Sonix for Enhanced Anaerobic Digestion: Final Report (15 July 2002)

*[**Note:** OCSD tested an ultrasonic device for improving the efficiency of digesting thickened waste activated sludge (TWAS) in anaerobic digesters. This technology, which is referred to in this report by its Sonix brand name, is installed in the TWAS feed line to a digester and uses ultrasonic energy to break open cells found in TWAS, which makes the organic material inside the cells more susceptible to digestion. This report is a slightly edited version of the final project report submitted to OCSD by WS Atkins, the engineering consulting firm that oversaw the test at OCSD's Plant 2 facility.]*

Overview

This final summary report presents the complete data for the OCSD Sonix trial. The gas production from digester H (test) continued to be significantly greater than for digester E (control).

Simple payback periods for the technology are around 2 years (1.83 years for Plant 2, 2.05 years for Plant 1). This is based on savings due to increased gas production, enhanced dewatering, and improved solids reduction.

The Sonix plant operated with virtually no problems or unplanned downtime. There were no breakages or horn failures. Since the trial commenced in mid-February 2002, the Sonix plant was operational for 98.9% of the available time.

Lithium tracer studies on digesters E and H showed that the test digester H had a larger dead zone than E. The data also indicated that short-circuiting appeared to be occurring in digester H. The tracer studies were useful in confirming previous conclusions, drawn from the solids destruction data, that E is a significantly better-mixed digester.

Dewatering tests were undertaken in the laboratory at Plant 2. From 16 May 2002, nine separate dewatering tests were done. The results showed that the exit sludges from the test digester dewatered to a greater solids concentration than those from the control. The difference between the two cakes ranged between 1.10 and 2.58 percentage points. The mean was 1.64 percentage points with a 95% confidence interval of 0.32 points. In the cost models, a conservative difference of only 1.5 points was assumed.

TWAS before and after Sonix treatment was examined under the microscope to evaluate the effect of sonication. Representative photographs are included as Figure 8.

Summary Data

TWAS feed

Figure 1 shows that the mean (7 day average) proportion of TWAS fed to both the control digester and the test were well maintained for the duration of the trial. Typical daily operation resulted in a TWAS feed of approximately 60 - 65% of the total feed volume.

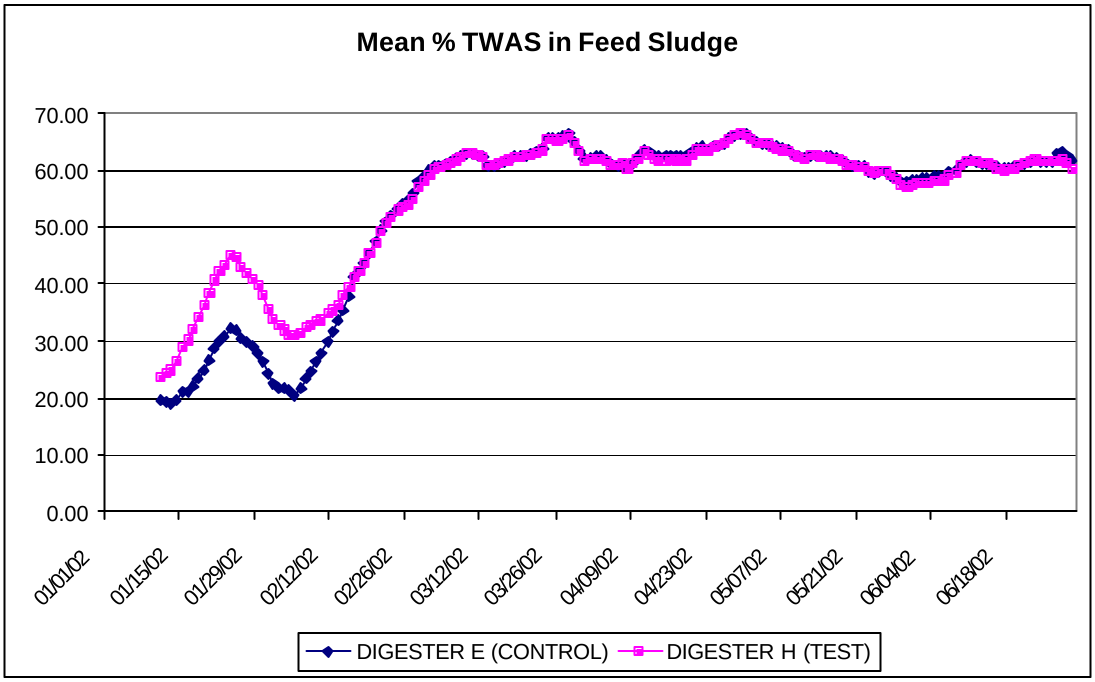


Figure 1 Mean % TWAS in feed sludge

Digester HRT

The amount of TWAS fed is also reflected in the digester hydraulic retention times (HRT) as seen in Figure 2.

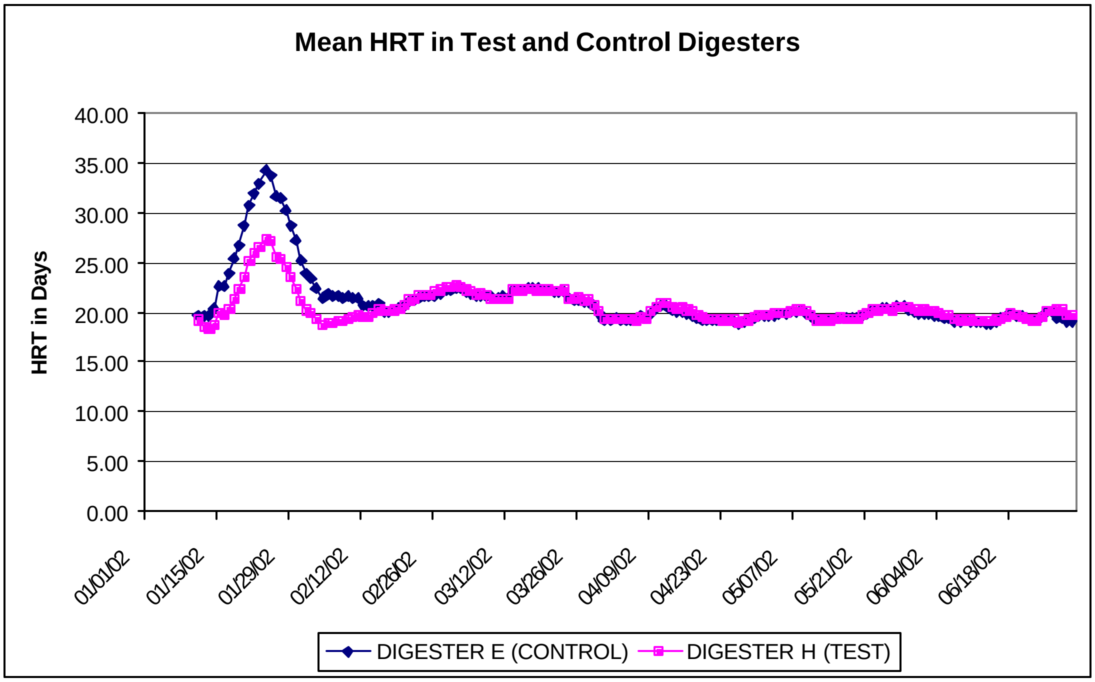


Figure 2 Mean HRT in test and control digesters

Gas Production

Figure 3 shows the change in gas production following the start of the trial. Once the sonication threshold was overcome by turning up the power on the Sonix, the gas production in the test digester was seen to increase and then stabilize. The increased gas production was further confirmed following the installation of a new Panametrics flow meter on digester E.

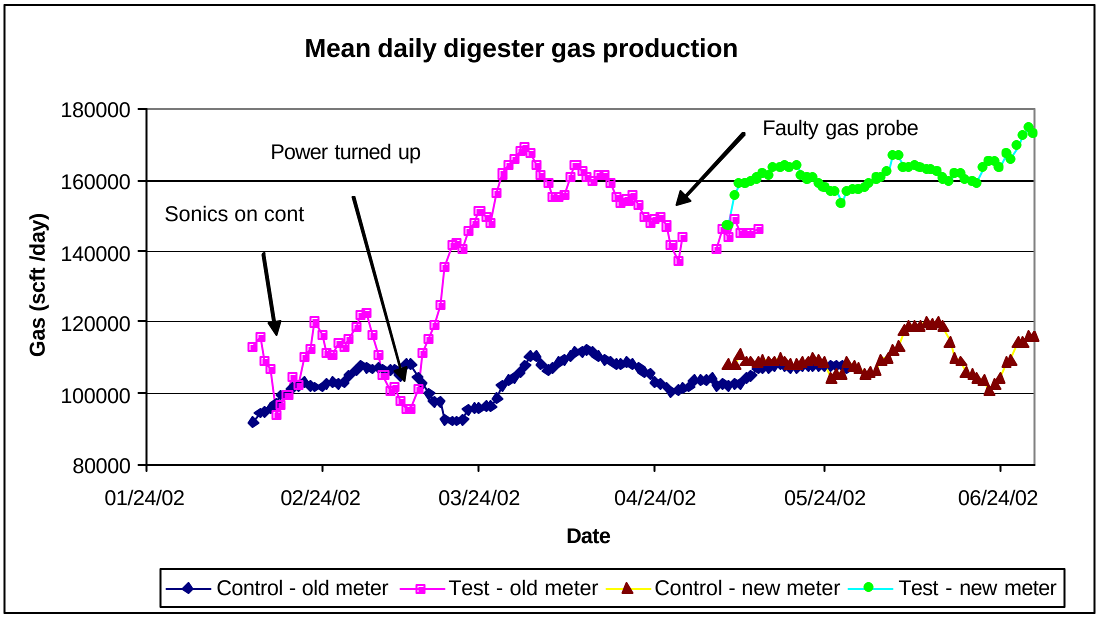


Figure 3 Mean daily gas production

It should be noted that the apparent drop during April in the gas production for the test digester (referred to as "H normal") was probably due to problems with the gas meter probe. It was noted that the probe, which was being manually cleaned on a regular basis at that time, was becoming bent and distorted (due to the practical difficulties associated with removing the probe from the line). The effect of this was to reduce the cross-sectional area over which the flow was measured and thus reduce the recorded flow. It should be noted that a new Panametrics meter on H recorded gas production rates very similar to the rate that was observed in the "H normal" meter in April, before the problems with the probe occurred.

Specific Gas Production

Specific gas production data shown in Figure 4 supports the trend in actual gas production seen in Figure 3.

Figure 4a shows the gas production per lb of VS **fed** to the digester. It can be seen that, following the installation of the Sonix, the gas production rose from around 0.35 m^3/kg VS fed (or approximately 5.6 ft^3/lb VS fed) to around 0.55 m^3/kg VS fed (8.8 ft^3/lb VS fed). This is an increase of around 50%.

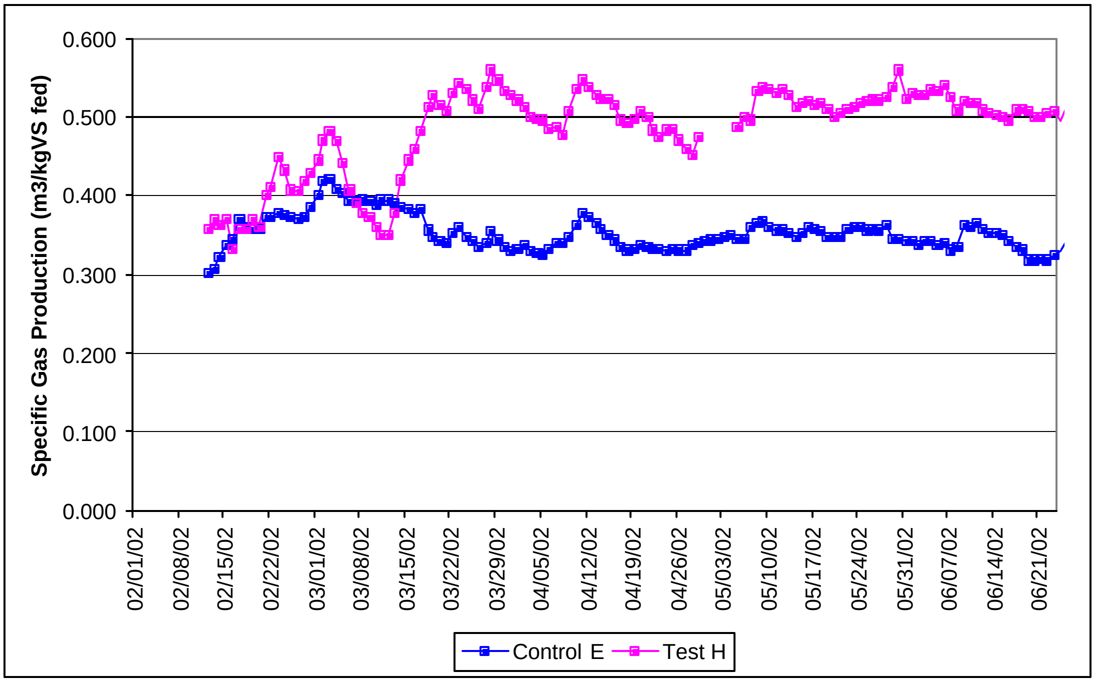
As Table 1 shows, these results are very similar to what has been observed in similar trials at Avonmouth in the UK (in an approximately 1 million gallon digester during a 6-month trial using an identical V5 Sonix plant). Furthermore, the observed gas production rates are very comparable with rates recorded in the scientific literature:

- TWAS 6.2 ft^3/lb VS
- Primary 9.9 ft^3/lb VS (Sato *et. al.*, *Water Sci. Tech.*, 2001)

Table 1 Gas production per VS fed

Digester gas, ft^3/lb VS fed	**Control**	**Test**
Avonmouth	4.0 – 5.2	7.1 – 8.8
OCSD	5.5 – 7.5	8.7 – 11.4

(4a)



(4b)

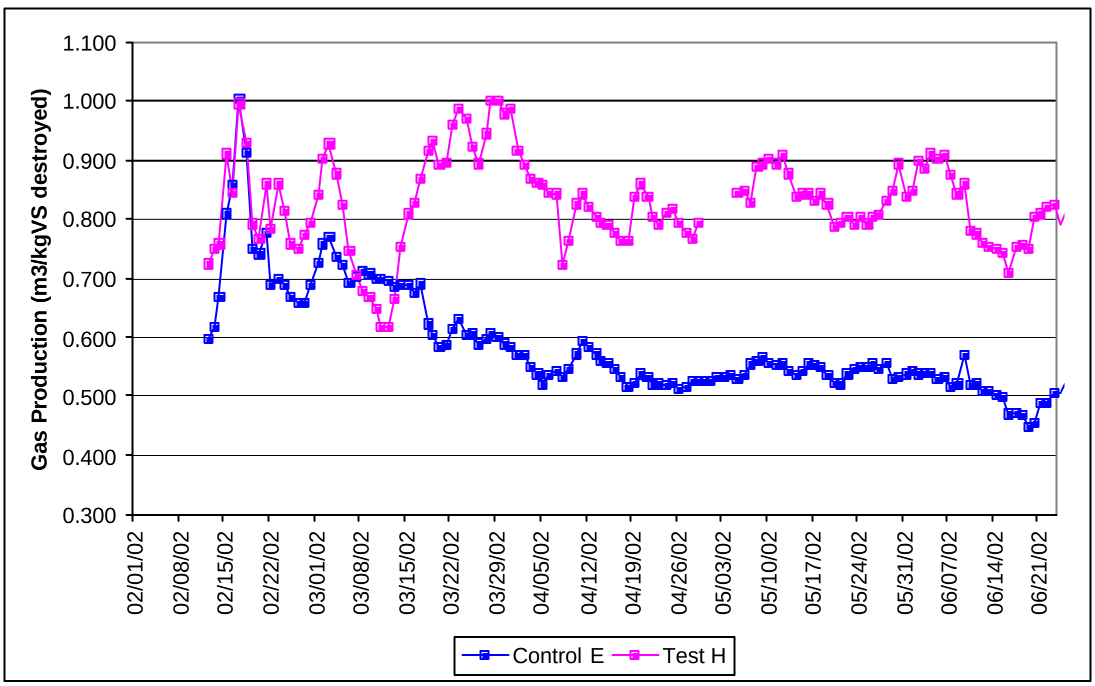


Figure 4 Specific gas production based on (a) solids fed (b) solids destroyed

In Figure 4b the gas production per kg of VS destroyed is presented. In general, one would not expect to observe as great an increase in this parameter with any sludge treatment (be that heat, enzymes, Sonix, or pressure) because the rate of gas production *per unit VS destroyed* is mainly dictated by the microbial degradation pathway, and pretreatment is unlikely to dramatically change this rate.

A "standard" rate of 1 m^3/kg VS destroyed (or approximately 16 ft^3/lb VS) is widely accepted as normal and indicative of a good digestion process. As can be seen from Figure 4b, the specific gas production initially increased in the Sonix digester (by around 20%) but subsequently returned to the 0.8 – 0.9 m^3/kg VS destroyed value that was occurring before the Sonix was started. This is as would be expected.

What is perhaps more noteworthy is the fact that the specific gas production for the control digester dropped significantly as the amount of TWAS feed was increased. This could be interpreted as indicating that the control digester was struggling to cope with the high TWAS feed. In real terms the data shows that the control digester was maintaining its gas production (in terms of the gas volume produced each day) but since it was actually being fed a greater amount of VS (due to the increased TWAS), the digestion process was becoming less efficient. However, this data should not be considered without due examination of the solids destruction data below, because trends there may help explain the trends observed in Figures 4a and 4b.

Solids Destruction

The solids destruction data is presented in Figure 5.

This data shows that prior to the Sonix trial, the test digester was performing significantly worse than the control digester, with the solids destruction in the test digester being 8% to 15% less than that observed in the control digester. In terms of actual solids composition, this represented a difference in exit sludge thickness of about 0.5% solids. For example, prior to the Sonix trial the solids concentration in the test digester ranged from 2.8% to 3.8% dry solids (DS), whereas in the control it was 2.5% to 3.1% DS.

Following the commencement of the Sonix use, the performance of the two digesters became very similar. The only change in digester operation that could explain this is the start of the Sonix unit. Beginning in March there was a steady increase in the solids destruction percentage in both digesters.

The most likely explanation for the test digester achieving less solids destruction than the control prior to the Sonix start is that the mixing in the test digester was less effective. This expectation was confirmed by lithium tracer studies. These studies showed that the test digester H has a larger dead zone than digester E. The data also indicated that short-circuiting appeared to be occurring in digester H. The effect of this short-circuiting is important since it not only confirms the poorer mixing dynamics for this digester, but it also means that the calculated dead zone proportion for this digester is likely to be even greater than was estimated (since the short-circuiting would have resulted in a significant proportion of the lithium tracer being lost from the digester).

The tracer results confirmed that E is better mixed than H and thus that the ~10% improvement in solids destruction in H observed in March probably is due to the Sonix.

It should be noted that there was a high rate mixer pump installed on the control digester E on 21 March in preparation for the digester's decommissioning and cleaning once the Sonix trial was complete. The test digester H did not have a similar pump.

The exit sludge samples for both digesters were, from the start of the trial, taken from the recirculation pump rather than the overflow weir. Ideally, and under normal circumstances, the solids concentration should be the same from the overflow and from the recirculation line. However, the large amounts of grit in these digesters could have affected this. This appears to be confirmed from samples taken at the overflow weirs in early May (labeled as "Sartorious control" and "Sartorious test" in Figure 5). Eleven samples taken from the overflow weirs (i.e., on each working day for ~2 weeks in May) showed that the mean solids concentrations were 1.98% in the test digester and 2.49% in the control digester. This (limited) data appears to support the "expected" result of improved solids destruction in the test digester. This difference in solids concentration continued to be observed in the final weeks of the tests as shown in Figure 5.

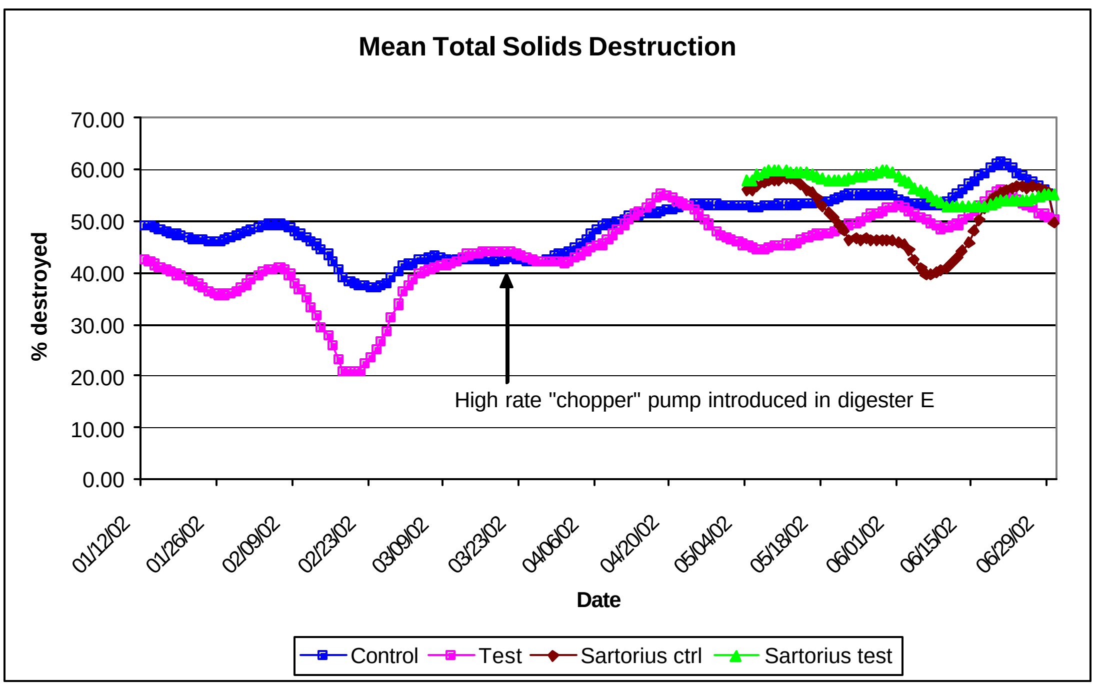


Figure 5 Mean total solids destruction

Other parameters

- ***Alkalinity:*** The average alkalinity in the test digester over the last month of the test was 4006 mg/l compared to 3729 mg/l in the control. A higher alkalinity level is usually regarded as indicating a more stable digestion process.

- ***VFAs:*** The volatile fatty acid (VFA) levels in both the test and control digesters were stable at below 50 mg/l for the last month of operation (as they generally were throughout the test).

- ***Methane concentration:*** The methane concentration in both the test and control digesters was stable at 60 - 65%.

- ***Soluble CODs and VFAs pre- and post-sonication:*** As shown in Figures 6 and 7, the Sonix unit was very effective at increasing the soluble COD and VFA concentrations of the TWAS. These are widely accepted measures for cell disruption, and these results indicate that the Sonix unit was performing as expected.

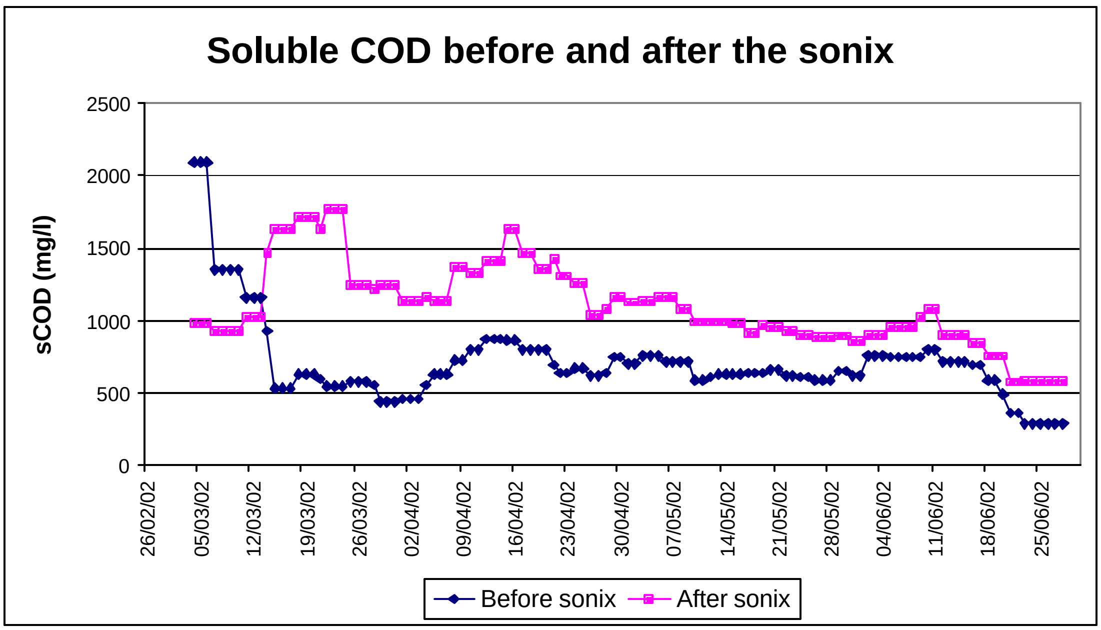


Figure 6 Soluble COD pre- and post-sonication

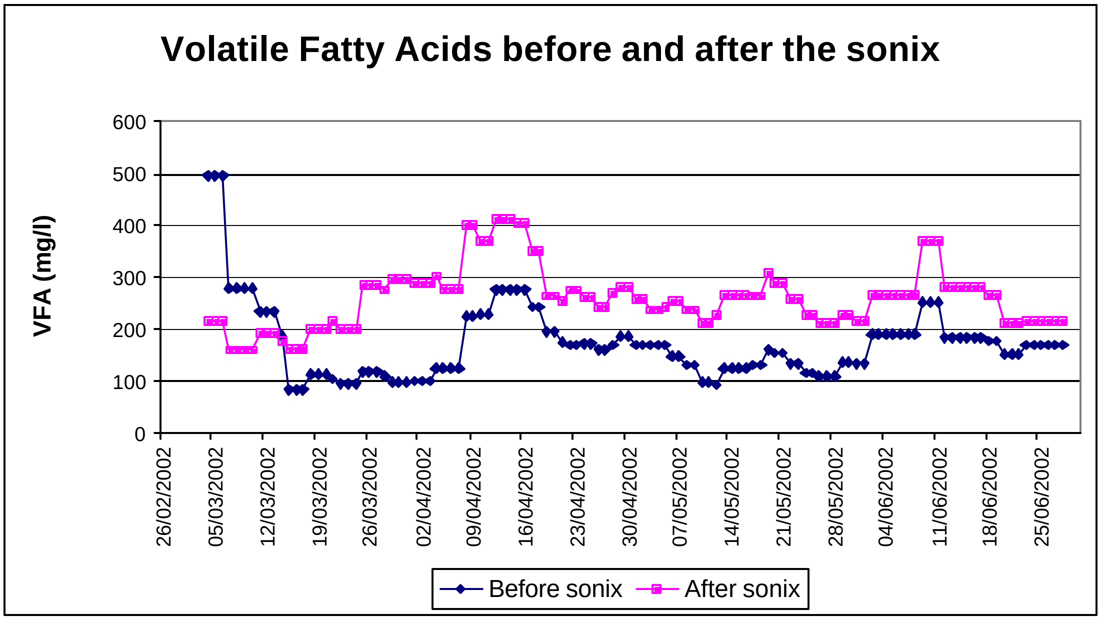


Figure 7 VFAs pre- and post-sonication

Sonix Operation

There were no problems with the operation of the Sonix hardware throughout the trial with the exception of a temporary failure in stack #4 in March 2002. This was due to a loose connection between the transducer and the booster, which caused an overload. However, this problem was resolved immediately by replacing the cable. In case the root cause was a faulty transducer, it was later replaced as a precaution.

Table 2 shows the total number of operating hours for each of the horns and the percentage of up-time during that period. The potential operating time since the official trial start date was 2880 hours. However, due to normal Sonix shutdown from low levels in the TWAS feed tank, this value could not have been achieved. It should also be noted that stack #5 was not brought on-line until 11 March.

Overall the figures in the "up-time" column of Table 2 indicate that the whole plant's operational record was 98.9%.

Table 2 Summary of Sonix operation

Stack no.	Hours of operation	Up-time (actual operation as % total)
1	2594	99
2	2618	100
3	2616	100
4	2314	95
5	2178	100

Dewatering Tests

Dewatering tests were undertaken in the laboratory at Plant 2 using a bench-scale belt press apparatus. From 15 May 2002, ten separate dewatering tests were undertaken. In the results presented below, the data from the first test (on 15 May) was removed from the data set since it was notably different from the remaining data. (It showed a 0.65 percentage point improvement in dewaterability for Digester H.) It is suspected that this first test produced an anomalous result due to operator unfamiliarity with the dewatering test unit.

For the nine tests undertaken since 16 May, the results show that the exit sludges from the test digester (H) dewater to a greater solids concentration than those from the control (E). The difference between the two cakes ranged from 1.10 to 2.58 percentage points more in the digester H cake. The mean was 1.64 percentage points with a 95% confidence interval of 0.32 points. In the cost models, a conservative improvement of only 1.5 points was assumed.

Microscope Results

As mentioned previously, microscope examination of the untreated and sonicated TWAS was done so the effect of the Sonix could be further confirmed and represented visually. Photographs of the samples were taken, and a sample set is shown in Figure 8. In every instance, a clear contrast was seen between the sludge before sonication, where the cells were still intact, and after sonication, where the Sonix had caused cell destruction.

(a)

(b)

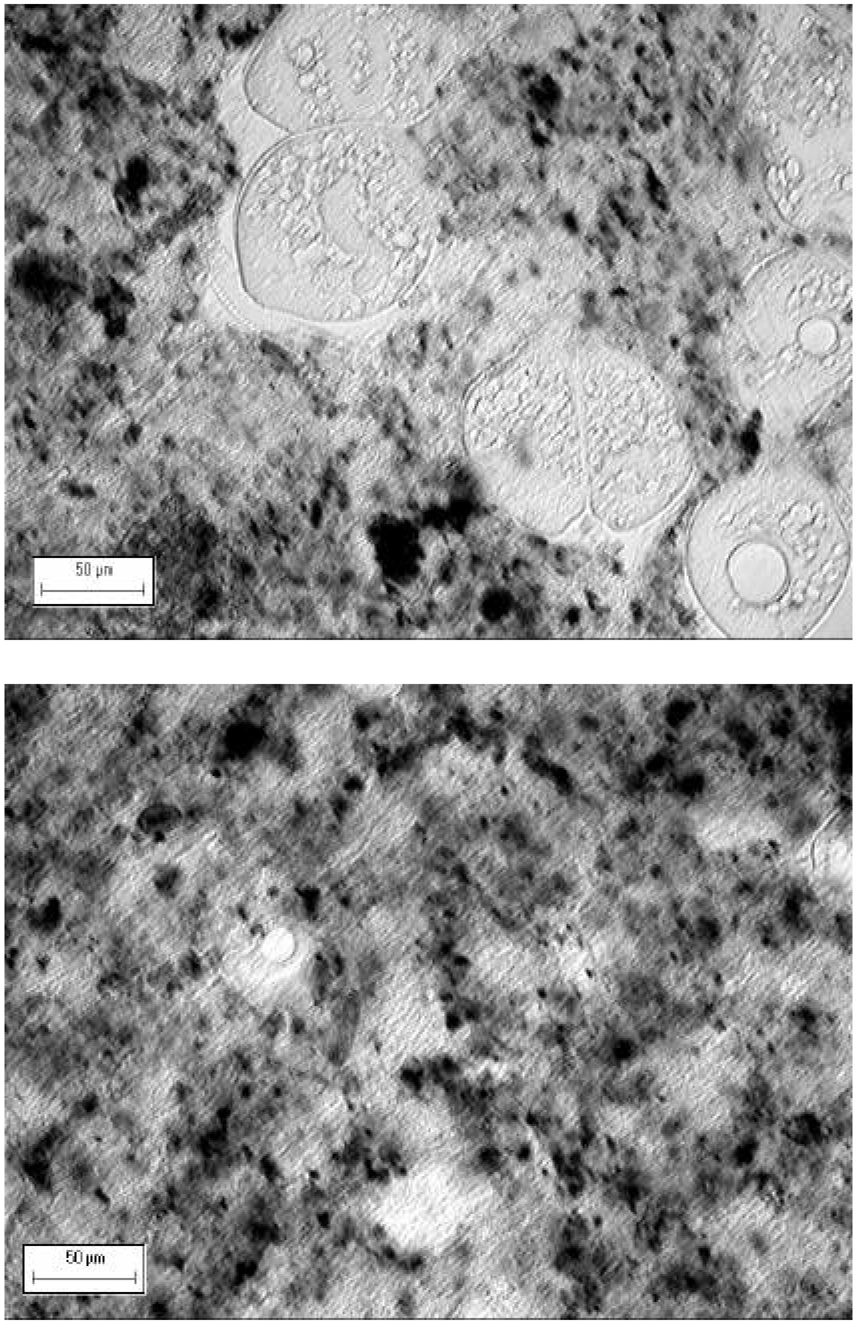


Figure 8 TWAS under the microscope (a) before Sonix and (b) after Sonix

Cost Analysis

A detailed cost model was developed to calculate both the required level of Sonix hardware for a specific sludge throughput and to quantify the operational benefits associated with the technology.

The key benefits associated with the Sonix are as follows:

- Increase in gas production: resulting in a reduced need to purchase natural gas for the cogeneration (central power generation) facility;
- Improved dewatering: resulting in less cake for transportation and disposal;
- Enhanced solids destruction: resulting in less total sludge for transportation and disposal.

To the extent possible, OCSD-specific costs were used (e.g., for purchased natural gas, dewatering costs, solids hauling, etc.). A summary of the findings are presented in Table 3.

Table 3 Summary of Cost Model Results

	Plant 1	**Plant 2**
Number of Sonix heads required	**15**	**20**
Capital cost of hardware	**$855k**	**$1140k**
Operational costs (power, staffing, and maintenance)	**$89k/year**	**$117k/year**
Cost savings		
Savings due to increased gas production	$201k/year	$307k/year
Savings due to improved dewatering/solids destruction	$305k/year	$433k/year
Total Savings	**$506k/year**	**$740k/year**
Simple payback period	**2.05 years**	**1.83 years**

The cost model allowed detailed sensitivity analyses to be performed to examine the impacts of changes in various input values. A summary of the results are presented in Table 4. The base case values are shown first for each parameter, followed by lower and upper values used for sensitivity analyses. Each parameter was varied separately (e.g., when the electricity cost value was changed, the other parameters stayed at their base case values).

Table 4 Summary of Sensitivity Analyses

Input Parameter	Value	Payback for Plant 1 (years)	Payback for Plant 2 (years)
Electricity	\$0.070 / kWh	2.1	1.8
	\$0.065 / kWh	2.0	1.8
	\$0.110 / kWh	2.1	1.9
Biosolids Disposal	\$34 / ton	2.1	1.8
	\$30 / ton	2.3	2.0
	\$40 / ton	1.9	1.7
Natural Gas	\$6 / 10^6 Btu	2.1	1.8
	\$5 / 10^6 Btu	2.2	2.0
	\$8 / 10^6 Btu	1.8	1.6
Dewatered Cake Dryness	+1.5 percentage points	2.1	1.8
	+1.1 percentage points	2.4	2.1
	+2.6 percentage points	1.6	1.4
Solids Destruction	+8 %	2.1	1.8
	+5 %	2.2	2.0
	+15%	1.7	1.5
Capital Cost	+0% from base case	2.1	1.8
	+20% from base case	2.5	2.3
	+40% from base case	3.1	2.7