Batch Processes to Produce Class A Biosoldis from AD Effluent at Terminal Island Treatment Plant

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Abstract Terminal Island Treatment Plant converted its digesters to thermophilic operation with the objective to comply with the U.S. EPA Part 503 Biosolids Rule requirements for Class A biosolids. The following processes were tested: a) single-stage continuous; b) two-stage continuous; c) single-stage sequencing batch. *Salmonella* sp. were always non-detect in digester outflows (<3 MPN/4 g dry wt), whereas fecal coliform densities were usually below the Class A limit of 1000 MPN/g dry wt. However, the recurrence of fecal coliforms in post-digestion caused non-compliance with the Class A limit at the truck loading facility as the last point of plant control for compliance. After several design modifications of the post-digestion train, operation of the digesters as sequencing batch digesters according to the time-temperature requirement of Alternative 1 of the Part 503 Biosolids Rule achieved compliance for both Salmonella sp. and fecal coliforms at the last point of plant control (truck loading facility).

Keywords Class A biosolids, thermophilic anaerobic digestion, Part 503 Biosolids Rule

Introduction

In 1999, the City of Los Angeles initiated the Class A Biosolids Program for biosolids disinfection in thermophilic digesters at the Terminal Island (TITP) and Hyperion Treatment Plants (HTP). HTP demonstrated compliance with the Class A standards of the U.S. EPA Part 503 Biosolids Rule in December 2002 (Iranpour et al. 2006a, b, c; Wilson et al., 2004), which has allowed this plant to continue the land application of its biosolids in Kern County, California. TITP recently demonstrated compliance with the Class A standards after testing several processes. This contribution summarizes the results of biosolids disinfection and compliance using the following processes:

- single-stage continuous process (Phase I);
- two-stage continuous process (Phase II);
- single-stage sequencing batch process (Phase III; final certification tests).

The general requirement of the Part 503 Biosolids Rule for Class A biosolids is that either the fecal coliform density should not exceed 1000 MPN/g dry wt, or the *Salmonella* sp. density should not exceed 3 MPN/4 g dry wt (U.S. EPA, 1993; Iranpour et al., 2004). Local regulations, such as in Kern County, may require that both limits be met. Federal and local regulations require that compliance shall be demonstrated at the last point of plant control (truck loading facility and/or the farm for land application). In addition, the biosolids must comply with one of six Alternatives containing operational standards and/or additional

monitoring requirements. The full-scale tests at TITP focussed on compliance with Alternatives 1 (disinfection in a batch with time-temperature requirements) and 3 (no operational standards, but demonstration of non-detect levels of viable helminth ova and enteric viruses).

Materials and Methods

TITP is located near Los Angeles Harbor, treats an average flow of $3.7x10^4$ m^3/day and produces about 20,000 wet tons of biosolids per year. TITP has four egg-shaped digesters of 4500 m^3 each that are equipped with the possibilities of gas mixing (14 m^3/min) and mixing by pumps (1.9 m^3/min) (Figure 1). The design allows for digester operation as a single stage or a two-stage process. After the digesters, biosolids are transported to the dewatering centrifuges and the silos at the truck loading facility where the biosolids are stored for a maximum of one day prior to transport to the farm for land application. Based on earlier experiences at HTP, TITP implemented the following design modifications to the post-digestion train in 2004: a) bioslids transport on conveyor belts was replaced by transport through pipes and pumps; b) the top of the silos at the truck loading facility were covered; c) the post-digestion train was equipped with insulation and electrical heat-tracing between the digesters and the silos at the truck loading facility.

Phase I: Single-stage continuous process

Phase I was done with Digester 1 from February to June 2000 with the other digesters still at mesophilic temperatures. In a period of 8 days without sludge feeding, the temperature of Digester 1 was rapidly increased from 33.9°C to 56.1°C, followed by a gradual increase of

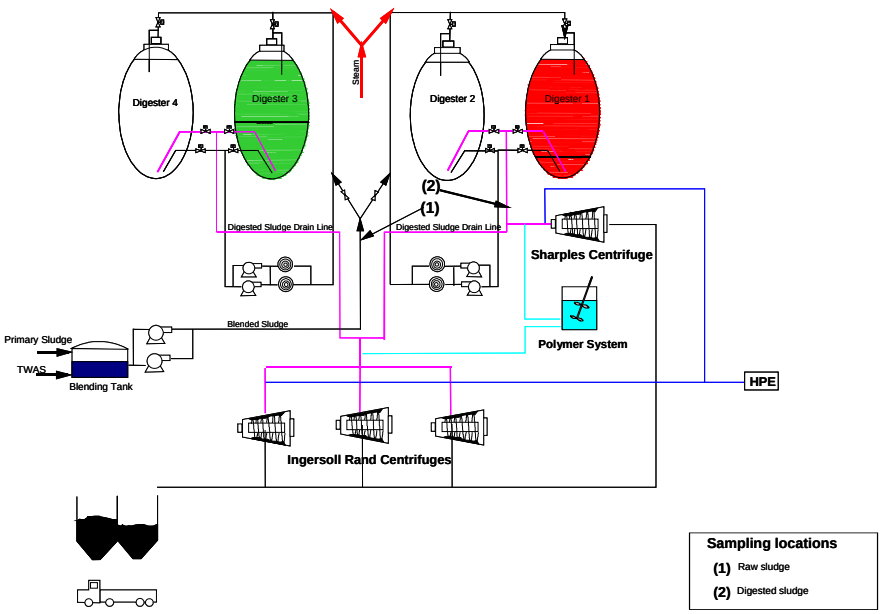

Figure 1 TITP digestion and post-digestion process.

the sludge feed rate over a two-month period. The final feed sludge rate was 307 m^3/day, corresponding to a hydraulic retention time (HRT) of 17 days, with operation in continuous mode.

Phase II: Two-stage continuous process

From July 2000 to April 2001, TITP used two thermophilic digesters in series, both in a continuous mode. Digester 1 received the feed sludge and steam to maintain a temperature of 55.0°C. Because the digesters are well insulated, Digester 2 as the second-stage digester could be maintained at 53.9°C without supplementary heat. The average total HRT initially was 25 days, but reduced to about 15-17 days after one month into Phase II.

Phase II & certification tests: Single-stage sequencing batch process

Operation as sequencing batch reactors started in July 2001. Each digester was operated in 3-day cycles of sludge feeding, holding and withdrawal (Table 1), providing a batch holding time of 24 hours and an average HRT in each digester of 22 days. The digester temperature was kept slightly above 55.0^0C to comply with the Alternative 1 requirements for 24 hours holding in a batch. The final certification tests were conducted in April-May 2004 after completing the design modifications of the post-digestion train as previously described. The digesters were operated as sequencing batch digesters in a similar manner as in Phase III but at an average HRT of 31 days. The batch holding time was 24 hours, requiring a temperature during holding of at least 55.0^0C.

Table 1 Cycles of feeding, holding and withdrawing for sequencing batch digesters.

Day	Day 1	Day 2	Day 3	Day 4
Hours 0	12	24 36	48 60	72 84 96
Digester 1	Feed (104 gpm)	Hold	Withdraw (104 gpm)	Feed (104 gpm)
Digester 2	Withdraw (104 gpm)	Feed (104 gpm)	Hold	Withdraw (104 gpm)
Digester 3	Hold	Withdraw (104 gpm)	Feed (104 gpm)	Hold

Analytical procedures

Microbiological and chemical parameters were determined on a daily basis over the reported periods, using the following procedures: digester temperature (resistance temperature detector in recirculation line); total solids (Part 2540 B in APHA et al., 1992); total volatile solids (Part 2540 E in APHA et al., 1992); pH (Part 4500-H^+ B in APHA et al., 1992); volatile fatty acids (Part 5560 in APHA et al., 1992); alkalinity (Part 2320 B in APHA et al., 1992); fecal coliforms (Part 9221 E.2 in APHA et al., 1992); *Salmonella* sp. (Kenner and Clark, 1974); viable helminth ova (U.S. EPA, 1987); enteric viruses (ASTM, 1992). Sampling locations included the digester inflow, digester outflow and additional locations in the post-digestion train.

Results and Discussion

Thermophilic digestion performance

Phase I: Single-stage continuous process
The pH was 7.3 ± 0.15 during the conversion from mesophilic to thermophilic operation. The VFA to alkalinity ratio increased to a maximum of 0.5 one week after raising the temperature to 54.4^0C, coinciding with a peak in the VFA concentration of 1525 mg/L as acetic acid. Both parameters rapidly declined thereafter, with typical ranges of 200-600 mg/L for VFAs and 0.07-0.2 for the VFA to alkalinity ratio. The alkalinity was 3300 ± 280 mg/L as $CaCO_3$. These results demonstrate that stable thermophilic operation can be achieved relatively fast by following the procedure of rapidly increasing the temperature and gradually increasing the sludge feed rate. Further details on the conversion to thermophilic operation is provided by Iranpour et al. (2002) and Shao et al. (2002).

Phase II: Two-stage continuous process
Table 2 demonstrates that the VFA concentration was almost always higher in the first stage, whereas the total alkalinity was in general higher in the second stage. Consequently, the average VFA to alkalinity ratio was almost twice as high in the first stage. Although most volatile solids reduction occurred in the first stage, there was some additional digestion in the second stage. Overall volatile solids destruction over the two stages was on average 60%.

Phase III: Single-stage sequencing batch process.
The process displayed a similar digestion performance as the processes in the previous phases.

Table 2 Summary of digestion performance (Phase II).

Parameter	Inflow	First stage	Second stage
Temperature		53.2 ± 1.9	52.2 ± 1.7
Total solids (%)	3.6 ± 0.3	2.13 ± 0.19	1.91 ± 0.26
Volatile solids (% of total solids)	76 ± 2.4	59.9 ± 2.2	57.6 ± 2.9
pH		7.12 ± 0.17	7.17 ± 0.14
VFAs (mg/L as acetic acid)		304 ± 172	191 ± 69
Alkalinity (mg/L as $CaCO_3$)		2613 ± 575	2961 ± 293
VFA to alkalinity ratio		0.116 ± 0.064	0.064 ± 0.029

Disinfection performance

Phase I: Single-stage continuous process
The fecal coliform density in the feed was typically between 10^5 and 10^6 MPN/g dry wt. Of 46 daily samples from the digester outflow, 7 samples exceeded the fecal coliform Class A limit of 1000 MPN/g dry wt. Most of these exceedances occurred during the first two weeks after starting the sludge feed. When the sludge feed to Digester 1 had reached the target rate

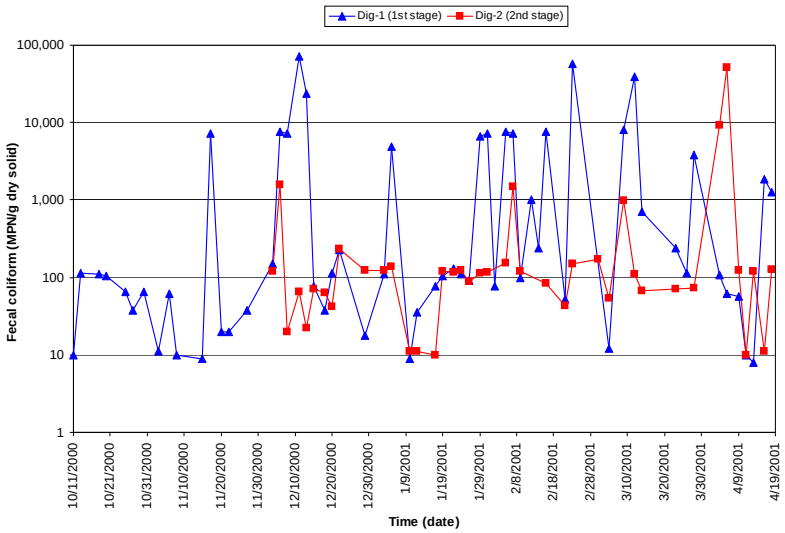

Figure 2 Fecal coliform densities in digester outflow biosolids from the first and second stage.

of 307 m^3/day (HRT of 17 days), the fecal coliform density was usually less than 100 MPN/g dry wt. *Salmonella* sp. were never detected in the digester outflow.

Phase II: Two-stage continuous process

Figure 2 shows that the fecal coliform density in the digester outflow from the first stage exceeded the Class A limit in 30% of 57 samples. Hence, fecal coliform reductions were less than observed in Digester 1 during Phase I when this digester was operated as a single-stage continuous digester. This can possibly be attributed to the reduction of the HRT in Digester 1 from 17 days in Phase I to 7.5-8.5 days in Phase II. Further reduction of fecal coliforms was observed in the second stage, with only 10% of the samples exceeding the Class A limit. This was comparable to the fecal coliform reductions in Phase I. Helminth ova were not detected in composited samples of the digester inflow and outflow. Enteric viruses were present in the digester inflow at a density of 8 Plaque Forming Units/4 g dry wt, but were not detected in the outflow of the first-stage digester. Hence, this two-stage continuous process complied with the additional requirement of complete disinfection of non-bacterial pathogens in Alternative 3.

Phase III: Single-stage sequencing batch process

Operation as sequencing batch digesters usually reduced the fecal coliform density to the range of 10 to 100 MPN/g dry wt, but exceedance of the Class A limit was observed in 13% of the samples (Figure 3). This can most likely be attributed to the fact that digester temperatures did not always met the target value of 55.0^0C as required by Alternative 1. *Salmonella* sp. were never detected in the digester outflows (<2.2 MPN/4 g dry wt). Helminth ova and enteric virus analyses were performed on composited samples. The feed contained significant levels of enteric viruses but none were detected in the digester outflow. Likewise, helminth ova were below the detection limit in the digester outflow.

Salmonella sp. were not detected in biosolids from the dewatering centrifuges and in the

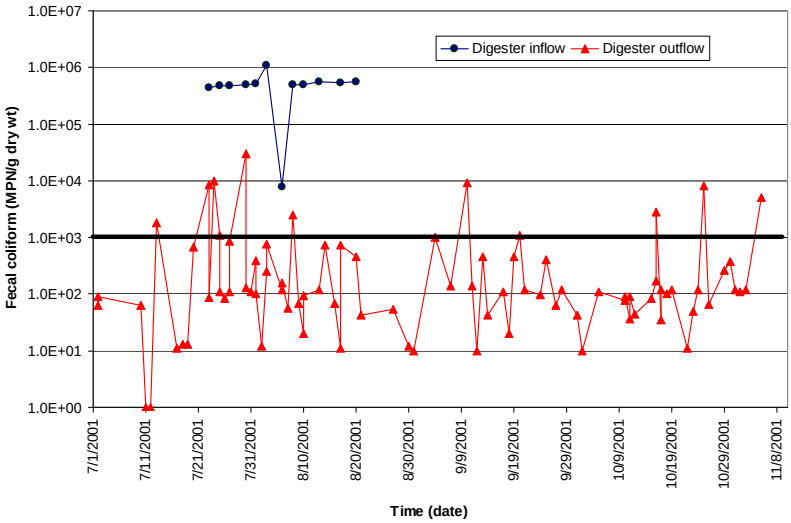

Figure 3 Fecal coliform densities in inflow and outflow of sequencing batch digesters.

silos of the truck loading facility. However, a small increase of the fecal coliform density was observed at the centrifuge outlet, whereas silo biosolids contained fecal coliforms in densities that exceeded the Class A limit by a factor of 10 to 100. This observation indicated the possibilities of contamination of biosolids with fecal coliforms, the reactivation and growth of fecal coliforms during post-digestion, or a combination of both (Iranpour et al., 2006d). Plant surveys indicated the accumulation of residual biosolids on conveyor belts, which could potentially contaminate the biosolids during transport from the dewatering centrifuges to the silos in the truck loading facility. A contributing factor to the reactivation and growth of fecal coliforms could have been the large drop of biosolids temperature during transport of the biosolids on the conveyor belt (Table 3), which caused the temperature at the silos to decline to below the maximum temperature for growth of fecal coliforms.

Certification tests; Single-stage sequencing batch process. After completion of the post-digestion modifications to prevent fecal coliform recurrence, certification tests were conducted to demonstrate compliance with the general requirement for Class A biosolids and the time-temperature requirement of Alternative 1. Continuous measurements of the digester temperatures indicated that the lowest temperature recorded during these certification tests was 55.6^0C, which implies compliance with the time-temperature requirement of Alternative

Table 3 Post-digestion biosolids temperatures (Phase III).

Biosolids sampling location	Temperature (^{0}C)
Digester outflow	53.5
Centrifuge outlet	50.9
Halfway on conveyor belt	48.4
End conveyor belt and silo	43.1

Alternative 1 (T>55.0^{0}C at 24 hours holding). Temperature measurements along the post-digestion train indicated that insulation and electrical heat-tracing prevented the large temperature drop over the post-digestion train that was observed in Phase III. Densities of fecal coliforms in biosolids sampled from the silos at the truck loading facility are shown in Figure 4. Fecal coliforms were also often not detected and, if present, their density was at least 10 times below the Class A limit of 1000 MPN/g dry wt. *Salmonella* sp. were never detected.

Conclusions

1. All tests showed consistent elimination of *Salmonella* sp., enteric viruses and helminth ova to levels that were below the detection limits. The main challenge of producing Class A biosolids is therefore to meet the Class A limit for fecal coliforms.
2. The Phase I single-stage continuous process significant reduced the fecal coliform density in digester outflow biosolids at a HRT of 17 days and longer, but exceedances of the Class A limit were sometimes observed.
3. Reduction of fecal coliforms in the Phase II two-stage continuous process was more stable by the addition of the second-stage.
4. The Class A limit for fecal coliforms was sometimes exceeded in digester outflow biosolids from the Phase III single-stage sequencing batch process. This was probably caused by relatively low digester temperatures that not always met the time-temperature requirement for batch treatment, Alternative 1 of the Part 503 Biosolids Rule.
5. Fecal coliform densities in post-digestion during Phase III increased after the dewatering centrifuges. This caused exceedance of the Class A limit in biosolids at the truck loading facility as a last point of plant control.
6. Design modifications of the post-digestion train solved the problem of fecal coliform recurrence.
7. Certification tests demonstrated consistent compliance with the time-temperature requirement for batch treatment in Alternative 1 and the Class A limits for fecal coliforms and Salmonella sp. in biosolids at the truck loading facility.

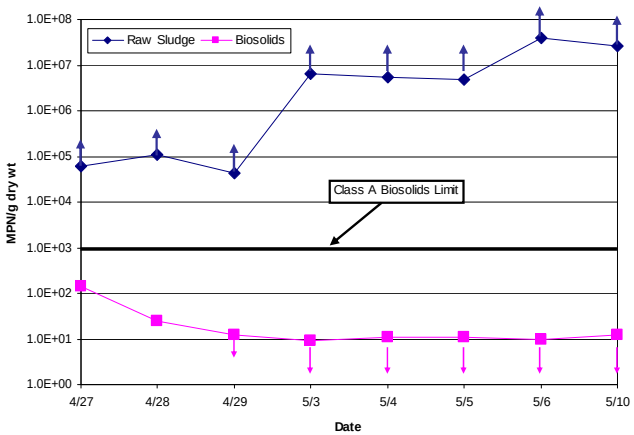

Figure 3 Fecal coliform densities in digester inflow and silo biosolids (last point of plant control) during certification tests.

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