CHARACTERIZATION OF LANDFILLED MUNICIPAL SOLID WASTE FOLLOWING *IN SITU* AEROBIC BIOREDUCTION

By

Matt C. Smith, K. C. Das, E. W. (Bill) Tollner
Biological and Agricultural Engineering Department
The University of Georgia
Athens, Georgia

William H. Johnson, Tim L. Davis
Arcadis, Geraghty & Miller
Atlanta, Georgia

J. Gordon Layton
Waste Management of Georgia
Atlanta, Georgia

INTRODUCTION

In January 1997, a pilot-scale project to assess the feasibility of *in situ* aerobic bioreduction of municipal solid waste was initiated at the Live Oak Landfill, located near Atlanta, Georgia. The high costs (money, regulatory hurdles, societal objections) of developing new landfills are making recovery and reuse of existing landfill space an increasingly attractive alternative. One of the first examples of landfill mining in the U.S. was the Collier County, FL landfill that began mining operations in 1986 (von Stein and Savage, 1993). The Collier County demonstration did not include aerobic bioreduction before mining. Some benefits of aerobic bioreduction of municipal solid waste (MSW) landfills include: reduced emissions of methane and reduced methane recovery costs; extended life of currently operating landfills; potential minimization of leachate and landfill gas contamination of ground water; stabilization and/or complete removal of old, unlined landfills.

This pilot-scale project was carried out in a lined cell containing approximately 70,000 yd^3 of MSW. The cell had been constructed using conventional techniques for the landfill and was approximately 30 feet in depth. The materials in the cell had been placed no more than three years before beginning this project. They were not segregated, or specially selected in advance, for this project, and the materials contained a significant portion of biosolids from waste water treatment plants.

To stimulate aerobic decomposition of the MSW, air and water (recycled leachate and additional fresh water) was injected into the fill material through wells. Routine monitoring of the process included temperature measurement; landfill gas composition; water volumes pumped and leachate generation; and physical, chemical, and biological chacterization of leachate. The details of the aerobic bioreduction process will be presented in future publications.

The purpose of this paper is to present a brief introduction to the project and to discuss initial results from analyses of the characteristics of the aerobically treated MSW.

AEROBIC BIOREDUCTION PROCESS

Water additions to the cell were initiated in mid-January 1997. Water additions were continued for approximately four weeks before initiating air injection to increase the moisture content of the MSW and reduce chances for fire. Average temperatures within the cell began to increase within three weeks of introducing air. Average temperatures within the cell during the process were approximately 120 °F. There were large variations in temperature throughout the mass, and some areas reached temperatures exceeding 160 °F. At about the same time as temperatures increased, landfill gas composition changed from greater than 40 percent methane and 0 percent oxygen to less than 10 percent methane and 1-5 percent oxygen. Microbial counts in the leachate increased at about the same time as shown in Figure 1. These factors suggested significant increases in biological activity within the cell.

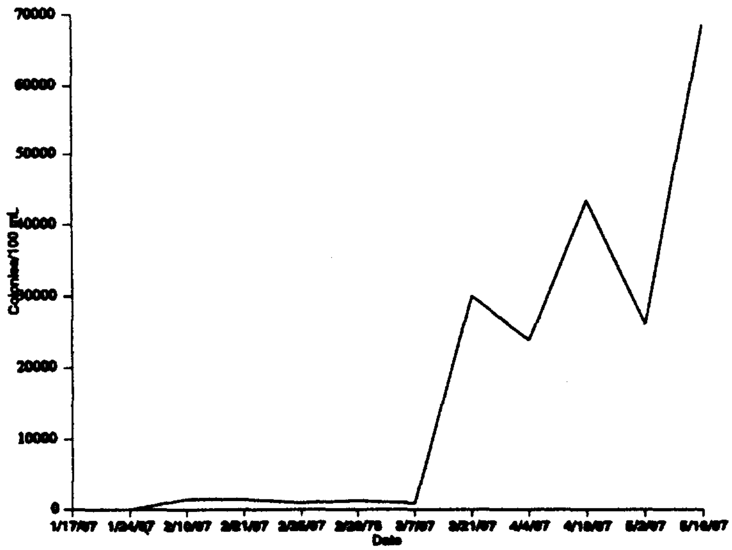

Figure 1. Microbial counts in leachate from Cell 3.

In May, the landfill mass was sampled by drilling in seven locations. Samples of the cuttings were collected during each five-foot progression of the drill bit. These were analyzed for, among other things, moisture content. The results showed that water content increased with depth, and that near the surface, the landfill mass was not much wetter than what would be expected in a normal landfill, *i.e.* water additions were not affecting moisture contents in the top of the fill. The results of these measurements are shown in Table 1. Visual observations during the drilling operation showed that the drier materials were the least decomposed and that the wetter areas were where the most degradation had occurred. These observations resulted in the redesign of the water distribution system to deliver water to the upper layers of the landfill mass. Figure 2 shows microbial counts as a function of depth in the augured samples.

Table 1. Average moisture content of bulk fill material as a function of depth from seven test holes

Depth, feet	**Moisture Content, % wet weight basis**
0-5	24.3
5-10	26.5
10-15	29.3
15-20	39.5
20-25	54.5

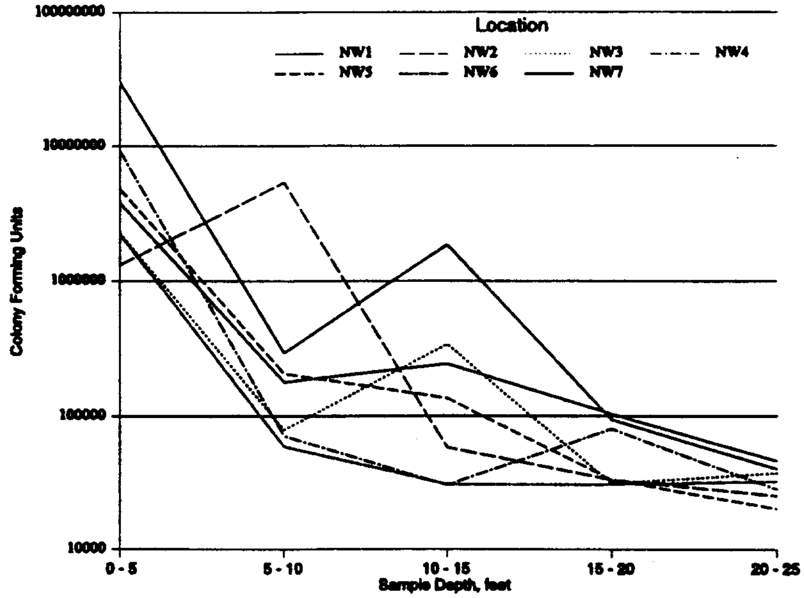

Figure 2. Microbial counts as a function of depth in drilled samples.

Accurate values of the amounts of water pumped into the cell are not available due to intermittent problems with flowmeters, particularly the meter on the leachate sump. The flowrates in the system were often low enough to allow flow through the meter without overcoming the inertia of the impeller, thus the meter failed to record all of the water pumped through it. From early January through mid October, at least 1,766,200 gallons of water were pumped into the cell. This is an average of 47,735 gallons per week or 6,819 gallons/day. The measured flow from the leachate sump totaled 703,920 gallons over the same period or 19,024 gallons per week (2,717 gallons per day.) The difference between total water pumped and leachate pumped represents makeup water provided from several sources - primarily city water and water from a nearby sediment pond.

There are at least two major conclusions to note related to water additions in Cell 3A. The first is that the aerobic bioreduction process requires tremendous quantities of water. Through the period of water additions discussed above, an average of approximately 25 gallons of water was added per cubic yard of fill. Even with these additions, there was no noticeable increase in the quantity of leachate produced by the cell. It is believed that much of the water was lost due to vapor diffusion through the boundaries of the cell and some water merely raised the moisture content of the fill without exceeding its water holding capacity. The second observation is that the quantity of leachate produced within a cell is entirely inadequate to supply the water requirements of the aerobic bioreduction process. Additional water from other sources is required.

CHARACTERIZATION OF BIOREDUCED LANDFILL MATERIALS

Beginning in October 1997 and continuing into 1998, small sections of cell 3A were mined and separated to assess procedures, equipment needs, and to characterize the materials recovered. To date, no attempt has been made to optimize the separation processes. The typical separation process used so far has been to pass the material through a trommel with a two-inch screen to remove the large fractions. The material that passes through the trommel screen is then conveyed into a second screen with 3/8 to 3/4 inch screens. The material passing through the second screen is generally a mixture of soil, composted organics and small bits of glass and metal. The materials that do not pass the second screen are generally large pieces of paper, plastic, wood, rock, *etc.*

Samples collected from each hole drilled in May were collected, screened (<0.5 inch), and composited to produce one sample for each depth increment. These samples were analyzed for oxygen uptake to determine whether they were essentially fully composted, *i.e.*, whether they were stable. These results showed that none of the materials were completely stabilized at the time of drilling.

Three samples were randomly collected from the small fraction (< 3/4 inch) obtained during the first dig and separation in October. These samples were again tested for stability and were stable with oxygen uptake rates ranging from 0.167 to 0.351 mg of oxygen per gram of volatile solids per hour. Respirometry measures of this type performed on compost have determined that oxygen uptake rates of less than 0.5 mg of oxygen per gram of volatile solids per hour indicate stable compost. Besides respirometry, these samples were analyzed for composition in terms of the fractions of recyclable materials. The results showed that the small fraction contained between four and 8 percent plastic, less than 1 percent metal, and less than 8 percent glass. The rest of the sample contained degraded organic materials, soil, and paper. Laboratory analyses of the metals content of the humus fraction showed that all of the metals were well within limits set for high quality compost.

Samples from several different excavations and combinations of separation equipment have been analyzed. Results of analyses of the smallest fraction (passing a 3/8 - 3/4 inch screen) obtained during separations in February 1998 are shown in Table 2. It is clear from Table 2 that additional processing of the fine fraction obtained during the initial separation will be required to remove inert materials such as glass, plastic, and metals from any material destined to be taken off site as compost.

Approximately 10 yd^3 of the materials that did not pass through the trommel screen were hand sorted to determine the composition. The results of this separation are presented in Table 3. This material probably contained more soil than it did coming out of the trommel due to scraping up soil with the sample as it was loaded for transport. As it was, paper and plastic accounted for 15.6 and 12.1 percent of the material, respectively, by weight. If we remove the soil and other small fractions, the fractions for paper and plastic would change to 35 and 27 percent by weight, respectively.

SUMMARY AND CONCLUSIONS

The demonstration of aerobic bioreduction of Cell 3A has achieved the initial goals set for the project. We have shown that we can convert the cell to aerobic metabolism. We can control the aerobic process within safe limits. We learned many things during the demonstration that will allow improved operation and performance of the process during full-scale operations.

The organic materials in the small fractions are stable, indicating that they were substantially degraded. The high percentage of paper in the large fraction, however, indicates that large paper objects such as magazines have not degraded well in Cell 3A. This may be due to insufficient water, or insufficient time. In any case, if we cannot modify the bioreduction process enough to increase degradation of these products, it might be necessary to consider some post processing to separate the paper products, chop them and recompost them along with the already degraded organics. This will serve to reduce the amount of nondegraded paper that must be disposed of and provide an opportunity to cure, further stabilize, and deodorize the final compost. This process might also be where we aim to achieve the minimum temperature-time combination necessary to prove significant pathogen reduction.

If the soil and degraded organic material fraction is going to be used off-site, it will be necessary to significantly improve removal of the small glass and metal fragments that are currently present in this fraction. Such separation effort might not be justified, however, and on-site use as intermediate cover might be a better use of this material. Samples of the fractions generated during this pilot-scale study are being evaluated for their potential for off-site use/recycling. These efforts are continuing and no final dispositions for the mined materials have been determined. The more these materials that can be used off-site, the more landfill air space will be recovered, and the more economically attractive this process becomes. It is possible, however, that the in situ bioreduction of MSW landfills can be economically justified on other grounds such as environmental impacts.

Many remaining questions will be answered as proceed with a full-scale test of the aerobic bioreduction process. In this test, we will be applying these techniques to a cell containing approximately 1,000,000 yd^3 of MSW. Results from this test should be available during the next two years.

REFERENCES

von Stein, E. L., G. M. Savage. 1993. Evaluation of the Collier County, Florida Landfill Mining Demonstration. U.S. Environmental Protection Agency, Cincinnati, OH. EPA/600/R-93/163.

Table 2. Characteristics of smallest fraction after separation.

Characteristic	Average	Std. Deviation
Physical/Chemical		
Moisture Content, % dwb	38.2	6.1
Volatile Solids, %	18.2	3.7
Respiration Index, mg O_2/g-VS/hr	0.552	0.296
Germination Index, %	68.2	10.1
pH	7.64	0.55
Electrical Conductivity, dS/m	1.97	0.52
Water Holding Capacity, %	82.0	11.2
Bulk Density, kg/m^3	1134.2	86.9
Avg. Particle Size, cm	0.53	0.08
Inerts, % of dry wt.	9.0	3.7
Sharps, % of dry wt.	0	0
Nutrients		
C, %	6.36	3.07
N, %	0.33	0.15
P, %	0.12	0.03
K, %	0.13	0.03
Ca, %	0.79	0.37
Mg, %	0.57	0.07
Mn, %	0.08	0.01
Trace Elements/Metals		
As (EPA Limit 41 mg/kg)	3.24	1.63
Cd (39)	1.19	0.72
Cr (1,200)	315.06	155.38
Cu (1,500)	97.68	13.77
Pb (300)	61.32	23.64
Mo (18)	0.78	0.35
Ni (420)	110.36	17.76
Se (36)	0.33	0.35
Zn (2,800)	252.73	139.95

Table 3. Composition of materials rejected by the trommel (> 2 inch).

Fraction	Weight, lbs	Percent by Weight
Wood	355.6	3.7
Plastics	1,155.4	12.1
Paper	1,484.8	15.6
Metal	415.6	4.4
Textiles	487.5	5.1
Rocks & Misc.	311.9	3.3
Soil & Other		
Inerts	3,242.6	34.1
Volatiles	1,121.6	11.8
Water	945.0	9.9
Total Soil & Other	5,309.2	55.8
Overall Total	9,520.0	100.0