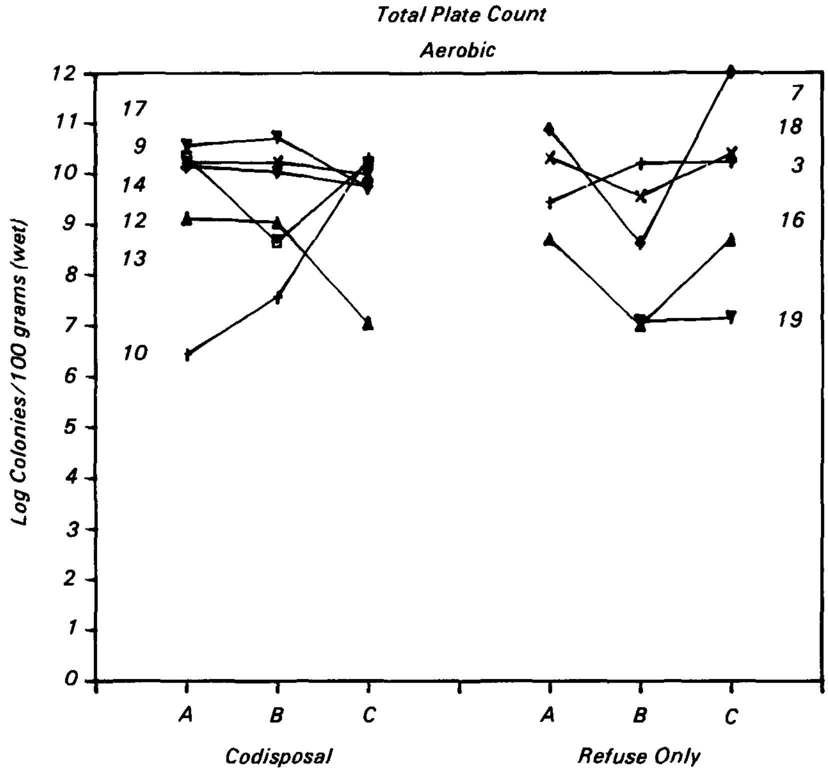

Figure 1. *Results from total aerobic plate counts.*

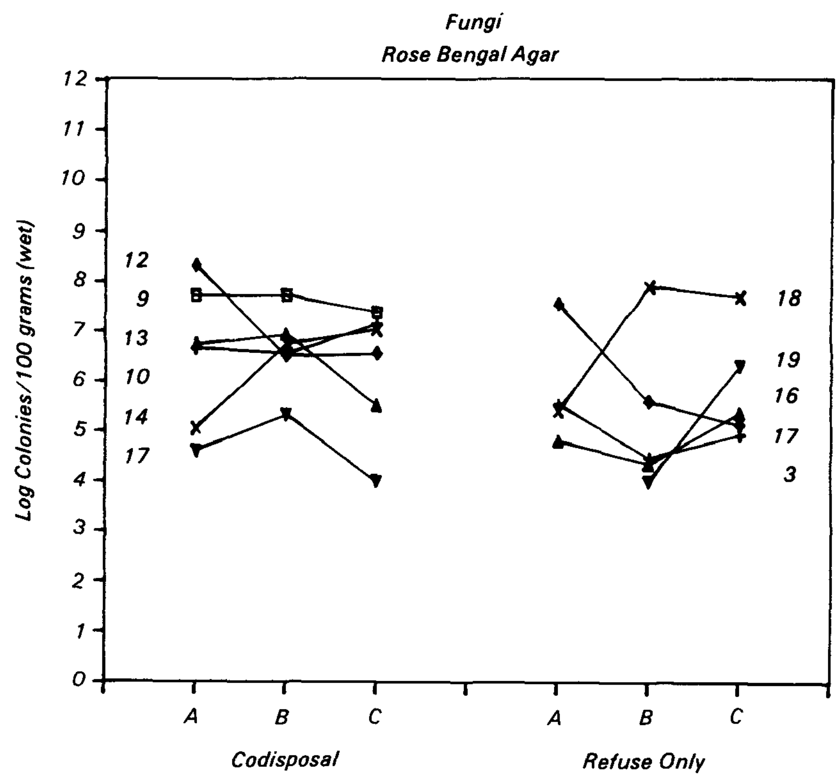

Figure 2. *Fungi levels using Rose Bengal agar.*

Table 2. Pathogenic Organisms Identified in Refuse

Organism		*Disease*[a,b,c]
Clostridium	C. bifermentans	*gas gangrene (wounds)*
	C. botulinum	*food poisoning* *infant botulism*
	C. difficile	*fatal diarrhea*
	C. histolyticum	*gas gangrene*
	C. novyi	*gas gangrene*
	C. perfringens	*food poisoning* *gas gangrene*
	C. ramosum	*intra-abdominal infections*
Fungi	Aspergillus fumigatus	*pulmonary aspergillosis*
	Aspergillus niger	*fungus-ball (lungs)* *swimmers ear*
	Aureobasidium *sp.*	*allergies*
	Monosporium apoispermum	*mycetoma*
	Madurella *sp.*	*pulmonary infection* *mycetoma*
	Trichophyton *sp.*[d]	*ringworm*
	Fonsecaea *sp.*	*chromomycosis*
	Epidermophyton floccosum	*skin and nail infections*
	Aspergillus nidulans	*mycetoma*
	Aspergillus flavus	*pulmonary aspergillosis*
Gram Negative Rods	Aeromonas hydrophila	*wound infections* *diarrhea*
	Klebsiella pneumoniae	*wound infections*
	Klebsiella ozaenae	*wound infections*
	Acinetobacter *sp.*	*meningitis and septicienum*
	Moraxella kingii	*wound infections*
	Yersinia enterocolitica	*gastroenteritis* *mesenteric adenitis*
	Yersinia intermedia	*gastroenteritis* *mesenteric adenitis*
	Alcalcigenes *sp.*	*urinary tract infections*

a Davis et al. (1980).
b Koneman et al (1983).
c Lennette et al (1980).
d Pathogenic species.

Table 3. *Permeabilities and Specific Yield*

Test Cell	*Permeability* (cm/sec)*	*Specific Yield (ft^3/yd^3)*
1	1.26×10^{-2}	6.37
2	1.14×10^{-2}	5.88
4	1.00×10^{-2}	3.20
16	1.05×10^{-2}	4.10

**Mean of three replicate results.*

Table 4. *Chemical Analysis of Refuse (Dry Weight Basis)*

	Minimum	*Mean*	*Maximum*
% Moisture	45.6	57.9	68.6
COD g/kg	305	1760	3290
TOC g/kg	597	1360	2110
TKN g/kg	6.93	16.0	33.9
Cl g/kg	1.18	3.0	11.4

Chemical Analyses

In general, chemical analyses of the refuse substantiated the results of the physical examinations (Table 4). Considerable carbon-containing materials remained in all cells. The mean TOC value for the refuse-only cells was 1270 g/kg on a dry weight basis and 1260 g/kg for the co-disposal cells. Mean COD values further substantiated the presence of considerable chemical oxidizable material in the cells after 10 years. The mean COD value for the refuse-only cells was 1750 g/kg on a dry weight basis and 1520 g/kg for the co-disposal cells on a dry weight basis. Considerable amounts of chloride and nitrogen remained in the waste materials in all cells. Nutrients should not have been limiting in any lysimeter.

The bottom gravel appeared to be in excellent condition in all cells. There was some intermingling and sticking of waste materials to the gravel at the waste gravel interface, but basically the gravel was like new. Some thin layers of black residue were on the gravel. Analysis of the gravel residue indicated the presence of sulfide in some cells and residual oxidizable organics in the residue from all cells.

The final leachate from the cells did not change significantly from the final sampling during the actual ten-year project in April 1983 to June 1984, when leachate was collected for this study. Based on the results obtained, no clear conclusion can be drawn concerning the effect of the lack of moisture on leachate quality.

Summary and Conclusions

Industrial sludges did not prevent biological decomposition, nor did these sludges eliminate indicator organisms that were found in relatively high levels in all cells. Many of the organisms isolated are known pathogens. Even after 10 years of disposal, many items were easily recognized and undoubtedly in their "as disposed of" condition. Disposable diapers containing fecal matter were found intact in all test cells. Protective wrappings such as plastic and paper bags had protected food wastes and other readily biodegradable material from decomposition. In fact, the protective wrappings appeared to be more inhibitory for biodegradation than the industrial sludges, indicating that plastic and paper bags should be torn open as much as possible to permit readily biodegradable material to decompose in the landfill environment. Leachate from refuse-only cells was not appreciably different from leachate drained from the codisposal cells. Moisture content positively affected decomposition. The higher the moisture content, the greater the decomposition found.

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Riley N. Kinman, Janet Rickabaugh, Jean Donnelly, David Nutini, and Martha Lambert are with the University of Cincinnati, Cincinnati, OH 45221.
***Joseph K. Burkart** is the EPA Project Officer (see below).*
The complete report, entitled "Evaluation and Disposal of Waste Materials Within 19 Test Lysimeters at Center Hill," (Order No. PB 86-176 336/AS; Cost: $16.95, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
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Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
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U.S. Environmental Protection Agency
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