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Project Summary

Evaluation of Mixing Systems for Biogasification of Municipal Solid Waste

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An investigation was conducted of systems for mixing municipal solid waste (MSW) with municipal sewage sludge (MSS) in an anaerobic digester to produce usable fuel (methane gas). Adequate mixing is of paramount importance to the success of this biogasification process. Gas draft tubes and mechanical agitators were evaluated for use in a 387,500-L (100,000-gal), 10.7-m-diameter digester. Feed ratios of MSW to MSS were either 3:1 or 9:1. Loading rates of volatile solids varied from 1.25 to 3.125 g/L per day, and total solids in the feed were 4, 7, or 10 percent. Hydraulic retention time was 22.5 days, except for one 11-day study.

Problems that occurred during the study were dense scum formation (hard cellulose mats up to 1.5 m thick), heavy wear on the mixing systems as a result of the cellulose fibers and grit from the MSW/MSS mixture, and insufficient amounts of volatile solids in the mixed zone. The digester operated without problems as long as the total solids level was 5 percent or below; higher concentrations resulted in insufficient mixing and operational problems.

Increased mixing power would improve the distribution of volatile solids, probably decrease scum formation, and result in increased gas production. But maintenance problems resulting from the nature of the MSW/MSS mixture and the increased energy costs of a higher-powered mixer would detract from system performance. MSW/MSS mixtures with high cellulose contents are therefore judged not to be amenable to anaerobic digestion using the same methods employed for municipal wastewater.

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

Introduction

Background

The production of usable fuels from municipal solid waste (MSW) is a subject of great interest and concern in view of current costs and supplies of energy. One possible method of fuel recovery from MSW is the production of methane gas during anaerobic digestion.

Anaerobic digestion has been associated with wastewater treatment plants for many years, but the nature of municipal sewage sludge (MSS) is quite different from MSW. Incoming wastewater solids of MSS are approximately 70 percent organic and 30 percent inorganic. Much of the inorganic material is removed in pretreatment units and thus is kept from the anaerobic digestion units. Normally, these units receive both raw and biological (secondary treatment) sludge. Natural decomposition then proceeds on this MSS.

MSW, on the other hand, contains a much larger inorganic fraction than MSS, and its organic fraction is composed largely of water insoluble cellulosic materials. A large part of the organic fraction of MSS is also cellulosic, but it is made up mostly of toilet paper that has been pretreated to improve its solubility. (Insolubility limits the rate of degradation because of enzyme accessibility to certain areas.) Also, the grit in the MSW feed is highly abrasive to the system operation.

As part of a research program on fuel recovery from municipal solid waste, the U.S. Environmental Protection Agency (EPA) sponsored this investigation of the feasibility of mixing MSW and MSS in anaerobic digesters to produce methane gas. This biogasification study employed a 387,500-L, 10.7-m-diameter digester to which was fed various ratios of MSW:MSS at various loading rates of volatile and total solids

Previous Investigations

Investigations dealing with the anaerobic digestion of the entire organic fraction present in MSW have been conducted. In most cases, MSS was added to the reactors to provide nutrients. The digestion studies of Golueke and McGouhey[1] showed that MSW could be digested. Their organic loading rates were the same as those used in this study. Pfeffer[2] studied the various technical and economic aspects of anaerobic digestion of a MSW/MSS mixture. He reported that gas production varied, depending on the loading rate, detention time, and temperature. Klass and Ghosh[3,4] studied the anaerobic digestion of MSS and shredded refuse in which the organic materials (including paper fiber) were separated from the inorganics. The Dynatech Research and Development Company[5] conducted laboratory experiments and made preliminary cost estimates for a refuse biogasification plant and concluded that the process was feasible. But their estimates of mixing requirements were based on wastewater treatment practice and are probably too low. Diaz et al.[6] conducted studies in which scum layer accumulation was noticed. Addition of a mechanical mixer to the laboratory-scale reactor resolved this problem.

Methods and Materials

Methods

Before a large-scale study was undertaken, a laboratory investigation was conducted using two 208-L laboratory digesters at several MSW:MSS ratios and volatile solids loading rates. These initial studies showed that cellulose tended to accumulate and form a fibrous mat at the top of the digester.

Following this laboratory study, a 378,500-L digester was used for a full-scale 75-day study. The study was terminated early as a result of the formation of a scum layer 0.6 to 1.5 m thick. Additional tests were then performed with the same digester vessel to compare mixing methods. Four tests were conducted with gas draft tubes, and five were done with mechanical agitators. Operating parameters observed were the mixing mode, feed ratio, loading rate, and percent of total solids in the feed.

Apparatus

The digester vessel was equipped with a 10-hp (7.5 kW) Chemineer Model 4HTD10* mechanical mixer with 1.4-m agitator blades, an Aerohydraulics Model 3-12 expanding piston gas mixer, and a 40-hp (30kW) Vaughan Model 300 scum breaker pump. The scum breaker was added for startup operations and for helping to breakup excessive scum layers. The gas mixer used the self-generated biogas as its mixing gas. Figure 1 shows the location of the apparatus and the sampling points. Oiled-fired hot water coils at the perimeter provided temperature control of the digester.

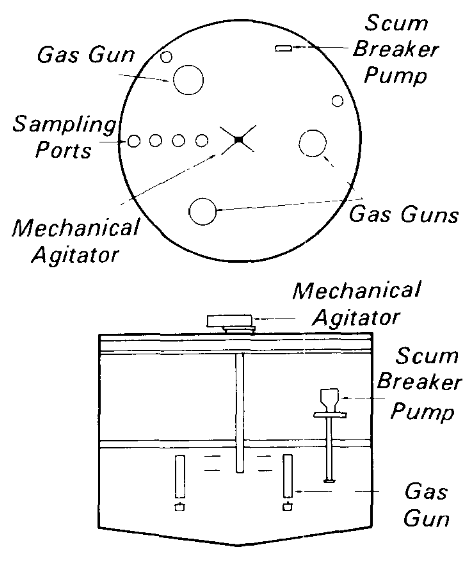

Figure 1. Schematic view of anaerobic digester.

Feedstock

The feedstock used for this study was a MSW/MSS mixture. The MSS came from the regional wastewater treatment plant in Franklin, Ohio, and the MSW consisted of the organic reject stream from the Black Clawson Fiberclaim Corporation plant at Franklin, Ohio. The organic reject is a finely pulped slurry of MSW that has been cleaned of excessively gritty organic and inorganic materials and typically has a solids concentration of 4 percent.

Procedures

Evaluations were made of nine independent tests at various loading rates and ratios of MSW to MSS; total solids concentrations varied from 4 to 10 percent. Table 1 provides a summary of the operating conditions.

Total and volatile solids distributions were measured for each test. Samples were taken from five sampling ports at the top, middle, and bottom of the digester vessel (Figure 1). Results provided a profile of the digester contents and were used to determine the effectiveness of each test.

Digester Control

No process can be operated without having adequate control and an indication of its progress. The total solids test was used as an external control to monitor what was coming into the digester. Measurements of temperature, volatile acids, alkalinity, and pH were used as internal controls for assessing the condition of the microbial culture inside the digester.

The digester was heated to mesophilic temperatures (32° to 35°C) and controlled in this range for the nine independent tests. To measure the microbial condition in the digester, volatile acids, pH, and alkalinity results for the digester effluent and some random internal samples were determined for each independent test. Total and volatile solids were measured each day at the three different digester levels to access the mixing modes.

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*Mention of trade names or commercial products does not constitute endorsement or recommendation for use

Table 1. *Summary of Operating Conditions*

	Mixing Mode	*Feed Ratio (MSW:MSS)*	*Loading Rate (g volatile solids/ L/day)*	*Total Solids in Feed (%)*
1.	Gas	3:1	1.25	4
2.	Mechanical	3:1	1.25	4
3.	Gas	3:1	2.35	4
4.	Gas	9:1	1.25	4
5.	Mechanical	9:1	1.25	4
5.	Mechanical	9:1	2.19	7
7.	Gas	9:1	2.19	7
8.	Gas	9:1	3.125	10
9.	Mechanical	9:1	3.125	10

The pH of the digester was maintained near neutral (6.8 to 7.2) for all nine tests. Figures 2 and 3 show daily pH values for the second (mechanical) and eighth (gas) mixing tests. The pH is a simple test, but it should not be depended on as a process control parameter because of the alkalinity in the digester.

The volatile acids/alkalinity ratio is the major internal process control measurement and can vary from 0.05 to 0.35 without significant changes in digestion. The volatile acids/alkalinity relationship was generally maintained in this range except for startup and the third test, which had a retention time of 11 days rather than 22.5 days. Figures 4 and 5 show the ratio over time for the second (mechanical) and eighth (gas) mixing tests.

Examination of the internal operational-control parameters indicated that the digester was healthy. Even though individual parameters sometimes exceeded the optimal ranges, there were no signs that the digesters had become sour. The optimal ranges quoted were recommended for MSS digesters. Because of its resistance to degradation, the cellulose acts as a stabilizing parameter with regard to digester upset.

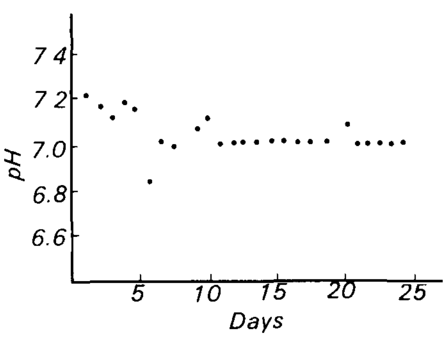

Figure 2. *pH values over time for second test (mechanical mixing).*

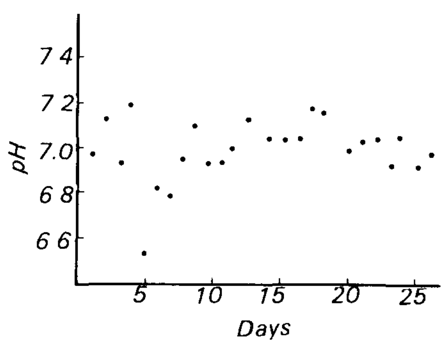

Figure 3. *pH values over time for eight test (gas mixing).*

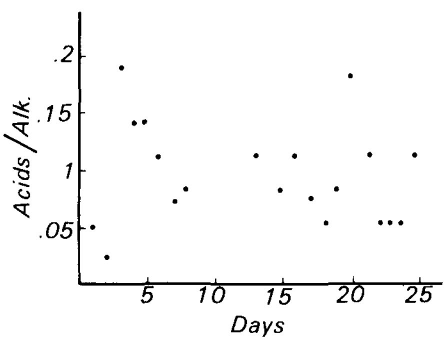

Figure 4. *Volatile acids alkalinity ratio over time for second test (mechanical mixing).*

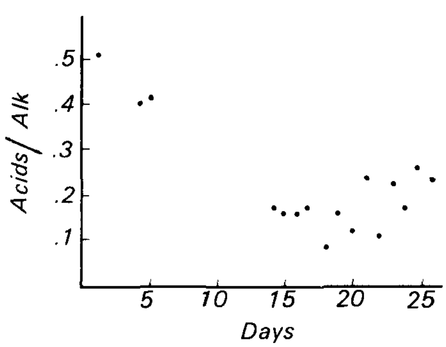

Figure 5. *Volatile acids alkalinity ratio over time for eighth test (gas mixing).*

Results

The results of the first gas mixing test using a 3:1 ratio of MSW to MSS at a loading rate of 1.25 g of volatile solids/L/day are presented in Tables 2 and 3.

For this first gas mixing test, total and volatile solids distributions were higher for the top layer than for the middle or bottom layers. A cohesive mat started to form on the top layer and randomly floated throughout the digester. The data in Table 4 show the average daily mass flow and the accumulation of total and volatile solids in the floating scum layer.

The second test was conducted using the mechanical mixer and was continued immediately after the first study. Within 3 weeks, an extensive scum layer 0.6 m thick with an average of 25 percent total solids developed at the top of the digester. At the end of the test, the scum layer was 0.9 to 1.5 m thick at various sampling points. As in the first test, high total solids corresponded to high volatile solids. In this and the following tests, the differential between the highest total solids percentages for the top level and the lowest total solids percentages for the middle and bottom levels increased. Moreover, the volatile solids percentages for the top level generally became disproportionately higher than those for the other two levels. Thus the greater the total solids concentration was at the top level, the greater was the entrapment of volatile solids in the scum layer. Consequently, the volatile solids (substrate for the microorganisms) were removed from the active level of the digester.

Visual inspection of the digester contents indicated that mixing was not uniform in the digester. Movement was turbulent near the center-mounted agitator shaft and slower near the walls of the digester. This observation and the data trends confirmed the manufacturer's statement that for solids distribution to be uniform, a more powerful motor would be required. The small motor was used in this study to provide a scale comparable with the gas draft tubes. To supplement mixing, the scum breaker pump was operated intermittently in these first two tests.

The third test (gas mixing) was an attempt to lower the retention time from 22.5 to 11 days. High volatile acids/

Table 2. *Percent Total Solids Distribution for Test 1**

Level	Date	Port Number 5 (wall)	4	3	2	1 (center)
Top	8/01	6.14	8.68	3.87	7.15	1.93
	8/04	6.01	6.29	4.38	4.35	3.23
	8/08	3.92	3.88	3.16	4.73	3.04
	8/11	2.48	10.29	5.55	2.54	2.04
	8/15	9.52	3.21	4.21	3.25	2.83
	8/18	12.52	3.45	3.27	4.20	2.66
	8/22	9.62	13.21	10.44	6.59	5.26
	8/25	5.55	5.50	5.56	7.94	11.41
Middle	8/01	2.98	2.69	2.99	2.92	2.62
	8/04	3.64	3.84	6.40	3.93	2.42
	8/08	2.81	3.29	4.83	3.23	3.00
	8/11	3.48	3.65	2 19	2.30	2.53
	8/15	3.25	2.76	2.76	2.65	2.80
	8/18	2.41	2.54	2.47	2.30	2.58
	8/22	3.47	5.30	4.55	2.83	3.57
	8/25	2.64	3.36	2.80	3.21	3.08
Bottom	8/01	2.40	2.54	1.82	2.77	2.92
	8/04	5.28	4.20	—	4.43	3.75
	8/08	3.72	4.84	3 94	3.06	3.30
	8/11	0.93	1.62	3.11	2.89	6.02
	8/15	—	5.00	3.48	3.77	3.46
	8/18	3.60	4.69	2.50	3.88	2.80
	8/22	4.13	3.35	3.14	5.42	3.37
	8/25	3.12	2.91	3.27	3.63	3.14

Gas mixing mode; MSW:MSS, 3:1; volatile solids loading, 1.25g/L/day; total solids in feed, 4 percent.

Table 3. *Percent Volatile Solids Distribution for Test 1**

Level	Date	Port Number 5 (wall)	4	3	2	1 (center)
Top	8/01	63.1	64.1	64.0	65.7	83.7
	8/04	57.4	55.0	49.1	47.4	54.7
	8/08	53.3	51.5	52.6	59.8	48.7
	8/11	53.7	62.5	58.4	57.9	54.0
	8/15	61.0	52.8	60.6	51.9	56.0
	8/18	62.1	56.7	56.2	55.9	52.0
	8/22	62.3	61.0	54.9	61.7	55.6
	8/25	54.3	56.6	56.7	59.3	56.2
Middle	8/01	76.2	60.4	59.1	61.6	56.6
	8/04	50.0	53.5	54.5	53.2	56.5
	8/08	67.7	53.1	55.4	52.2	48.4
	8/11	51.9	47.6	44.4	48.5	51.0
	8/15'	51.6	53.2	50.9	48.0	52.1
	8/18	51.5	52.4	52.5	52.5	51.4
	8/22	56.2	57.3	52.6	48.6	54.7
	8/25	48.8	47.4	52.2	47.8	50.0
Bottom	8/01	75.0	58.6	79.6	57.7	69.4
	8/04	56.2	54.6	—	48.8	47.4
	8/08	61.7	57.1	53.0	42.4	47.5
	8/11	66.1	60.0	48.0	51.4	50.5
	8/15	—	52.2	50.0	52.1	51.6
	8/18	50.5	58.4	50.6	52.0	50.0
	8/22	51.0	54.2	58.9	49.3	50.5
	8/25	49.3	53.4	58.5	51.6	52.9

Gas mixing mode; MSW:MSS, 3:1; volatile solids, 1/25g/L/day; total solids in feed, 4 percent.

Table 4. *Average Daily Mass Flow for Test 1 (Gas Mixing)*

Parameter	Total Solids (kg/day)	Volatile Solids (kg/day)
Feed Blend	754	485
Effluent Liquid	580	295
Product Gas	77	77
Mass Out / Mass In	.871	.767

alkalinity ratios (near 1.0) indicated that the digester was not operating near optimal conditions.

The fourth and fifth tests (mechanical mixing) were conducted using a 9:1 MSW to MSS ratio, a loading rate of 1.25 g/L/day, and a 4-percent total solids feedstock. Results are presented in Tables 5 and 6.

Total solids buildup was very high within a week in the region near the wall. The total solids concentration was low around the center of the region of maximum agitation. The volatile solids increased with the total solids concentration and was more than 70 percent at many points in the top layer after a short period. Data indicated that the organic fraction is not completely digested when it is removed from the active mixing region.

Data from Test No. 4 (gas mixing) also indicate high total solids uniformly dispersed in the top layer after a week of operation. The volatile solids were also high in the top layer. The data in Table 7 show the average daily mass balance for the gas mixing test. Notice that more than 50 percent of the volatile solids have accumulated in the scum layer.

In the sixth (mechanical) and seventh (gas) mixing tests, the loading rate was increased to 2.2 g/L/day. In the mechanical testing, rapid buildup of solids (greater than 30 percent) occurred within 1 week. But the region around the agitator shaft remained low in total solids. The volatile solids concentration was again very high in the scum layer and low in the well-mixed region. Similar results were recorded with the gas mixing test. Total and volatile solids were evenly distributed throughout the top layer of the digester, however.

The eighth (gas mixing) and ninth (mechanical) tests were conducted using a 9:1 ratio of MSW to MSS, a loading rate of 3.125 g/L/day, and a 10-percent total solids feedstock. Results of the gas mixing test No. 8 (Tables 8, 9, and 10) indicate that the system allowed

Table 5. *Percent Total Solids Distribution for Test 5**

Level	Date	Port Number 5 (wall)	4	3	2	1 (center)
Top	4/20	18.8	25.5	0.9	0.9	0.9
	4/24	17.6	27.4	0.8	0.7	1.0
	4/27	14.9	17.6	0.7	0.7	0.7
	5/02	16.9	21.0	14.8	0.4	0.5
	5/04	22.0	19.7	13.8	0.7	3.7
Middle	4/20	1.3	1.2	—	0.8	1.0
	4/24	1.3	1.7	0.6	0.6	0.5
	4/27	3.2	1.3	0.9	0.6	0.7
	5/02	0.6	0.6	0.4	0.3	0.6
	5/04	2.2	0.6	1.4	0.6	0.6
Bottom	4/20	1.5	1.3	1.3	1.3	1.0
	4/24	3.6	1.2	0.8	0.8	0.6
	4/27	1.2	2.1	0.9	0.8	0.9
	5/02	1.4	1.8	0.9	1.0	0.7
	5/04	1.3	0.9	1.4	1.7	0.8

* *Mechanical mixing modes MSW: MSS, 9:1; volatile solids, 1.25g/L/day, total solids in feed, 4 percent.*

Table 6. *Percent Volatile Solids Distribution for Test 5**

Level	Date	Port Number 5 (wall)	4	3	2	1 (center)
Top	4/20	65.1	69.0	36.0	40.9	44.4
	4/24	68.3	67.8	42.9	47.6	48.2
	4/27	70.7	83.6	52.0	59.1	40.0
	5/02	72.0	76.1	76.6	75.0	75.0
	5/04	72.1	69.0	62.1	43.5	69.7
Middle	4/20	40.0	40.0	—	38.1	27.8
	4/24	57.1	63.6	66.7	62.5	73.3
	4/27	79.5	47.6	44.8	42.9	39.1
	5/02	52.9	64.3	70.0	70.0	66.7
	5/04	50.9	60.0	57.6	52.6	63.6
Bottom	4/20	47.9	46.7	43.8	36.7	47.8
	4/24	50.0	68.3	61.5	69.6	66.7
	4/27	50.0	61.4	42.9	50.0	50.0
	5/02	50.0	52.3	52.6	68.0	61.1
	5/04	43.3	60.0	52.6	53.0	52.0

* *Mechanical mixing mode; MSW: MSS, 9:1; volatile solids, 1.25g/L/day; total solids in feed, 4 percent.*

Table 7. *Average Daily Mass Flow for Test 4 (Gas Mixing)*

Parameters	Total Solids (kg/day)	Volatile Solids (kg/day)
Feed Blend	724	485
Effluent Liquid	369	176
Product Gas	40	40
Mass Out / Mass In	.565	.445

an increase at the top level of the digester in both total and volatile solids. Similar results for the mechanical mixing test (Table 11) show that 80 to 90 percent of the volatile solids were being retained in the scum layer and not in the active mixing region.

Discussion

The digester system experienced operational problems when the MSW: MSS ratio was above 3:1 and the loading rate and feedstock were above 1.25 g/L/day and 4 percent total solids. This condition was generally a result of poor mixing because of the low-powered motor, and it probably could be improved through the use of a higher-powered mixing system. But the improved mixing results in increased energy use, and thus the system does not appear feasible from the standpoint of energy requirements.

The major problem associated with the digestion process was the tendency of the solids to coalesce into floating, fibrous mats. Accompanying the formation of these fibrous mats was the movement of the volatile solids out of the zone of digestion into the mat area. This relocation resulted in a reduction in the bioconversion process. A prime cause of the coalescing and accumulation of solids is the high cellulose content of the MSW. Disintegration of the cellulose fibers requires (1) separation and exposure of their fibrils, (2) attack of fibrils by enzymes to break their molecular bonds, and (3) digestion of the resulting short-chained molecules by the microbes. Though the mixing of the MSW and MSS promotes these three processes, it also has the opposite effect of causing separated fibrils to coalesce into stringers and mats. Though the mats rise to the fluid surface in the form of large scum accumulations, the stringers interfere with the mixing equipment and retard the fluid flow, and consequently the enzyme and bacterial movement.

However, there is also the aspect that the strictly organic components (food waste, yard waste, etc.) were completely digested and that the cellulose fraction was not being digested. It is reasonable to assume this with the 20-to-30-day duration periods and 22.5-day solids retention time. Examination of the pH and the volatile acids/alkalinity ratio would support the above statement. Extended duration and solids retention time would provide further information of the cellulose degradation.

Equipment problems also resulted form the gritty cellulosic feedstock. Excessive wear on the Moyno pump and scum breaker pump was recorded. The operating life of this equipment would be likely to be short in a full-scale, continuous-operation plant. Inspection of the mechanical agitator showed excessive buildup of cellulosic material. Rope-like stringers became wound

Table 8. *Percent Total Solids Distribution for Test 8* (Gas Mixing, 9:1, 3.125, 10% TS Feed)*

Level	Date	Port Number 5 (wall)	4	3	2	1 (center)
Top	7/24	35.5	—	—	1.4	—
	7/27	29.8	35.2	35.6	14.8	—
	7/31	27.3	34.0	36.1	13.8	1.1
	8/03	32.8	33.7	40.2	22.1	18.6
	8/07	29.1	36.7	43.3	13.4	14.0
	8/10	23.5	14.8	31.6	12.9	13.7
	8/14	15.6	14.8	16.3	23.5	22.3
Middle	7/24	—	—	—	1.7	—
	7/27	—	—	—	1.1	1.1
	7/31	—	—	—	—	—
	8/03	—	—	—	0.3	0.3
	8/07	—	—	—	1.0	1.1
	8/10	0.9	1.1	0.7	0.9	1.4
	8/14	1.0	1.0	1.2	0.8	0.7
Bottom	7/24	—	—	—	1.2	—
	7/27	—	—	—	1.5	1.7
	7/31	—	—	—	—	—
	8/03	—	—	—	0.4	0.3
	8/07	—	—	—	1.0	1.1
	8/10	1.0	1.0	0.8	1.2	1.2
	8/14	1.2	0.9	1.1	0.7	0 8

* *Gas mixing mode; MSW: MSS, 9:1; volatile solids, 3.125g/L/day; total solids in feed, 10 percent.*

Table 9. *Percent Volatile Solids Distribution for Test 8**

Level	Date	Port Number 5 (wall)	4	3	2	1 (center)
Top	7/24	61 9	—	—	57.7	—
	7/27	60.4	61.6	51.5	74.8	—
	7/31	59.0	57.3	53.9	70.0	57.5
	8/03	58.8	63.7	58.2	63.2	57.4
	8/07	56.0	52.5	51.7	78.4	74.7
	8/10	69.3	76.8	61.7	73.5	81.5
	8/14	78.4	80.9	78 5	67.4	86.4
Middle	7/24	—	—	—	56.7	—
	7/27	—	—	—	54.7	53.9
	7/31	—	—	—	—	—
	8/03	—	—	—	27.9	27.3
	8/07	—	—	—	48.1	50.7
	8/10	48.3	49.5	46.1	49.3	67.6
	8/14	51.2	50.9	56.0	49.0	49.0
Bottom	7/24	—	—	—	54.0	—
	7/27	—	—	—	54.9	54.7
	7/31	—	—	—	—	—
	8/03	—	—	—	38.4	26.0
	8/07	—	—	—	49.1	49.9
	8/10	53.6	47.6	48.2	50.7	56.8
	8/14	56.3	52.6	54.3	50.2	55.7

* *Gas mixing mode; MSW: MSS, 9:1; volatile solids, 3.125g/L/day; total solids in feed, 10 percent.*

Table 10. *Average Daily Mass Flow for Test 8, Gas Mixing*

Parameter	Total Solids (kg/day)	Volatile Solids (kg/day)
Feed Blend	3960	2840
Effluent Liquid	660	360
Product Gas	80	80
Mass Out / Mass In	.187	.155

Table 11. *Average Daily Mass Flow for Test 9 (Mechanical Mixing)*

Parameter	Total Solids (kg/day)	Volatile Solids (kg/day)
Feed Blend	4272	3012
Effluent Liquid	510	261
Product Gas	73	73
Mass Out / Mass In	.136	.111

around the shaft and agitator arms and caused decreased mixing efficiency and excessive wear on the agitator drive mechanism.

The best methane production was observed in Test No. 2, which produced 6600 ft^3/day (187,000 L/day) of biogas at an average composition of 62 percent methane. In this test, 16 ft^3 (453 L) of gas was produced per pound of volatile solids destroyed—a reasonable rate for a healthy digester. An overall system mass balance for Test No. 2 shows that no solids accumulation took place. The volatile solids destruction observed was 38 percent.

Mixing employed throughout this test consisted of 24-hr/day operation of the 10-hp (7.5-kW) mixer and 4-hr/day operation of the 40-hp (30-kW) scum breaker pump. If full load operation is assumed for both and power generation efficiencies are ignored, the energy used for mixing is equal to 400 hp-hr/day (300-kW-hr/day). The methane produced was 4092 ft^3/day (116,000 L/day), which has an energy content of 1600 hp-hr/day (1190 kW-hr/day), which is only four times greater than the direct energy usage of our admittedly underpowered mixing systems.

To improve the mixing characteristics of this system, a 50- to 100-hp (37.5- to 75-kW) mechanical mixer would be required. The electrical energy required to operate this mixer would be approximately 350,000 to 700,000 kwh/yr[7]. The energy produced in the current system (1600 hp-hr/day) converts to 435,000 kwh/yr. Thus a 50-hp (37.5 kW) mixer would result in an overall 20-percent energy gain, and the 100-hp (75-kW) mixer would result in a 61-percent energy loss. The use of a larger mixer should produce an increase in volatile solids destruction and thus a subsequent increase in gas production. A doubling in gas production would be necessary to produce a net gain in energy by the 100-hp (75-kW) system. Note, however, that additional energy expenditures (such as digester heating, MSW processing, etc.) have not been considered in these energy calculations.

Conclusion

Data analysis indicates that MSW/MSS mixtures with high cellulose contents are not very amenable to anaerobic digestion, either with regard to operating procedures or energy recovery. Increased mixing power would improve the distribution of volatile solids, probably decrease scum formation, and result in increased gas production. But maintenance problems resulting from the nature of the MSW/MSS mixture and increased energy costs caused by mixing requirements would detract from system performance.

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The complete report, entitled "Evaluation of Mixing Systems for Biogasification of Municipal Solid Waste," (Order No. PB 81-171 597; Cost: $9.50, subject to change) will be available only from:

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