

THERMOPHILIC ANAEROBIC DIGESTION UNDER TIME TEMPERATURE TREATMENT PRODUCES CLASS A BIOSOLIDS AT TERMINAL ISLAND TREATMENT PLANT AFTER MODIFICATIONS OF POST-DIGESTION TRAIN

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ABSTRACT

Terminal Island Treatment Plant (TITP) operates a single-stage sequencing batch process with three thermophilic anaerobic digesters. This paper summarizes the certification tests for demonstrating compliance of this process with the Class A pathogen reduction requirements of Alternative 1 in the U.S. EPA 40 CFR Part 503 Biosolids Rule. The tests were conducted in April/May 2004 after implementation of several design modifications of the post-digestion train. This was to prevent the recurrence of fecal coliforms in post-digestion biosolids that was observed in 2001, 2002 and 2003. The modifications included insulation of the post-digestion train and replacement of the conveyor belts with transport of biosolids through pipes and pumps.

The digesters were operated with a batch holding time of 24 hours. The time-temperature requirement of Alternative 1 is that a temperature equal to or greater than 131⁰F shall be maintained if the batch holding time is 24 hours. Continuous monitoring of the digester temperatures at TITP demonstrated that the lowest temperature recorded during holding was 132.0⁰F.

The biosolids were sampled at the Truck Loading Facility and after three hours of transport by truck to simulate future sampling at the farm for land application, which are the last points of plant control where compliance with the Class A pathogen reduction requirements needs to be demonstrated. *Salmonella* sp. were never detected during the certification tests. Fecal coliforms were not detected in seven of nine samples, and counts were always well below the Class A limit if fecal coliforms were present. Thus, TITP biosolids met the time-temperature requirement for batch holding and the general pathogen reduction requirements of Alternative 1 (Class A limit for fecal coliforms or *Salmonella* sp.). TITP also met the stricter requirement of the Kern County ordinance that both Class A limits for fecal coliforms and *Salmonella* sp. shall be met. After these certification tests, TITP relocated the land application of its biosolids from Arizona to Kern County, California, thus achieving significant savings on hauling costs.

INTRODUCTION

In 2000, the Terminal Island Treatment Plant (TITP) started with the conversion of the anaerobic digesters from mesophilic to thermophilic operation with the objective of producing Exceptional Quality (EQ) biosolids (Shao et al., 2002). As specified in 40 CFR 503 (the U.S. EPA Part 503 Biosolids Rule), EQ biosolids must comply with the Class A pathogen reduction requirements (U.S. EPA, 1993). Initial full-scale tests evaluated the

disinfection of biosolids in single-stage and two-stage continuous digesters (Shao et al., 2002). Since 2002, TITP has employed a single-stage sequencing batch process to comply with the time-temperature requirement for batch treatment in Alternative 1 of 40 CFR 503. As most plants have implemented processes containing two or more phases, i.e., acid/gas and temperature-phased anaerobic digestion (Schafer et al., 2003; Wilson and Dichtl, 1998; Wilson et al., 2002), TITP probably is one of the first plants in the nation to have implemented a single-stage process.

Extensive testing in 2001, 2002 and 2003 of the digester's outflows revealed that the sequencing batch reactors produced biosolids that consistently met the Class A limits for fecal coliforms (1000 MPN/gram dry weight) and *Salmonella* sp. (3 MPN/4 g dry wt). However, biosolids sampling in the post-digestion train indicated a recurrence of fecal coliforms, causing the densities to exceed the Class A limit in biosolids at the Truck Loading Facility. This is the location of the last point of plant control where compliance with the Class A pathogen reduction requirements needs to be demonstrated. Likewise, fecal coliform recurrence in post-digestion biosolids was also observed at the City of Los Angeles Hyperion Treatment Plant (HTP). Potential causes were identified as: a) contamination of thermophilically digested biosolids with mesophilically digested biosolids containing fecal coliforms; b) a large drop of the biosolids temperature in post-digestion, possibly enabling the reactivation and/or growth of fecal coliforms (Iranpour et al., 2003a and b, 2004a, 2005a):

The Part 503 Biosolids Rule specifies that either the Class A limit for fecal coliforms shall be met, or the Class A limit for *Salmonella* sp. Since biosolids at the Truck Loading Facility did not contain *Salmonella* sp., the biosolids complied with the federal standards for Class A biosolids. However, the City of Los Angeles land applies most of its biosolids in Kern County, California, where a recent ordinance requires that both Class A limits shall be met. The fecal coliform recurrence in post-digestion at TITP thus caused non-compliance with this county ordinance.

Based on the earlier experiences at HTP (Iranpour et al., 2004b, 2005b and c), TITP implemented several modifications of the post-digestion train to prevent fecal coliform recurrence. These were completed in early 2004. Subsequently, certification tests were conducted in April and May 2004 to demonstrate compliance with the U.S. EPA Part 503 Biosolids Rule and the stricter ordinance in Kern County. The specific objectives of the certification tests were to demonstrate compliance with:

- The time-temperature requirement for batch treatment ($T \geq 131^{\circ}\text{F}$ at 24 hours holding; Alternative 1, 40 CFR 503.32).
- The general requirement of Alternative 1 (40 CFR 503.32) of meeting the Class A limits for fecal coliforms or *Salmonella* sp. in biosolids at the last points of plant control (Truck Loading Facility and/or farm for land application).
- The Kern County Ordinance requirement of meeting both Class A limits for fecal coliforms and *Salmonella* sp.

MATERIALS AND METHODS

Process description

The TITP process is shown in Figure 1. The plant's total feed sludge of on average 128 gpm (0.18 mgd) is digested in 3 egg-shaped digesters, each with a volume of 1.2 million gallons. Digester 1 was out of service during the certification tests (standard operation at TITP is with one digester in stand-by mode). Continuous mechanical mixing of the digester contents is accomplished by external circulation by pumps.

TITP uses a single-stage sequencing batch process for digestion. The cyclic operation of the three digesters with 24 hours feeding, 24 hours holding and 24 hours withdrawal allows for a continuous sludge feed to the digestion process, while ensuring a batch holding time of 24 hours (Table 1). Table 2 demonstrates the cyclic digester operations during the certification tests. The batch holding time in each digester was 24 hours, which required a minimum temperature of 131⁰F (Alternative 1). During each digester cycle of filling, holding and withdrawal, approximately 10% of the digester content was replaced.

Post-digestion modifications

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. In addition, temperature profiling indicated a large drop of the biosolids temperature on the conveyor belts. This resulted in a biosolids temperature in the silos that was low enough to allow for growth of fecal coliforms. Based on these observations, the following modifications were implemented:

- Transport of dewatered biosolids on conveyor belts was replaced by transport through pipes and pumps.
- The top of the silos at the truck loading were covered.
- The post-digestion train was equipped with insulation and electrical heat-tracing between the digesters and the silos at the truck loading facility.

Sampling and analytical procedures

From April 27 to May 10, 2004, raw sludge and biosolids in the silos at the Truck Loading Facility were sampled daily according to the schedule shown in Table 3. Sampling from silo biosolids at the Truck Loading Facility occurred during truck loading operations. The samples were analyzed for fecal coliforms, *Salmonella* sp. and total solids content by the Environmental Monitoring Division at the Hyperion Treatment Plant. Sampling procedures, analytical procedures and QA/QC were according to U.S. EPA requirements in 40 CFR Part 503, as summarized in Table 4.

TITP biosolids during the certification tests were transported by trucks to Arizona for land application. Biosolids samples were taken from these trucks after 3 hours of transport on April 28 and May 5, 2004. This was to simulate future sampling of farm

biosolids after transport from TITP to the Green Acres Farm in Kern County, which is estimated to take approximately 3 hours.

RESULTS AND DISCUSSION

Digester operation

Withdrawal of 10% of the digester content during each cycle resulted in an average hydraulic retention time of 31 days during the certification period. The data in Table 5 show that on some days the sludge feed rate to the digesters substantially differed from the average sludge feed rate. This was related to changes in plant operations upstream of the digesters. It should however be emphasized that these variations did not have an effect on the batch holding time, which was 24 hours in each digester and for all biosolids being produced by TITP during the certification tests.

Digester temperatures were continuously recorded with sensors located in the digesters. The data in Table 5 demonstrate that the daily average temperature was always greater than 131.8⁰F. In addition, the lowest temperature recorded in the digesters during holding was 132.0⁰F. Therefore, the digesters always complied with the time-temperature requirement of Alternative 1.

The digesters had been operated at a thermophilic temperature for at least two years prior to the certification tests. Periodic analysis of the biosolids indicated that the process was stable: average pH of 7.3, average volatile solids destruction of 53%, and average volatile acid to alkalinity ratio of 0.07.

Microbiological testing

Raw sludge contained fecal coliforms and *Salmonella* sp. in densities that exceeded the Class A limit (Table 6):

- The density of *Salmonella* sp. was always greater than 16.2 MPN/4 g dry wt.
- The density of fecal coliforms was always greater than 4.2×10^4 MPN/g dry wt.

The single-stage sequencing batch process of TITP consistently reduced the densities of fecal coliforms and *Salmonella* sp. to below their respective Class A limits, as illustrated in Figures 2 and 3. A detailed overview of the final test results is provided in Table 6. Sampling of biosolids in the silos at the Truck Loading Facility provided the following results:

- Fecal coliforms were only detected on the first two sampling days at densities of 140 and 24 MPN/g dry wt. Fecal coliforms were not detected (< 12 MPN/4 g dry wt) in samples collected on all other sampling days.
- *Salmonella* sp. were never detected (< 2.6 MPN/4 g dry wt) during the certification test.

These results indicate that the recurrence of fecal coliforms in post-digestion biosolids was probably prevented by the modifications of the post-digestion train, even though the cause of fecal coliform recurrence was not determined unequivocally. Temperature measurements at the Truck Loading Facility indicated that insulation of the post-digestion train was effective in maintaining a high biosolids temperature throughout post-digestion.

Fecal coliforms and *Salmonella* sp. were not detected in biosolids after 3 hours of transport by truck (Table 6), indicating that recurrence of fecal coliforms during transport of the biosolids did not occur.

CONCLUSIONS

TITP is the first plant in the nation to land apply biosolids that meet the Class A pathogen reduction requirements under Alternative 1 in a full-scale single-stage sequencing batch process:

- This process always complied with the time-temperature requirement for 24 hours batch holding in 40 CFR 503.32 Alternative 1 ($T \geq 131^{\circ}\text{F}$ at 24-hrs batch holding).
- TITP biosolids met the stricter general requirements in the Kern County Ordinance by complying with the Class A limits for both fecal coliforms and *Salmonella* sp.
- The Class A limits were met at the Truck Loading Facility and after three hours of transport by truck to simulate future sampling at the farm for land application in Kern County (last points of plant control). This can be attributed to the implementation of several design modifications (i.e., insulation and electrical heat-tracing of the post-digestion train, prevention of contamination of thermophilically digested biosolids) to prevent fecal coliform recurrence in post-digestion.

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Figure 1. Process Diagram of Sequencing Batch Reactors and Dewatering Process

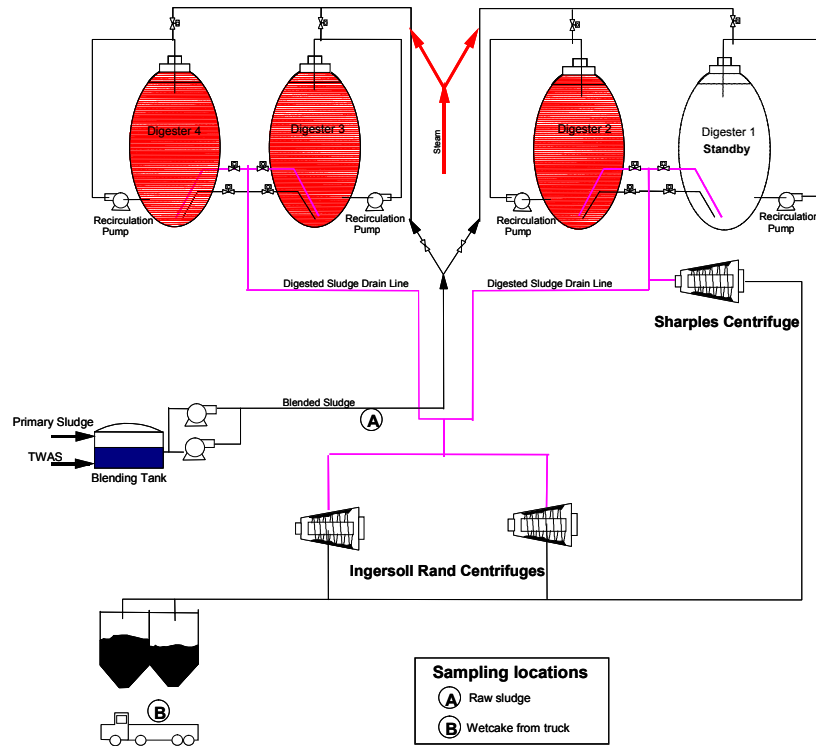


Figure 2. Fecal coliforms densities in raw sludge and truck loading facility biosolids

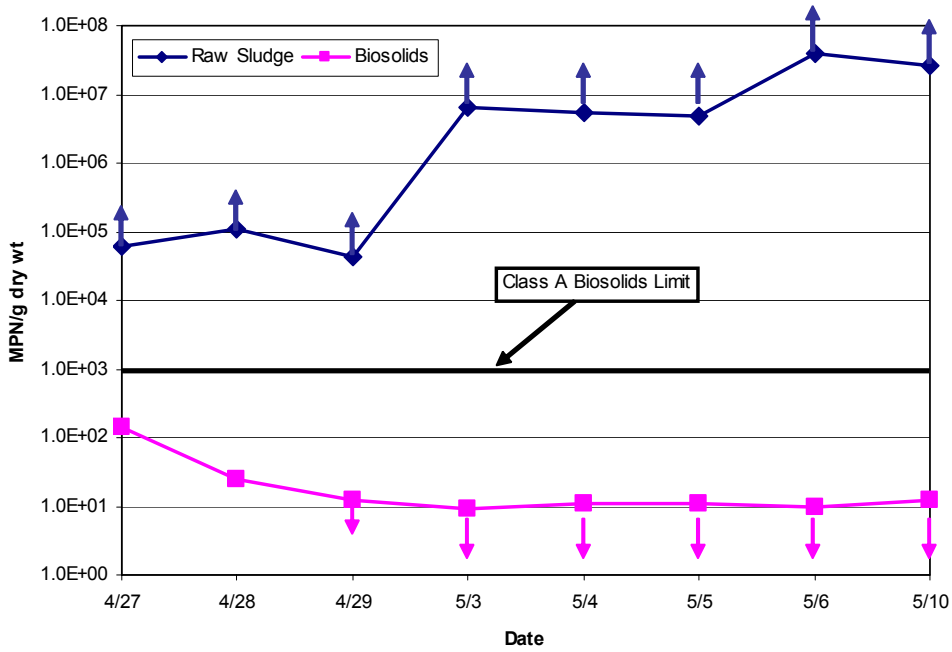
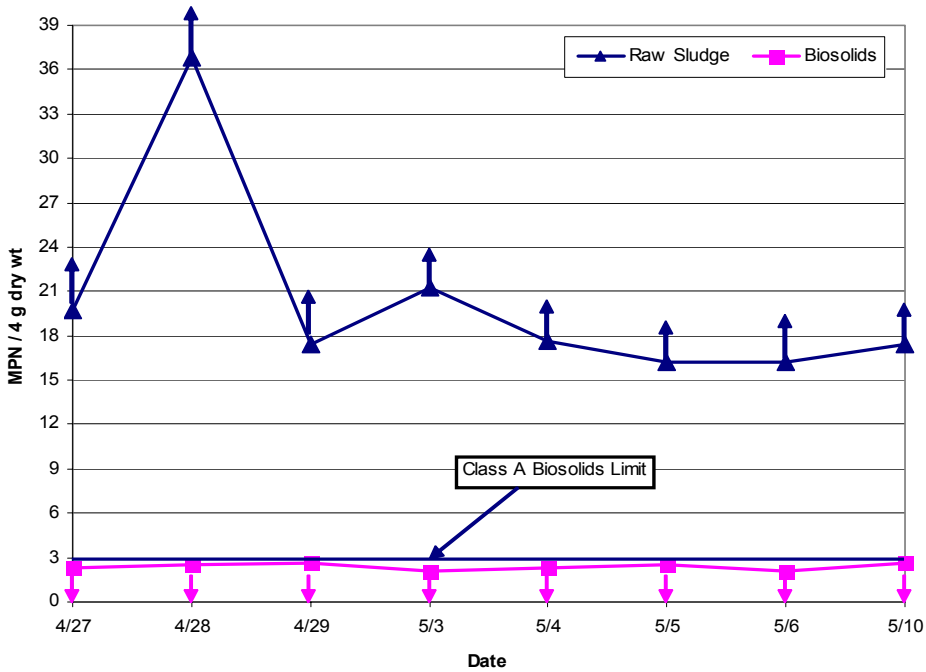


Figure 3. *Salmonella* sp. densities in raw sludge and truck loading facility biosolids



↑ means greater than or equal to (\geq , lower-bound value)
 ↓ means less than or equal to (\leq , upper-bound value)

Table 1. Feed/hold/withdraw cycles of sequencing batch digesters

	Cycle 1		Cycle 2		Cycle 3		Cycle 1	
Hours	0	24	48	72	96			
Digester 2	Feed		Hold		Withdraw		Feed	
Digester 3	Withdraw		Feed		Hold		Withdraw	
Digester 4	Hold		Withdraw		Feed		Hold	

Table 2. Digester feed/hold/withdraw cycles of sequencing batch digesters

Date	Day	Digester				* Min. Temp. for Holding Digester, °F
		#1	#2	#3	#4	
4/27	Tue	Stand-by	Feed	Hold	Withdraw	132.6
4/28	Wed	Stand-by	Hold	Withdraw	Feed	132.8
4/29	Thu	Stand-by	Withdraw	Feed	Hold	132.8
4/30	Fri	Stand-by	Feed	Hold	Withdraw	132.4
5/1	Sat	Stand-by	Hold	Withdraw	Feed	132.8
5/2	Sun	Stand-by	Withdraw	Feed	Hold	132.3
5/3	Mon	Stand-by	Feed	Hold	Withdraw	132.3
5/4	Tue	Stand-by	Hold	Withdraw	Feed	132.8
5/5	Wed	Stand-by	Withdraw	Feed	Hold	132.0
5/6	Thu	Stand-by	Feed	Hold	Withdraw	132.1
5/7	Fri	Stand-by	Hold	Withdraw	Feed	133.3
5/8	Sat	Stand-by	Withdraw	Feed	Hold	133.5
5/9	Sun	Stand-by	Feed	Hold	Withdraw	132.3
5/10	Mon	Stand-by	Hold	Withdraw	Feed	134.0

* The data in the last column show the lowest temperatures that were recorded by continuous temperature measurements during each holding phase.

Table 3. Sampling schedule for certification tests

Sample Type	Sample	Analysis	Sampling Time	4/27 Tue	4/28 Wed	4/29 Thu	5/3 Mon	5/4 Tue	5/5 Wed	5/6 Thu	5/10 Mon
Raw Sludge	Blended Sludge	Salmonella	5:00 AM	S	S	S	S	S	S	S	S
		Fecal Coliforms	5:00 AM	S	S	S	S	S	S	S	S
Biosolids	Silo 1 (Truck Loading Facility)	Salmonella	5:00 AM	S	S	S	S	S	S	S	S
		Fecal Coliforms	5:00 AM	S	S	S	S	S	S	S	S
	Truck on the Road *	Salmonella	9:00 AM	NS	S	NS	NS	NS	S	NS	NS
		Fecal Coliforms	9:00 AM	NS	S	NS	NS	NS	S	NS	NS

* On April 28 and May 5, the truck with biosolids on the way for transport to Arizona was sampled 3 hours after leaving TITP to simulate future sampling at the farm in Kern County (transport from TITP to Kern County estimated to be 3 hours).

S = sampling; NS = no sampling.

Table 4. Sampling and analytical procedures for certification tests

Constituent	Method/reference
Fecal coliforms	Parts 9221-B.1 and E1 in APHA et al. (1992)
<i>Salmonella</i> sp.	Kenner and Clark (1974)
Total solids	Part 2540-G in APHA et al. (1992)
QA/QC	Part 9020 in APHA et al. (1992)

Table 5. Summary of operation data of the sequencing batch digesters

Date	Day	Daily average digester temperature (°F)				Sludge feed flow (gpm)	DT (days)
		#1	#2	#3	#4		
04/27/04	Tue	Stand-by	132.6	133.4	132.1	85	42
04/28/04	Wed	Stand-by	132.9	133.0	132.8	136	26
04/29/04	Thu	Stand-by	132.3	132.8	132.6	132	26
04/30/04	Fri	Stand-by	132.4	132.7	132.4	73	48
05/01/04	Sat	Stand-by	132.4	132.4	132.8	101	35
05/02/04	Sun	Stand-by	132.2	132.3	132.7	143	25
05/03/04	Mon	Stand-by	132.3	132.6	132.2	210	17
05/04/04	Tue	Stand-by	132.4	132.3	132.8	196	19
05/05/04	Wed	Stand-by	131.9	132.0	132.6	136	27
05/06/04	Thu	Stand-by	132.1	132.1	131.8	126	30
05/07/04	Fri	Stand-by	132.1	131.9	133.3	91	41
05/08/04	Sat	Stand-by	132.2	133.5	132.2	142	26
05/09/04	Sun	Stand-by	132.3	134.1	133.2	100	37
05/10/04	Mon	Stand-by	132.3	132.7	134.2	117	32
Minimum		NA	131.9	131.9	131.8	73.4	17.0
Maximum		NA	132.9	134.1	134.2	209.7	48.0
Average		NA	132.3	132.7	132.7	127.7	30.8

NA = not applicable

DT = sludge detention time

Table 6. Fecal coliform and *Salmonella* sp. counts for certification tests

Sample Type	Sample	Analysis	Unit	Sampling Time	4/27 Tue	4/28 Wed	4/29 Thu	5/3 Mon	5/4 Tue	5/5 Wed	5/6 Thu	5/10 Mon
Raw Sludge	Blended Sludge	Salmonella	MPN/4 g dry wt	5:00 AM	>19.7	>36.8	>17.4	>21.3	>17.6	>16.2	>16.2	>17.4
		Fecal Coliforms	MPN/g dry wt	5:00 AM	>=6.0E+04	>=1.1E+05	4.2E+07	>=6.4E+06	>=5.3E+06	>=4.9E+06	3.9E+07	2.6E+07
Biosolids	Silo 1 (Truck Loading Facility)	Salmonella	MPN/4 g dry wt	5:00 AM	<2.6	<2.5	<2.6	<2.1	<2.3	<2.5	<2.1	<2.6
		Fecal Coliforms	MPN/g dry wt	5:00 AM	140	24	<12	<9.4	<11	<11	<9.5	<12
	Truck on the Road *	Salmonella	MPN/4 g dry wt	9:00 AM	NS	<2.6	NS	NS	NS	<2.5	NS	NS
		Fecal Coliforms	MPN/g dry wt	9:00 AM	NS	<12	NS	NS	NS	<12	NS	NS

* On April 28 and May 5, the truck with biosolids for transport to Arizona was sampled 3 hours after leaving TITP in order to simulate future sampling at the farm in Kern County (transport from TITP to Kern County estimated to be 3 hours).

NS = no sampling.