Abstract: MicroSludge® is a patented chemical and pressure pre-treatment process that liquefies waste activated sludge (WAS) to increase both the rate and extent that WAS is degraded in an anaerobic digester. The process uses chemical pre-treatment to weaken cell membranes and then a high-pressure homogenizer, or “cell disrupter”, to provide an enormous and sudden pressure change to burst the cells in WAS. The resulting solubilized WAS is then more readily converted to biogas.

At the Los Angeles County Sanitation Districts’ (LACSD’s) Joint Water Pollution Control Plant (JWPCP), a MicroSludge System with two 4,000 L/h cell disruption modules was continuously operated for 24 hours per day from October 2005 to October 2006 to process approximately 192 m³/day (50,000 GPD) of thickened WAS at 5 to 6% total solids (TS) concentration. The processed WAS was co-digested with primary sludge (PS) in a 75:25 by volume (approximately 68:32 by mass) PS:WAS mix at a nominal HRT of 19 days. The MicroSludge fed digester performance was compared to that of one of the other 23 digesters operated under similar conditions at the JWPCP, except that the WAS feed was not pre-treated.

Keywords: cell lysis, homogenization, MicroSludge, sludge pre-treatment

INTRODUCTION

MicroSludge is a chemical and pressure pre-treatment process that uses caustic pre-treatment to weaken cell membranes, and then high-pressure cell disruption to lyse the bacterial cells in WAS (Stephenson and Dhaliwal, 2000). The WAS is liquefied and, with or without primary sludge, is then anaerobically digested. Figure 1 illustrates the process.

METHODOLOGY

The MicroSludge equipment installed at the JWPCP processed 192 m³/d (approximately 50,000 USGPD) of WAS at 100% utilization. The equipment consisted of two cell disrupters and a central processing skid that with controls, instrumentation, tanks, screens, and pumps to pre-treat WAS. Figure 2 illustrates the process.

Figure 2 shows that thickened WAS flows through a coarse filter, caustic is added, and the mixture is then subjected to a high shear mixer prior to storage in a chemical conditioning tank. A rotary lobe pump transfers chemically conditioned WAS through a gas/liquid separator, fine filter, and then to the cell disrupter. The MicroSludge processed WAS then flows to the anaerobic digester.
MicroSludge processed all of the WAS that was fed at a rate of 8,000 L/h to one mesophilic anaerobic digester. Thickened primary sludge was also continuously fed to the digester for co-digestion. The average total solids concentration of the WAS was 5.3%, with a volatile solids fraction of approximately 78%. WAS constituted approximately 25% of the total volumetric flow to both the control and MicroSludge fed digesters. On a dry solids basis, the primary sludge mass fraction was 68%, and the WAS mass fraction was 32%. The average total solids concentration of the combined feed was 3.78%, with a volatile solids fraction of approximately 76%. Assays were performed according the Standard Methods of the APHA (1998).

Figure 2 MicroSludge Process Flow Diagram

RESULTS AND DISCUSSION

Liquefying WAS

Solubilizing WAS is needed to address the rate-limiting step of hydrolysis of WAS for conversion to biogas in an anaerobic digester. MicroSludge liquefied the microbes in WAS as proven by the following observations:

1. The viscosity of WAS, a thick slurry of microbes, was reduced by over 90%, from 258 centistokes to 25 centistokes.
2. Scanning electron microscope (SEM) images show the destruction of filaments and massive cell destruction. Figures 3a and 3b are SEMs that show the impact of MicroSludge processing of WAS at the JWPCP.

Figure 3a JWPCP WAS Before Treatment Figure 3b JWPCP WAS After MicroSludge

Figure 3a shows supernatant of untreated WAS from JWPCP with intact microbes present as branches, chains, rods, and clumps. As shown in Figure 3b, MicroSludge destroyed WAS cells, releasing the liquid contents from the cell membranes. Here, no branches, chains, or rods appeared to be intact. Jenkins (2006) confirmed these findings by light microscopy.

3. The concentrations of soluble biological oxygen demand (BOD) and soluble chemical oxygen demand (COD) in MicroSludge processed WAS are 100 times or greater than unprocessed WAS. This is important because
microbes can only utilize what has been solubilized. Figure 4 shows the results of supernatant that was decanted from samples after they were centrifuged at 30,000 rpm for 5 minutes. Untreated WAS at the JWPCP was present primarily in the solid phase. MicroSludge liquefied WAS to radically change the distribution of TS, VS, BOD, and COD from the solid phase to the liquid phase.

Figure 4  Effect of MicroSludge on Soluble TS, VS, BOD, and COD (mg/L) of WAS

Quantity of Digested Solid Residuals for Disposal

Results from a trailer-mounted belt filter press are summarized in Table 1.

Table 1  Characteristics of Digester Effluent at the JWPCP

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control Digester [mg/L]</th>
<th>MicroSludge Digester [mg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Solids</td>
<td>28,300</td>
<td>21,100</td>
</tr>
<tr>
<td>Volatile Solids</td>
<td>8,600</td>
<td>7,400</td>
</tr>
<tr>
<td>Fixed Solids</td>
<td>19,700</td>
<td>13,700</td>
</tr>
<tr>
<td>Total Dissolved Solids</td>
<td>6,000</td>
<td>6,600</td>
</tr>
<tr>
<td>Total Particulate Solids</td>
<td>22,300</td>
<td>14,500</td>
</tr>
</tbody>
</table>

For co-digestion with 68% by mass of primary sludge and 32% WAS, the concentration of total particulate solids (that is, the solids that are hauled off site for disposal) of the MicroSludge fed digester was 14,500 mg/L, and that of the control digester was 22,300 mg/L. This difference is 35% less solid residuals for disposal with MicroSludge compared to the control digester. This implies that the WAS processed by MicroSludge was eliminated from the residuals for disposal.

Volatile Solids Reduction (VSr)

Figure 5 illustrates the overall VSr of the control digester and the test digester at the JWPCP during the trial.
Figure 5 shows that the overall VSr at the JWPCP without MicroSludge was approximately 49.8%. With an assumed VSr of primary sludge at the JWPCP being 60%, this infers a VSr of WAS of 28.1% without MicroSludge. This is calculated as follows (Parkin and Owen, 1986):

\[ \text{VSr overall} = X_{\text{primary solids}} \times \text{VSr primary solids} + X_{\text{WAS}} \times \text{VSr WAS} = 0.68 \times 60\% + 0.32 \times 28.1\% = 49.8\% \]

where \( X_{\text{primary solids}} \) is the mass percentage of primary solids (68% at JWPCP) and \( X_{\text{WAS}} \) is the mass percentage of WAS (32% at JWPCP). With MicroSludge, the overall VSr increased to as high as 57%. This infers a VSr of WAS of 54% as calculated below.

Total VSr (Primary & WAS) = 0.68 x 60% + 0.32 x 50.6% = 57%

Increasing the VSr of WAS at the JWPCP from 28.1% to 50.6% is an 80% increase. However, this falls short of the 200% increase in VSr of WAS achieved at the Chilliwack plant, where the VSr of WAS increased from about 30% to over 90% (Rabinowitz and Stephenson, 2005). For a theoretical maximum of 95% VSr of WAS, an overall VSr of 70% is the maximum that could be achieved for the 68:32 mix of primary sludge and WAS at the JWPCP.

**Biogas Generation**

The monthly average biogas generation rates formed in the MicroSludge fed digester and the control digester are presented in Figure 7. Sludge characteristics specific to the JWPCP may have contributed to lower than anticipated results. Because MicroSludge processes WAS and not primary solids, the effects of pre-treatment are dampened by the large portion of primary solids also fed to the digesters.
**Biochemical Methane Potentials:** Biochemical Methane Potential (BMP) tests were conducted for a series of sludge samples from the JWPCP using the method described by NRC’s Biotechnology Research Institute (2006), a modification from Owen et al., (1979). The inocula was obtained from the JWPCP’s lab digester fed with MicroSludge processed WAS. Results are shown in Figure 7.

![Figure 7: Biochemical Methane Potential Test Results for JWPCP Sludge](image)

Figure 7 indicates that primary sludge from the JWPCP produced by far the most biogas in terms of volume of methane generated per mass of total volatile solids (TVS) of sludge added. Untreated WAS produced just over half as much methane as primary sludge. Compared to WAS without pre-treatment, 31% more methane was produced from MicroSludge processed WAS. Co-digestion of primary sludge with WAS (whether MicroSludge processed or not) at the JWPCP resulted in lower methane generation than if primary sludge and WAS were digested separately. With JWPCP anaerobic digester microbes, 20% more methane could be generated by separate digestion of primary sludge and MicroSludge processed WAS compared to 68:32 co-digestion of primary sludge and untreated WAS. With Jenkins (2006) findings of substantial destruction of filamentous microbes by MicroSludge processing, WAS only digestion could be performed without foaming.

**Activity Tests of Digester Microbes**

With lower than expected biogas generation and VSR, measures of the metabolic activity of anaerobic digester microbes were taken to assess the digester's capability to consume glucose, acetate, and hydrogen to quantify the metabolic activities of acid producing bacteria, acetate utilizing methane producing bacteria, and hydrogen gas utilizing methane producing bacteria.

The ability of the methane producing bacteria to use both glucose and hydrogen was very good for both the control digester and for the MicroSludge fed digester. However, Figure 8 indicates that the acetic acid utilizing methane producing bacteria were either largely absent or greatly inhibited for both the control digester and the test digester. This is important because normally 70% of the methane is generated from acetate and the other 30% from hydrogen (WEF, 1998). The relative inactivity of the MPB in both digesters shows that the inhibition was not caused by MicroSludge.
Figure 8 also shows the acetate utilizing activity of JWPCP digester microbes from a lab scale digester that had been digesting MicroSludge treated WAS only (no primary sludge) for over six months at the JWPCP. In sharp contrast to co-digestion of primary sludge and WAS, these test results show that the MicroSludge treated WAS only digester developed an excellent ability to consume acetate. This suggests that primary sludge at the JWPCP severely inhibits conversion of VFAs to biogas and that MicroSludge processed WAS only digestion at the JWPCP may result in significantly increased biogas and decreased residual solids. Novak (2006) concurred with this assessment.

The digester microbes at JWPCP have a good ability to generate VFAs but a poor ability to consume them. The increased ability of acid producing bacteria to produce VFAs from MicroSludge processed WAS was confirmed by lab scale digestion at the JWPCP. After 2 days of mesophilic acid phase digestion of untreated WAS, 2,430 mg/L total VFAs were measured in an acid phase digester. In contrast, with MicroSludge processing of WAS, the total VFA concentration increased to 11,900 mg/L, almost 5 times the total VFA concentration achieved without MicroSludge.

For the 19 day HRT full-scale digesters, the VFA levels in the digester effluent were reduced to near zero. This suggests that inhibition in the digesters that were fed WAS and primary sludge at the JWPCP slowed down the metabolism of acetate utilizing MPB, but did not stop them altogether.

**Effect of MicroSludge on Residuals Dewatering**

A trailer mounted belt filter press was used to compare dewatering performance in digested sludge from the experimental and control digesters to support a WERF odor study (Novak, 2007). Table 2 summarizes the results of the dewatering trial with the belt filter press.

**Table 2** Characteristics of the Belt Filter Cake from the Control and Test Digesters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control Digester</th>
<th>MicroSludge Digester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Solids [mg/L]</td>
<td>17,900</td>
<td>18,000</td>
</tr>
<tr>
<td>Volatile Solids [mg/L]</td>
<td>10,840</td>
<td>10,110</td>
</tr>
<tr>
<td>Volatile Solids/ Total Solids [%]</td>
<td>61</td>
<td>56</td>
</tr>
<tr>
<td>Total Metals [mg/L]: Ag, As, Ba, Be, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Sh, Se, Ti, V, Zn</td>
<td>296</td>
<td>312</td>
</tr>
</tbody>
</table>

The belt filter press dewatered cake showed no significant change in characteristics between the MicroSludge fed digester and the control digester. Both displayed low metals concentrations compared to the regulatory ceiling concentrations for each of the regulated metals. There was also no difference in the dewatering polymer dose for the digesters. MicroSludge did not adversely affect the ability to dewater residuals.
**Filtrate Quality:** Table 3 indicates that the concentrations of nitrogen, phosphorus, metals, and BOD of the dewatering liquid from a belt filter press for the control digester and the test digester at the JWPCP were not significantly affected by the upstream processing of WAS by MicroSludge. A 39% higher concentration of fixed solids (ash) was measured in the return stream from the belt filter press. Although the fixed solids content of the return stream was elevated, the concentrations of metals were not of environmental concern. This dewatering liquid stream could be returned to the head works of the plant with no adverse effects on WWTP operations.

### Table 3 Characteristics of Return Stream from Belt Filter Press

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control Digester [mg/L]</th>
<th>MicroSludge Digester [mg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Solids</td>
<td>7,010</td>
<td>8,320</td>
</tr>
<tr>
<td>Volatile Solids</td>
<td>2,830</td>
<td>2,500</td>
</tr>
<tr>
<td>Fixed Solids</td>
<td>4,180</td>
<td>5,820</td>
</tr>
<tr>
<td>BOD</td>
<td>390</td>
<td>385</td>
</tr>
<tr>
<td>TKN</td>
<td>477</td>
<td>480</td>
</tr>
<tr>
<td>NH₄-N</td>
<td>475</td>
<td>472</td>
</tr>
<tr>
<td>TP</td>
<td>10.6</td>
<td>9.60</td>
</tr>
</tbody>
</table>

**CONCLUSIONS**

1. MicroSludge was effective in solubilizing WAS.
2. After anaerobic digestion, MicroSludge processed WAS remained in the liquid phase and did not report to the dewatered digested cake.
3. The increase of volatile solids reduction of MicroSludge processed WAS at the JWPCP was less than expected due to inhibition of acetate utilizing methane producing bacteria during co-digestion with primary sludge. This inhibition was at least partially due to the presence of primary sludge at the JWPCP.
4. No negative impacts of MicroSludge processing on the dewatering of digested residuals were observed:
   a. The characteristics of the dewatered solids cake from a belt filter press with MicroSludge processed WAS were not significantly different compared to those of digested sludge from a conventional anaerobic digester.
   b. The concentrations of nitrogen, phosphorus, metals, and BOD of the dewatering liquid from a belt filter press for the control digester and the test digester at the JWPCP were not significantly affected by MicroSludge.
5. Microbial activities of anaerobic digesters at municipal WWTPs vary considerably, acetate utilization in particular. Consequently, the microbial activities of anaerobic digesters should be tested to determine if a given anaerobic digester is a suitable candidate for sludge pre-treatment.

**REFERENCES**


