Biotreatment of Municipal Solid Waste in Aerobic and Anaerobic Laboratory Bioreactors

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Research Questions

As the requirements for stabilization and containment become increasingly stringent operating landfills as bioreactors is becoming more economically feasible. To compare the use of aerobic and anaerobic management strategies three 200-liter tanks filled with fresh waste materials were used to provide the following conditions: (a) aerobic (air injection with leachate recirculation), (b) anaerobic (leachate recirculation), and (c) a dry-tomb anaerobic landfill (no air injection, no water addition and no leachate recirculation). The tanks were monitored for metals leaching, nutrients, organic carbon, subsidence, gas composition, respiration rates, and microbiological activity for up to 500 days.

Experimental Design

Two aerobic and one anaerobic bioreactor, all three having leachate recirculation, (Figure 1) were constructed in 200-L acrylic tanks. Each was filled first with a 10 cm layer of gravel that was inoculated with a bacteria culture from an earlier landfill experiment, and then filled with MSW generated in the lab. Garbage composition is shown in Table 1. The waste was shredded by hand to approximately 2-inch pieces, mixed, and then added to all three tanks. Each tank had gas flow into the bottom and out the top (for the aerobic tanks) and leachate was collected from the bottom and distributed over the top of the waste (both the aerobic and anaerobic tanks). The leachate to be analyzed was sampled from the leachate recirculation tubing that transported the leachate from the bottom to the top of the tanks.

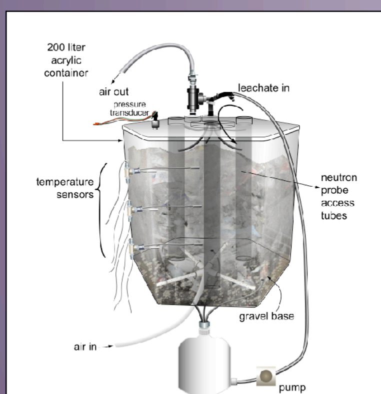

Table 1: Garbage Composition in Bioreactors
(mass shown is mass in each tank)

Component	Mass in Tanks A (aerobic) and C (anaerobic) (kg)	Mass in Tank B (aerobic) (kg)
Paper (mixed, cardboard)	5.88	5.88
Metal	1.12	1.12
Glass	2.55	2.55
Plastic (bottles, bags)	2.36	2.36
Garden Waste	6.64	3.32
Soil	2.06	2.06
Food Waste	6.98	3.49
Other Waste (wood, rubble, textiles)	2.06	2.06

Results

Leachate from the aerobic tank had significantly lower concentrations of all measured parameters, both organic and metal, after only a few weeks of operation. Respiration tests on the aerobic tank showed a steady decrease in oxygen consumption rates from 1.3 mol/day at 20 days to 0.1 mol/day at 300 days (see Figure 1). Over the test period, the aerobic tank settled 35%, the anaerobic tank 21.7% and the dry-tomb tank 7.5% (see Figure 2). Metals leaching were low throughout the test period for the aerobic tanks, and decreased over time for the anaerobic tanks (Table 2). Microbiological testing showed high biomass and diversity in both the aerobic and anaerobic bioreactors, high activity in the anoxic leachate, but low activity in the aerobic leachate.

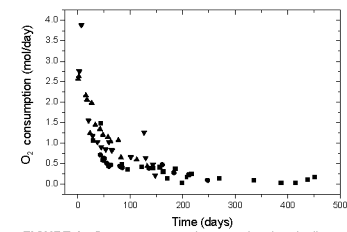

FIGURE 1. Oxygen consumption rate showing decline during aging of the MSW in the aerobic tanks.

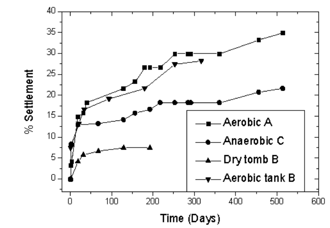

FIGURE 2. Cumulative settlement of the MSW from 0 to 500 days. The start time of the aerobic tank B has been corrected by 197 days for the period of time it was managed as a dry tomb.

Metals Composition

Element	Aerobic A (ppb)	Aerobic B (ppb)	Aerobic C (ppb)
Mg	7180	8360	37200
Mn	48.2	27.9	2290
Fe	63.3	48.7	1530
Si	1780	1590	6440
Sn	657	883	2410
Ca	22900	26800	219000
Na	79700	73200	855000
K	ND	31900	129000
B	426	360	199
Al	<PQL	26.5	<PQL
Sb	2.5	12.2	6
Ba	40.9	41.2	56.9
Cr	<PQL	<PQL	18.5
Co	<PQL	1	4.4
Cu	10.1	14.9	8.5
Pb	<PQL	<PQL	31.4
Ni	34.5	7.8	18.7
Zn	12.2	10	27.8
Sr	130	136	639
Cd	1.1	0.5	2.1

Parameter 1	Parameter 2	Correlation
Ammonia	Conductivity	0.998
	Salinity	0.997
	Total Dissolved Solids	0.998
	Calcium	0.959
	Zinc	-0.988
BOD	pH	-0.973
	Manganese	0.996
	Strontium	0.992
Nitrogen	Ammonia	0.977
	Conductivity	0.987
	Salinity	0.989
	Total Dissolved Solids	0.987
pH	Manganese	-0.988
	Strontium	-0.953
Phosphorous	BOD	0.982
	pH	-0.986
	Manganese	0.989
	Strontium	0.952
Sulfide	Potassium	0.963

Example Correlations from Correlation Matrix of Bioreactors

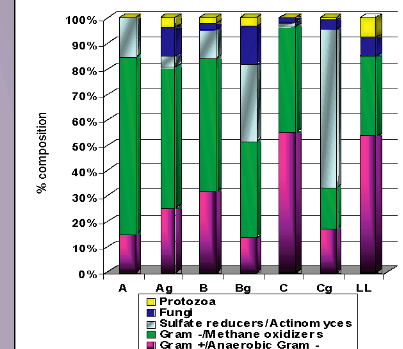

Figure 3. Microbial Community Distribution in Landfill Bioreactors and Landfill Leachate Samples

Average Values of Measured Parameters

Measured Parameter	Aerobic A Leachate	Aerobic B Leachate	Anaerobic C Leachate	Yolo County Emhanced Leachate
Phosphomonoesterase Activity (mg/hr)	23.7	37.8	23.2	18.9
Dehydrogenase Activity (mg/hr)	23.9	6.42	9.53	1.3
Nitrogen (mg/L)	25.7	25.9	312.1	81.6
Phosphorous	5.0	3.3	60.1	9.9
BOD (mg/L)	2712	1062	8901	112
COD (mg/L)	1096	509	2392	1685
Sulfides (mg/L)	0.31	0.26	0.38	0.36
Ammonia (mg/L)	20.3	25.5	215	144
TOC (ppm)	1208.3	2628	3.90	416
DOC (ppm)	1215.9	638	3.80	303
pH	7.6	7.5	6.5	7.6
Conductivity (mS)	4.2	3.1	12.7	14.08
Salinity (ppt)	2.2	1.6	7.2	6.1
TDS (mg/L)	1958	1566	7109	1226
Eh (mV)	161	182	25.9	108

Conclusions

This study demonstrated that maintaining the MSW landfill as an aerobic bioreactor increased the rates of settling and produced more environmentally benign leachate and gas. The aerobic landfill bioreactors showed significantly more settling than the anaerobic reactor and maintained a neutral pH and low levels of all measured parameters (nitrate, phosphate, BOD, COD, and metals) compared to the wet, anaerobic bioreactor leachate. The reduction in noxious odors was a significant advantage of the aerobic system. These results suggest that aerobic management of MSW landfills could increase the rate of stabilization, produce less potent greenhouse gases, eliminate the need for leachate and air emissions treatment systems, reduce odor, and reduce the need for extensive containment strategies.

References

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2. White, D.C., Davis, W.M., Nickels, J.S., King, J.D., Bobbie, R.J. Determination of sedimentary microbial biomass by extractable lipid phosphate. Oecologia. 1979. 40. 51-62.

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