TECHNICAL PAPER

ISSN 1047-3289 *J. Air & Waste Manage. Assoc.* **54**:815–822

Comparison of Aerobic and Anaerobic Biotreatment of Municipal Solid Waste

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ABSTRACT

To increase the operating lifetime of landfills and to lower leachate treatment costs, an increasing number of municipal solid waste (MSW) landfills are being managed as either aerobic or anaerobic bioreactors. Landfill gas composition, respiration rates, and subsidence were measured for 400 days in 200-L tanks filled with fresh waste materials to compare the relative effectiveness of the two treatments. Tanks were prepared to provide the following conditions: (1) air injection and leachate recirculation (aerobic), (2) leachate recirculation (anaerobic), and (3) no treatment (anaerobic). Respiration tests on the aerobic wet tank showed a steady decrease in oxygen consumption rates from 1.3 mol/day at 20 days to 0.1 mol/day at 400 days. Aerobic wet tanks produced, on average, 6 mol of carbon dioxide (CO_2)/kg of MSW as compared with anaerobic wet tanks, which produced 2.2 mol methane/kg of MSW and 2.0 mol CO_2/kg methane. Over the test period, the aerobic tanks settled on average 35%, anaerobic tanks settled 21.7%, and the no-treatment tank settled 7.5%, equivalent to overall mass loss in the corresponding reactors. Aerobic tanks reduced stabilization time and produced negligible odor compared with anaerobic tanks, possibly because of the 2 orders of magnitude lower leachate ammonia levels in the aerobic tank. Both treatment regimes provide the opportunity for disposal and remediation of liquid waste.

IMPLICATIONS

MSW landfills are currently regulated by Code of Federal Regulations Subtitle D guidelines, which, in effect, create a waste containment system with a 30-year post-closure monitoring requirement. Recent interest in the operation of landfills as bioreactors has created the need for comparative data to assess the potential advantages of aerobic and anaerobic bioreactors. This study considers MSW samples with the same composition under controlled laboratory conditions to compare settlement, gas production, and leachate quality to support the decision-making process concerning aerobic and anaerobic MSW landfill treatment strategies.

INTRODUCTION

The United States produces ~200 million t of municipal solid waste (MSW) annually,[1] of which 57% is disposed of in municipal landfills. With increasing costs and difficulties in permitting new landfill sites, existing landfill space is becoming a valuable commodity. Current regulations require capping of landfills to isolate waste from incoming rainwater and collection of leachate for treatment before release to the environment. In addition, landfill air emissions are required to be monitored to limit the release of methane (CH_4) and other volatile organic compounds. While this reduces the potential for contaminating surrounding air, soil, and groundwater, this design was intended to restrict exposure of air and water to the MSW. This slows or stops biodegradation rates, therefore, and increases the time required for landfill stabilization and contamination monitoring. A landfill is stabilized when leachate is no longer a pollution hazard, gas production is negligible, and the majority of settlement has occurred.[2]

In an effort to increase the biodegradation rates in landfills, there has been increasing interest in managing municipal landfills either as anaerobic or aerobic bioreactors. Bioreactors optimize the conditions for microbial decomposition and accelerate stabilization and settling, thus allowing for additional MSW disposal or faster land re-use. In both aerobic and anaerobic bioreactors, leachate produced by the MSW is recirculated, redistributing nutrients and bacteria through the MSW mass. In anaerobic bioreactors, the increased water content increases the rate of CH_4 production, making the collection and use of CH_4 for energy more economical.[3] If air as well as water is injected into the landfill, aerobic or at least microaerophilic conditions can be established in the landfill.[4] Aerobic biodegradation rates are more rapid and could potentially decrease the time to stabilization and increase settling rates of the MSW mass.

The addition of air stops CH_4 production, which is desirable in areas where CH_4 collection is not feasible. Under aerobic conditions, the ambient redox potential reverts from strongly negative to positive, which will affect metal speciation and movement and degradation of organic compounds. For example, aerobic conditions will limit fermentation reactions, which produce large amounts of acids and significantly reduce the pH, affecting solubility and sorption properties of organic and metal contaminants. Putrification and deamination processes that occur under anaerobic conditions, including the formation of hydrogen sulfide and ammonia (NH_3) compounds, are diminished in aerobic landfills, decreasing the noxious odors produced by the landfill.[5]

The strategy for the design and operation of landfill bioreactors will depend on several factors, including the economic, climate, environmental, and political status of the surrounding region. When deciding on an approach, the landfill operator will need to know how to compare the two regimes, possibly opting for a hybrid approach, operating in stages of aerobic and anaerobic digestion, thereby optimizing energy production, air space recovery, and long-term stabilization.

To understand the difference between aerobic and anaerobic bioreactors, more quantitative information is needed on CH_4 production rates and aerobic respiration rates. Although leachate recirculation to improve CH_4 production has been well studied in recent years,[1,3,6–8] there has been little work on aerobic biodegradation in landfills. Stessel and Murphy[9] designed and built aerobic landfill lysimeters filled with MSW gathered at a waste-collection facility. The air injection and leachate recirculation rates were varied to optimize decomposition. The study correlated increased airflow to increased settling and decreases in chemical oxygen demand (COD) of the leachate. In another study, March et al.[10] injected air and water into an existing landfill. They demonstrated increased settling and improvement in leachate quality as indicated by decreased heavy metals, biochemical oxygen demand (BOD), and COD. Increases in airflow were also correlated to increased microbial activity. In addition, volatile organic compounds, noxious odors, and CH_4 were negligible in the aerobic system.

While there have been successful full-scale implementations of both aerobic and anaerobic bioreactors, extreme heterogeneity and the large scale of MSW landfills makes comparison between the technologies difficult. This paper looks at mesoscale laboratory reactor systems that optimize the biodegradation parameters to measure respiration rates, CO_2 generation rates, subsidence, and leachate quality in three 200-L laboratory-scale bioreactors. Three treatments were applied to the bioreactors: (1) aerobic landfill (air injection with water addition and leachate recirculation), (2) anaerobic landfill (no air injection, water addition, and leachate recirculation), and (3) no treatment (no air injection or leachate recirculation), which was converted to a wet aerobic landfill (air injection with water addition and leachate recirculation) at day 197. In these closed systems, side-by-side comparisons of the degradation of identical but still heterogeneous and representative MSW samples are made to quantify degradation rates, gas production and respiration rates, and settlement in the aerobic and anaerobic systems.

BIOREACTOR EXPERIMENTS

Three bioreactors consisting of 200-L clear (height = 0.55 m, width = 0.71 m) hexagonal Lucite tanks (TruVu) were instrumented to monitor pressure, temperature, moisture, humidity, gas and leachate composition, and flow rates. All tanks contained 0.1 m of gravel at the bottom, overlain by 30 kg of typical MSW (see Figure 1). Air was injected into the bottom of the tanks for aerobic treatment, and gas was vented out the top. Leachate could be collected at the bottom of the tanks, recirculated, and sprinkled over the top of the MSW. The tanks were insulated on the sides and top with 2-in. solid foam and covered with vinyl fabric to block light. The aerobic tanks had a continuous flow of humidified air through the tanks. The anaerobic tanks were vented at the top to prevent pressure buildup.

The MSW was created from collection of fresh waste and was segregated by type and chopped manually to a

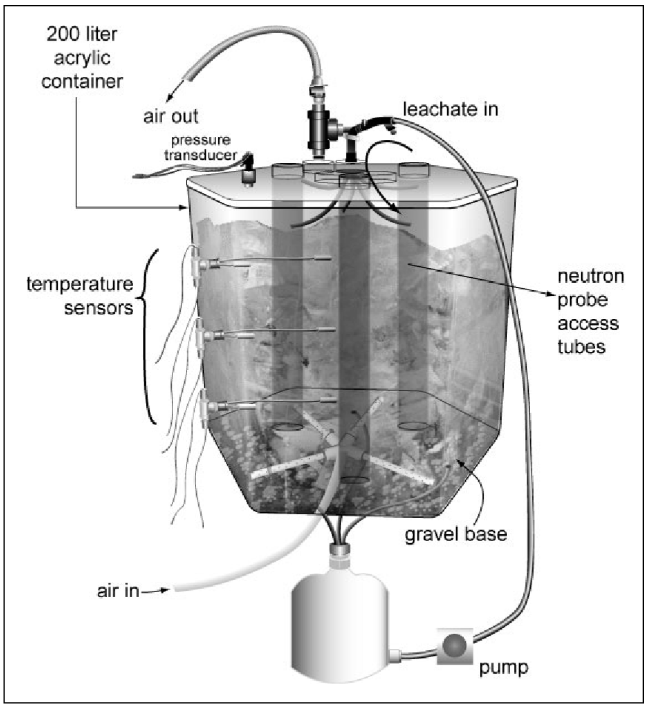

Figure 1. The laboratory bioreactor.

maximum width of ~5 cm. Sufficient MSW was prepared to fill three tanks simultaneously and was homogenized by mixing on a large tarp before filling the tanks. MSW composition was based on average values as determined by a literature search,[11–14] recognizing that composition of MSW streams are regionally and temporally variable. Table 1 shows average compositions from the literature and the compositions used in the bioreactors. The components were weighed as received, with no additional drying. Each bioreactor was loaded with 30 kg of MSW to give a final density of 164 kg/m^3. This density is scaled down from the compaction density (400 kg/m^3) of most landfills,[11–14] which was necessary to have proper fluid flow through the laboratory MSW bioreactor.

Table 2 illustrates the conditions in each of the tanks during the test period. Two experimental runs of 400 days were completed. In Experiment 1, one aerobic and one anaerobic bioreactor tank were tested, and the third tank was used to simulate conversion of a conventional dry anaerobic landfill to a wet aerobic landfill. To accomplish this, one tank from the experiment was not treated with water or air until day 197, when it was converted to an aerobic tank with leachate recirculation. Experiment 2 consisted of two aerobic and one anaerobic bioreactors. When the tanks were emptied and refilled between the two experimental runs, the gravel and the leachate were retained to act as inoculum for the second experimental run.

Both airflow rates and leachate recirculation rates are key operating parameters for landfill operators who wish to design a bioreactor. However, these values will be highly dependent on the geometry, compaction, and composition of the landfill system. For both Experiment 1 and Experiment 2, the tanks were wetted by adding deionized water to the MSW until leachate was produced. The leachate was then collected in a sump and recirculated at a rate of 20 mL/min. The recirculation rate was based on previous work by Stessel and Murphy[9] and was used as a fixed value. Water was replaced to maintain 3 L of water in the sump. This flow rate allowed for saturation of the MSW to occur after a few days.

The moisture content of the MSW was measured using a neutron probe (CPN). Neutron probes have been shown to be useful in monitoring the moisture content of landfills[14] as long as the count ratio is calibrated to the MSW composition. The calibration was established by measuring the probe response to a separate, but identical, MSW sample at various moisture contents. The tanks were each fitted with three 5-cm-diameter vertical Lucite tubes distributed evenly through the MSW mass (see Figure 1). The neutron probe measures the average water content in a 15-cm sphere surrounding the probe. The separation between the tubes allowed for three independent measurements of the moisture content, which were then averaged. For each reading, the probe was lowered to a point in the middle of the MSW mass, and duplicate readings were taken. Moisture content measurements were confirmed at the end of each experiment by drying 10 representative samples from the tanks and repeating the calibration curve on mature MSW.

Airflow rates, in addition to being dependent on the system configuration, are affected by the settling of the MSW, which can cause substantial changes in flow paths and even decrease the air permeability of the MSW. The goal was to provide sufficient air to maintain aerobic conditions but not to cause excessive drying or cooling of the tank. The oxygen (O_2) composition in the aerobic tanks was monitored in air exiting the tank, and it was determined that an airflow rate of 1.3 L/min (6.5 L/min/m^3 of waste) at standard temperature and pressure was adequate for the system. The aerobic tanks were aerated with this flow rate during the entire experiment. The O_2 concentrations in the exit air were generally the same as atmospheric levels. The injected air was humidified before entering the tank by sparging the air through water. Because the leachate drain was located near the air injection points, it was necessary to close the leachate drain after considerable subsidence had occurred to force

Table 1. MSW composition in bioreactors.

Component	Weight (kg)	Weight (%) with Soil	Weight % without Soil	Average Weight % from Literature
Paper (mixed, cardboard)	5.7(dry)	19(dry)	25.7(dry)	42.2(wet)
Food waste	3.6	12	16.2	12.1
Metal (aluminum, steel)	2.1	7.1	9.6	7.8
Glass	2.5	8.4	11.4	9.4
Plastic (bottles, bags)	2.4	8	10.8	6.4
Garden waste	2.7	9	12.2	12.8
Other waste (wood, rubble, textiles, rubber, leather, soil)	11	10.5	14.2	8.2
Soil	7.8	26	—	—

Table 2. Tank operating conditions.

Tank Description	Duration (Days)	Treatment Description	Recirculation Rate (mL/min)	Airflow Rate (L/min)
		Experiment 1		
Aerobic, wet	400	Air injection Leachate recirculation	20	1.9
Anaerobic, dry	0–197	No air injection No leachate recirculation	None	None
		Converted to		
Aerobic, wet	197–400	Air injection Leachate recirculation	20	1.9
Anaerobic, wet	400	No air injection Leachate recirculation	20	None
		Experiment 2		
Aerobic, wet	400	Air injection Leachate recirculation	20	1.9
Aerobic, wet	400	Air injection Leachate recirculation	20	1.9
Anaerobic, wet	400	No air injection Leachate recirculation	20	None

air through the MSW to maintain aerobic conditions. The drain was opened daily to allow for drainage and recirculation of the leachate.

Headspace gas analysis of CO_2, CH_4, and O_2 were measured as %-by-volume using a landfill gas monitor equipped with a data-logging function (CES LandTec). This instrument was able to give the desired accuracy (±0.2%) and had the advantage of being able to collect automatic gas composition data, which was necessary for obtaining respiration rates. Calibration was established for each of the gas components using manufacturer-supplied gas standards and concentrations of the components in standard air.

Data collection of temperature, pressure, and gas flow rate was automated using LabView Data Acquisition software (National Instruments). Each tank was fitted with six temperature sensors (Watlow) and two pressure transducers (Setra). The air outflow of the aerobic tanks was measured with a flow meter (McMillan), and the air inflow was controlled with a mass flow controller (Aalborg). One pressure transducer was located at the top of the tank, to monitor air pressurization of the landfill tanks. Another pressure transducer was located at the bottom of the tank. This measured the water pressure head at the bottom of the tank.

Leachate samples were taken from the bottom of the tanks to assess leachate quality and stabilization of the waste mass. COD, BOD, conductivity, Eh, pH, and total dissolved solids were determined using standard methods.[15] NH_3 was analyzed using the Nessler method.[14]

For purposes of comparison, leachate samples were taken from the Yolo County (California) Central Landfill (YCCL) bioreactor project. Leachate samples were collected from the leachate pump station in sterile glass bottles and kept at 4 °C during transport. All analyses were completed within 24 hr.

RESULTS AND DISCUSSION

As mentioned previously, the neutron probe gives an average measurement of 15-cm measurements around the probe. Three measurements per tank varied as much as 20%. This could be caused either by differential wetting or by differences in the MSW composition surrounding the probe. Even so, the average moisture content of the wetted reactors was relatively consistent between tanks. The moisture data as determined by neutron probe measurements indicated that the bioreactors maintained an average volumetric moisture content (volume of H_2O/volume of MSW) of 0.16 ± 0.02. With an MSW density of 164 kg/m^3, this corresponds to 54% moisture by weight (weight of water/[weight of water + MSW]). At the end of the experiments, the randomly selected dried MSW samples had an average of 42 ± 16% moisture by weight. The lower values are most likely caused by draining of the water during dismantling of the tanks. The average volumetric moisture content of the dry tank was 0.7 kg/m^3. The exit air of the tanks maintained 100% relative humidity throughout the test. The pressure transducers located at the bottom of the bioreactors did not record any increase in pressure because of water accumulation and verified that the pressure in the tanks was the same as atmospheric throughout the experiments.

Temperature profiles in the tanks during the first 20 days of treatment increased from room temperature (20 °C ± 3 °C) to 27 °C for the aerobic and anaerobic tanks, and to 34 °C for the dry tank. The temperature in the dry tank was higher because there was no air or water flow to cause cooling. After 20 days, the tanks returned to room temperature for the duration of the experiment. A similar temperature increase was seen when the dry anaerobic tank was converted to an aerobic system. Although attempts were made to insulate the tanks, the airflow and water circulation combined with the large surface-area-to-mass ratio did not allow the tanks to maintain elevated temperatures. Temperature sensors indicated that the temperature was uniform throughout the tank. Previous field demonstrations of aerobic landfill treatments have shown temperature increases up to 60 °C.[10] It is well known that temperature plays an important role in the kinetics of reactions. Therefore, degradation rates measured at 20 °C may not be representative of field reactions that may occur at elevated temperatures. Because it is likely that the decomposition rates seen in this experiment would have been much higher if the temperature had been closer to expected field conditions, these results represent the conservative expectations for the reactions measured.

CH_4 and CO_2 production rates for the anaerobic tanks are shown in Figure 2. To maintain conditions for methanogen growth, the pH of the leachate was maintained at 7.5 by addition of sodium bicarbonate ($NaHCO_3$) and purging the headspace with nitrogen to lower CO_2 concentrations. After the nitrogen purge, the rate of CH_4 and CO_2 production rate was measured by monitoring gas composition changes. Total CH_4 production for the anaerobic tanks was 2.2 mol/kg MSW, for a total of 1.5 m^3 CH_4 per tank (0.05 m^3 CH_4/kg garbage).

O_2 concentration in the outlet air of the aerobic tanks was typically between 19 and 20%, and CO_2 concentrations were 0–1%, similar to atmospheric conditions. Periodic respiration tests were conducted to measure the O_2 consumption rates by stopping air injection and monitoring the consumption of O_2 and production of CO_2 in the tank. A typical respiration test is shown in Figure 3. The O_2 consumption rate, or respiration rate, was estimated using the slope of the O_2 depletion curve. The respiration rates declined steadily in the tanks because of the loss of readily degradable material (see Figure 4). The O_2 respiration data was fit with a logarithmic curve ($O_2 = -0.5 \ln(t) + 2.9$; $r^2 = 0.779$, with t = time in days). This was used to calculate the total production of CO_2 from the aerobic tanks. The aerobic tanks produced, on average, 6 mol of CO_2/kg of MSW as compared with the anaerobic tanks, which produced 2.2 mol of CH_4/kg and 2.0 mol of CO_2/kg.

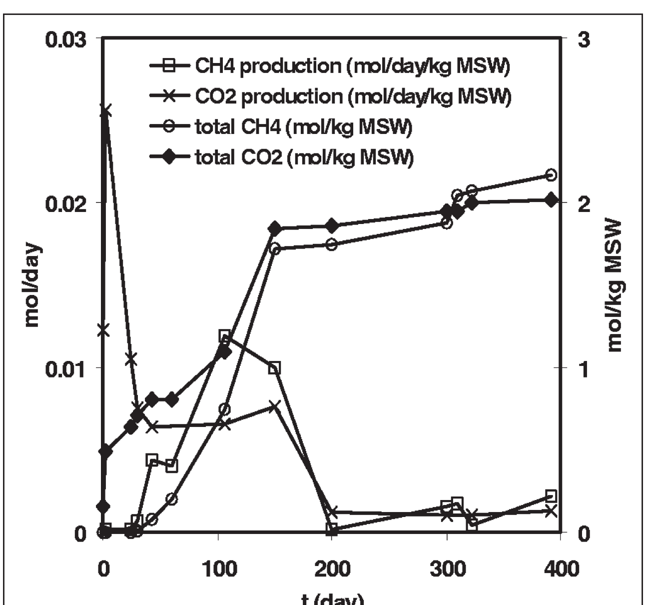

Figure 2. Landfill gas composition from the anaerobic wet tanks.

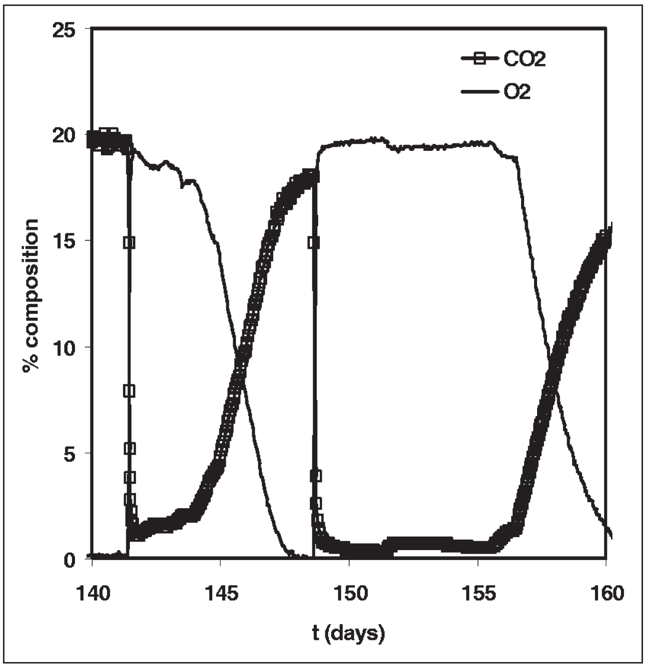

Figure 3. Typical gas composition for the wet aerobic tanks over a 20-day period. This figure shows an example from a wet aerobic tank from Experiment 1, from day 140 to day 160. The dip in the O_2 concentration and increase in CO_2 concentration is caused by respiration tests. CH_4 was not detected.

As mentioned previously, one tank was maintained dry and anaerobic for the first 197 days. This tank developed anaerobic conditions within 48 hr of filling and sealing the tank and maintained 20% CO_2 concentration. The tank appearance at day 197 was very similar to that at

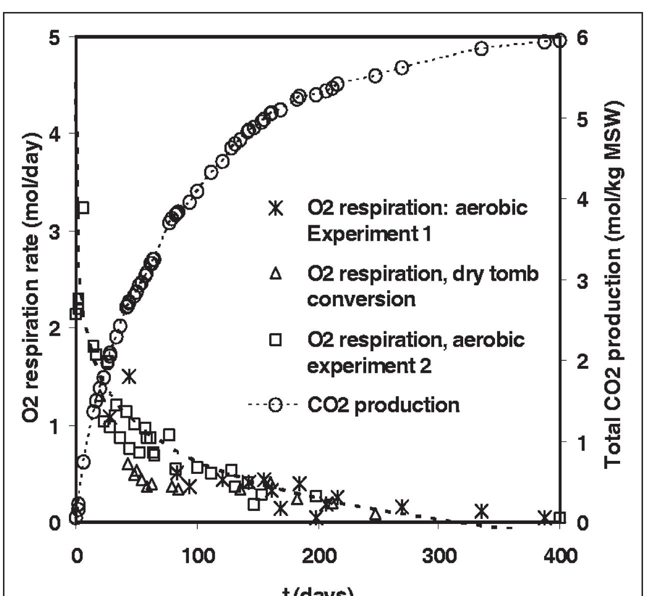

Figure 4. Decline in O_2 consumption rates and average total CO_2 production as the MSW aged in the aerobic wet tanks. The dashed line through the O_2 consumption rates represents a logarithmic curve fit through data from all tanks.

day 1 of the experiment, and the tank produced little odor and no leachate. At day 197, this tank was converted to aerobic conditions by addition of water and air to the tank. Respiration test data for this tank were fitted to the curve established by the other aerobic tests by adjusting the time scale to the start of the aerobic experiment on day 197. The similarity to the aerobic tank data after the correction confirms that little decomposition of the MSW had occurred during the dry treatment.

The aerobic tanks and the anaerobic tanks both changed in appearance over the course of the experiment. The only recognizable objects in the aerobic tanks at 400 days were the metal, plastic, glass, rubber, and some textiles. The appearance of the residual MSW in anaerobic tanks was similar except for the paper products, which, other than effects of wetting, were nearly pristine.

There was a discernable difference in the odor between anaerobic wet tanks and aerobic tanks. No noxious odors were detected from either of the aerobic tanks throughout the test period. The noxious odors from the anaerobic tank, however, necessitated careful sealing and venting to prevent escape of odoriferous leachate or gas. Contributing to the odor were high NH_3 (400 mg/L) and sulfides (0.6 mg/L) in the anaerobic leachate compared with the aerobic leachate.

The pH was monitored throughout the experiment in all tanks except for the dry anaerobic tank, which did not produce any leachate until after the water addition at day 197. The pH of the aerobic tanks was 7.8 ± 0.4 throughout the experiment. During conversion from the dry anaerobic to aerobic, the pH was initially 6 ± 0.3, but after day 213 the pH remained stable at 7.5 ± 0.4. The pH of the anaerobic tanks was adjusted to 7.5 by a one-time addition of 500 g of $NaHCO_3$ to the leachate sump. The Eh in the aerobic tanks consistently remained between 200 and 300 eV. The Eh in the anaerobic tanks dropped from −100 eV to −300 eV when CH_4 production began. The conductivity of the tanks was fairly constant over time and averaged 3.7 ± 0.6 mS for the aerobic tanks and 15 ± 3 mS for the anaerobic tank.

COD and BOD are often used to determine the degree of degradation of the MSW. Although the criteria vary, there is some consensus that stabilized landfill leachate has a BOD/COD value of less than 0.1, a BOD value less than 100 mg/L, and COD less than 1000 mg/L.[16] At 365 days, the BOD of the aerobic tank was 4 mg/L and the COD was 159 mg/L, giving a BOD/COD value of 0.03. The anaerobic tank at 365 days had values of 137, 305, and 0.45, respectively (see Figure 5). By these general criteria, the aerobic tank had reached a more stable state, because both COD and BOD indicate that there is more nondegraded organic material in the anaerobic tank leachate than in the aerobic tanks. For comparison, the more mature (~6 years) YCCL anaerobic bioreactor[17] leachate had values of 102.7 mg/L for the BOD and 2419 mg/L for the COD, giving a BOD/COD ratio of 0.042.

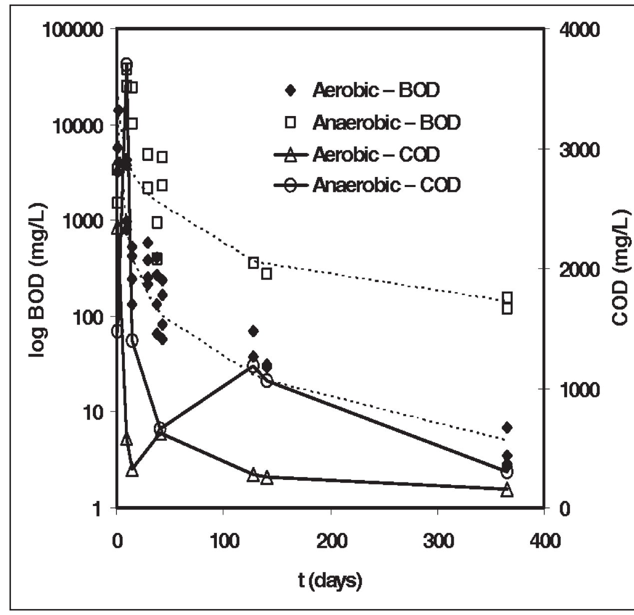

Figure 5. BOD and COD measurements from the aerobic wet and anaerobic wet bioreactors. All data are from Experiment 2.

Leachate NH_3 levels in the aerobic treatment tanks started as high as 100 mg/L but rapidly dropped to ~2 mg/L (see Figure 6). The NH_3 levels in the anaerobic system, however, continued to rise, reaching 400 mg/L at 365 days. This value is comparable to leachate samples taken from the YCCL anaerobic bioreactor project that had a value of 558 mg/L of NH_3. Because high NH_3 levels can inhibit methanogenesis,[18] the NH_3 would eventually have to be removed using secondary treatment. The high NH_3 levels may also affect the BOD values, although the microbial community in the anaerobic leachate may not have a large enough community of nitrifiers to cause significant oxidation of NH_3 in a 5-day bottle test. Recent studies[19] have indicated that NH_3 may be a longer-term pollutant issue than organic carbon in the leachate, mainly because no mechanism for its removal exists under methanogenic conditions.

Settlement or subsidence of MSW is a key parameter that distinguishes between the dry landfill and a bioreactor landfill.[18] Although subsidence will depend on the type of MSW in the landfill, moisture content, style of filling, and compaction, increased subsidence caused by the bioreactor effect is a compelling benefit. Several previous studies have measured subsidence. The YCCL bioreactor project measured a 16% subsidence with leachate recirculation over a period of 4 years as compared with a 3% subsidence in the control cell.[7] In a laboratory aerobic

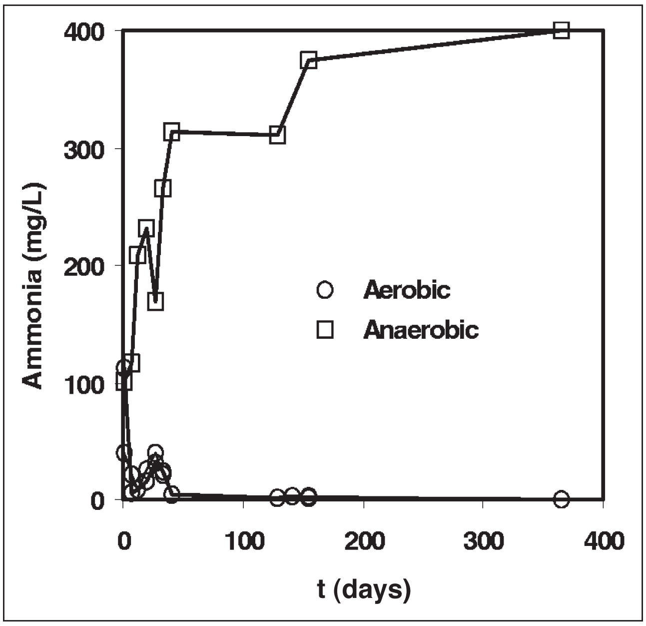

Figure 6. NH_3 concentrations in the aerobic and anaerobic bioreactor leachate. Data from Experiment 2.

bioreactor filled with municipal waste, Stessel and Murphy[9] demonstrated 18–30% settling over a 65-day test period. Figure 7 shows the settlement for the bioreactors in the current experiment. The clear sides of the reactor allowed estimation of MSW settlement by observing the average height of the MSW mass in the tanks. An initial rapid settlement was observed in all the tanks immediately after filling because of the wetting of the paper and settling caused by gravity. The aerobic treatment demonstrated the most settling over the test period, with a maximum settling of 32% observed at 400 days. The anaerobic treatment showed 20% subsidence, and the dry anaerobic tank settled 7% before conversion to aerobic conditions. For comparison, the MSW was weighed when removed from the tanks. The average weight of the residual wet anaerobic MSW was 43 kg, corresponding to a dry weight of 23 kg, giving a 23% net loss of MSW. For the wet aerobic tanks, the average wet weight was 35 kg, corresponding to a dry weight of 19%, which is a 36% loss in MSW mass. These measurements correlate well to the settlement observations.

At the end of an experimental run, the anaerobic tanks were aerated to gain a comparative measurement of the garbage decomposition state. Air was pumped into the tanks for 3 days, and respiration tests were performed that were identical to the type performed routinely on the aerobic tanks. The O_2 consumption rate of the anaerobic bioreactor was 0.25 mol/day. This value corresponded to the rates observed in the aerobic tank at 200 days. There are three sources of O_2 demand in the anaerobic tank: (1) partially decomposed MSW, (2) dissolved organics in the leachate, and (3) NH_3 in the leachate. Using this closed-system respiration test technique, the decomposition state of the anaerobic tanks would be ~50% of the aerobic tanks after 400 days. This correlated well with the subsidence values in Figure 7 and the mass losses calculated from wet weights. O_2 demand required for complete removal of the 400 mg/L NH_3 in the anaerobic leachate would be ~1.6 mol. However, the combination of the short aeration, which would not have given sufficient time for a nitrifying population to develop, coupled with the high BOD value in the leachate (140 mg/L) suggests that the O_2 demand stems from other sources rather than NH_3. Additional studies are needed to determine how fast the microbial population responds to aeration.

CONCLUSIONS

In this study, side-by-side comparisons of the degradation of identical but heterogeneous and representative MSW samples were undertaken to quantify degradation rates, gas production and respiration rates, and settlement in the both aerobic and anaerobic bioreactors. The results indicate that maintaining the MSW landfill as an aerobic bioreactor increased the rates of settling and stabilization and produced more environmentally benign leachate and gas. The aerobic landfill bioreactors showed significantly more settling and mass loss than the anaerobic bioreactor and maintained a neutral pH and low levels of all measured parameters, including BOD, COD, and NH_3, compared with the wet anaerobic bioreactor leachate. The reduction in noxious odors was also a significant esthetic advantage of the aerobic system.

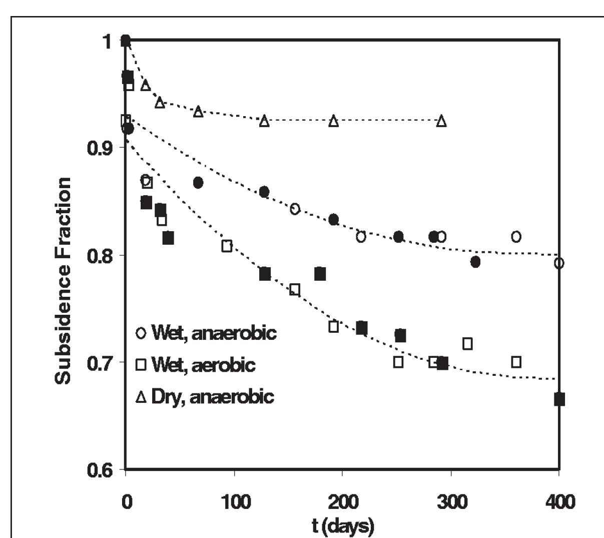

Figure 7. Cumulative settlement of the MSW from 0 to 400 days. Settlement levels from Experiment 1 have open symbols and those from Experiment 2 have closed symbols. The dashed lines are second degree polynomial fit to the data (aerobic, r^2 = 0.8983, and anaerobic, r^2 = 0.8091) and connected symbols for dry anaerobic.

ACKNOWLEDGMENTS

This work was supported by the Director, Office of Science, of U.S. Department of Energy under Contract No. DE-AC03–76SF00098. The authors thank the following LBNL staff for invaluable assistance on this project: Ramin Yazdani from the Yolo County Central Landfill for aiding in the collection of leachate samples, Barry Freifeld of LBNL for setting up the data acquisition system, Shelly Worsham of LBNL for help with the MSW collection, and Dominique Joyner for her help with sample analysis and materials processing. The authors also thank Will Stringfellow and Jil Geller for their careful reviews of this manuscript.

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