DRAFT

Class A Biosolids

Terminal Island Treatment Plant

Startup Process and Protocols
June 1999

Applied Research

Energy Management and Applied Research
Wastewater Engineering Services Division
Bureau of Sanitation
City of Los Angeles

FORM GEN. 160 (Rev. 6-80).

CITY OF LOS ANGELES

INTER-DEPARTMENTAL CORRESPONDENCE

DRAFT

DATE: June 24, 1999

TO: John Crosse, Assistant Director
Bureau of Sanitation

FROM: Omar Moghaddam, Manager
Energy & Utility Management/Applied Research Group

SUBJECT: Start-up Procedure and Protocol for Class 'A' Biosolids at TITP

This is the first draft of our plan for establishing a thermophilic-mesophilic digestion process to produce Class 'A' Biosolids at Terminal Island Treatment Plant. We have concluded that the reliability of this process had been sufficiently demonstrated that a pilot test is not necessary, and hence preparations should be made for establishing it in the two digesters that currently are not in use. We are confident that the process can be started in a few weeks, as described in the plan, although it is likely that some later adjustments will be needed to optimize the process as experience accumulates.

These conclusions are based on an extensive review of the literature. The most important sources appear in the reference list of the plan.

Several additions need to be made for the final version of the plan. An inspection needs to be made to verify the equipment condition. Also, meetings must be held with the operators to secure their cooperation and to obtain their input about details needed for successful completion of the startup. The draft will be amended to include these additions. There may also be other minor changes, such as adjustments of the list of parameters to monitor or the frequencies of measurement.

We now also believe that the process can be implemented at Hyperion in the same manner, except for adjustment of filling and draw rates and related parameters to suit the larger quantities of sludge and numbers of digesters at Hyperion.

We hope that this meets with your approval. Please let us know if you want additional information or if you have any question(s) please contact Reza Iranpour or Zafar Karimi of the Applied Research Group at 310-648-5028 and 310-648-5002, respectively.

DRAFT

Attachment

C:

J. Mundine
S. Fan
C. Turhollow
R. Birk
C. Mansell, Jr
Y. J. Shao
Hi Sang Kim
C. Montgomery
P. Cheng

For Information:

J. Wilson
J. Langley
G. Garnas
T. Haug

cc: Ing Yee
Lucy Tsao
Sumi Roy

Maintance or TITP
Dave Troesh?

DRAFT

TABLE OF CONTENT

Start-up Procedure & Test Protocol for Class 'A' Biosolids at TITP

1.	Introduction	1
2.	Major Process Options	1
3.	Recommendations for Either Option	2
4.	Parameters to be Monitored	3
5.	Start-up Plans	4
6.	Other Issues	7

DRAFT

1. Introduction

In 1993 USEPA developed a set of standards to protect public health and the environment from the adverse effects of contamination in biosolids. This resulted in CFR 40, Part 503, which specifies that for biosolids to be in Class 'A,' and hence suitable for unrestricted use, the concentrations of the fecal coliform and salmonella in the digested sludge are never to exceed 1,000 and 3 MPN (Most Probable Number) per gram of volatile solids on a dry weight basis, respectively.

Since we already comply w/ metal limit set by state w/ class B, class A bio solids won't change the composition for complying w/ state permit.

If certain parameters are adjusted and changes in operating procedures are made, Class 'A' biosolids can be achieved at the TITP. Temperature-phased anaerobic digestion (TPAD) is a process in which the sludge undergoes thermophilic digestion at around 55°C for a few days under conditions that favor production of volatile fatty acids (VFA) and then undergoes mesophilic digestion at around 35°C for ten days or more under conditions that favor production of methane. Previous experience has shown values of pH, total volatile fatty acids (VFAs), alkalinity, etc. that indicate satisfactory operation of the process, so stable operation will be recognized by the attainment and maintenance of values close to the desired ones.

The purpose of this exercise is to use TPAD at TITP by using one of the digesters as a thermophilic digester and the other as a mesophilic digester to achieve Class 'A' biosolids. The remaining two digesters will continue to perform as the regular mesophilic digesters and no obstruction will occur in the plant's normal operation.

2. Major Process Options

2.1. Original Dague, et. al. temperature-phased anaerobic digestion (TPAD): 5 days thermo at 55°C and pH around 7.0, 10 days meso at 35°C and pH around 7.5, with gas production in both phases.

Advantages:

a. Tested both in extensive laboratory and pilot tests and in full-scale operation at a 3.1 MGD plant

b. Faster volatile solid destruction and gas production than mesophilic digestion

DRAFT

Disadvantages:

a. Patented; may require payments to patent holders

b. Relatively slow startup (recommendation to do start-up as fast as possible!)

2.2. Huyard, et al. modification of TPAD: 2 days thermo at 55°C and pH aournd 5.5, 10 days meso at 35°C and pH around 7.5, with gas production only in the meso phase.

(Too short time @ (Thermo Detention time)

Advantages:

a. Fast startup.

b. Less heat loss through the digester walls than Option A.

c. Additional reserve capacity for future flow increases at TITP compared to Option A.

Disadvantages:

a. Not tested beyond pilot scale.

b. Not known whether relatively brief heat treatment in acid environment is certain to kill poliomyelitis viruses and helminth ova.

3. Recommendations for Either Option

3.1. The heating is to be provided by compressing steam by the 100 hp, 500 cfm rotary vane compressor that is already in place and injecting the steam around the lower portion of the digester through the existing pipe system.

3.2. Feeding the thermophilic digester is to be performed in draw and fill mode, so that no incoming sludge enters the digester until all outgoing sludge has been removed. The digester is expected to be a perfectly mixed reactor, so a fraction of each new charge will be withdrawn at the next extraction, and hence the Part 503 requirement for pasteurization at the temperature of the thermo reactor must be met under the minimum residency conditions set by the draw and fill schedule. Hence, at 55°C feedings cannot be more frequent than once a day, but at 57°C twice a day should be possible, according to the formula

Why is not good to recirculate the sludge continually!

$$D = 50{,}070{,}000/10^{0.14T},$$

DRAFT

where D is the minimum pasteurization period in days and T is the temperature in °C. Bacteriological testing will be needed to verify that pasteurization is being accomplished and to tune the process.

4. Parameters to be Monitored

The following list of parameters is suggested for monitoring the chemical state of the digestion process. Further experience may show that once operation is established the frequency of measurement of some of the parameters can be reduced further, or they may be eliminated entirely. All parameters are to be measured at the Bureau's EMD Laboratory using the procedures in the latest edition of Standard Methods.

1. Temperature (°C)
2. pH
3. Alkalinity (as mg $CaCO_3$/L)
4. Oxidation/Reduction Potential (ORP) (volts)
5. Total VFAs (as mg acetic/L)
6. VFA composition: concentrations of acetic, butyric, propionic and pentanoic acids (as mg acetic/L)
7. Protein Concentration (mg/L)
8. Total Kjeldahl Nitrogen (TKN) (mg/L)
9. NH_3--N (mg/L)
10. Total suspended solids (TSS) (mg/L)
11. Volatile suspended solids (VSS) (mg/L)
12. Total organic carbon (TOC) (mg/L)
13. Biogas Flowrate (L/hr)
14. CH_4 content of biogas (%)
15. CO_2 content of biogas (%)
16. Heavy or toxic metals: Pb, Cr, Cd, Hg, etc. (µg/L) (mesophilic only)
17. Oil and grease (mg/L)
18. Fecal coliforms (MPN/gm dry VS) (thermophilic influent and mesophilic effluent)
19. *Salmonella* (MPN/gm dry VS) (thermophilic influent and mesophilic effluent)

DRAFT

The suggested frequencies of measurement appear in Table 1. If time allows, additional testing will further enhance our information.

Table 1: Suggested monitoring frequencies

Parameter	Startup	Stabilization	Operation
1.Temp	4/day	daily	Daily
2.pH	Daily	daily	Weekly
3. Alk	Daily	daily	Weekly
4. ORP	Daily	weekly	Weekly
5. VFAs	Daily	daily	Weekly
6. Individual acids	Daily	weekly	Weekly
7. Protein	Daily	weekly	Weekly
8. TKN	Daily	weekly	weekly
9. NH_3—N	Daily	weekly	weekly
10. TSS	Daily	weekly	weekly
11. VSS	Daily	weekly	weekly
12. TOC	Daily	weekly	weekly
13. Gas flow	Daily	daily	weekly
14. CH_4	Daily	daily	weekly
15. CO_2	Daily	daily	weekly
16. Metals	Daily	weekly	weekly
17. Oil and grease	Daily	Weekly	weekly
18. Coliforms	Daily	Daily	weekly
19 *Salmonella*	Daily	Daily	weekly

5. Startup Plans

The following options are based respectively on the TPAD process developed by Dague and his colleagues at Iowa State University (Streeter, et al., 1997), and on the modified TPAD described by Huyard et al. Other options may be formulated with additional work.

5.1 Gas Production in Both Phases

Note: during the startup period, when sludge consumption in the thermo digester is below daily production from primary and secondary treatment, the rest of the

DRAFT

sludge goes to the present meso process, which is maintained until the thermo-meso process reaches full operation.

1. Divert 50,000 gpd of sludge for 5 days with no extraction to fill Digester 1 to 250,000 gal, with heating to 55°C as fast as possible.

2. Feed 5,000 gpd of sludge with no extraction until gas production rises to above 0.9 L/g VS destroyed (expected to take around 20 days, based on experience at the Newton, Iowa plant).

3. Raise feed rate to 1/5 the volume in the thermo digester and begin extracting at the same rate to establish 5-day HRT. (If 20 days of feeding were needed in step 2, the volume will be around 350,000 gal, for a flow of 70,000 gpd.) Continue for at least one week to verify process stability. This will put at least 490,000 gallons into Digester 2.

4. When extraction from Digester 1 begins, use it to begin filling Digester 2 to establish mesophilic methanogenic digestion. Digester 2 needs to be filled to 1.2 million gallons to provide a HRT of 10 days for the full flow of around 120,000 gpd.

5. Establish an excess of feed over extraction in Digester 1 to fill it to around 600,000 gal to provide a 5-day HRT at around 120,000 gpd. A possible plan is shown in Table 2

Table 2: Tentative filling schedule for Digester 1

Days from beginning	Inflow (gpd)	Outflow(gpd)	Initial volume (gal)
1-2	70,000	45,000	350,000
3-4	80,000	55,000	400,000
5-6	90,000	65,000	450,000
7-8	100,000	75,000	500,000
9-10	110,000	85,000	550,000
11 and after	120,000	120,000	600,000

Therefore, at the end of this period, Digester 1 will have been filled to 600,000 gal, so that the inflow and outflow from this digester are raised to the full 120,000 gpd. Likewise, Digester 2 will have accumulated all or most of the needed 1.2 million gallons, so extraction from Digester 2 begins at 120,000 gpd if the digester is full, or at a slightly lower level, such as 110,000 gpd if additional filling is needed.

5.2. Gas Production in the Second Phase

Notes: (A) As for Option 1, during the startup period, when sludge consumption in the thermo digester is below daily production from primary and secondary treatment, the rest of the sludge goes to the present meso process, which is maintained until the thermo-meso process reaches full operation. (B) If operation under Option B proves unsatisfactory, it would be possible to adapt the filling schedule to make a transition to Option 5.1..

1. Divert 50,000 gpd of sludge for 2 days with no extraction to fill Digester 1 to 100,000 gal, with heating to 55°C as fast as possible.

2. Feed 50,000 gpd and begin extracting at the same rate to establish 2-day HRT. Continue for at least one week to verify stability of VFA production.

3. When extraction from Digester 1 begins, use it to begin filling Digester 2 to establish mesophilic methanogenic digestion. Digester 2 needs to be filled to 1.2 million gallons to provide a HRT of 10 days for the full flow of around 120,000 gpd.

4. Establish an excess of feed over extraction to fill Digester 1 to around 240,000 gal to provide a 2-day HRT for the full flow of around 120,000 gpd. A possible plan is shown in Table 3.

DRAFT

Table 3: Tentative filling schedule for Digester 1

Days from beginning	Inflow (gpd)	Outflow(gpd)	Initial volume (gal)
1-2	50,000	40,000	100,000
3-4	60,000	50,000	120,000
5-6	70,000	60,000	140,000
7-8	80,000	70,000	160,000
9-10	90,000	80,000	180,000
11-12	100,000	90,000	200,000
13-14	110,000	100,000	220,000
15 and after	120,000	120,000	240,000

Therefore, at the end of this period, the thermo digester will have been filled to 240,000 gal, so that the inflow and outflow are raised to the full 120,000 gpd. Likewise, Digester 2 will have accumulated the needed 1.2 million gallons after approximately 12 days, so extraction from Digester 2 begins at 120,000 gpd when the digester is full.

6. Other Issues

6.1 Precautions/Safety Requirements

A. All participants in the project shall meet regularly to coordinate their activities.

B. All valves and gates leading to digesters not in service shall be closed and properly tagged.

C. The safety coordinator for the plant is to be consulted to ensure compliance with all other applicable safety procedures.

6.2. Recommendations for Long-Term Operation under Either Option

A. Installation of insulation on the external walls of the thermo digester: Metcalf and Eddy (1979, p. 625) recommend estimated heat loss factors for insulated digesters that are 1/3 the heat loss factors for bare walls.

B. Investigation of heat conservation measures to transfer heat from outgoing to incoming sludge for the thermo phase: for example, if a 10°C temperature difference were maintained between the incoming and outgoing sludge along the length of a countercurrent sludge-sludge heat exchanger, reducing the outgoing sludge from 55°C to 35°C would heat the incoming sludge from around 25°C to around 45°C, cutting the burden of heating incoming sludge to approximately 1/3 of what it would be otherwise, and eliminating the unwanted heat input to the meso phase. However, the draw and fill mode of operation needed to meet the pasteurization standard would require detention of the incoming sludge in another tank until the outgoing sludge transfer were complete. Hence, heat conservation is too complex to be addressed here and is under study by the Energy Group.

C. Investigation of the interaction between this process and the plans for additional electricity generation at Terminal Island. Two related topics are evident now:

a. The adequacy of the digester gas supply for the planned uses.

b. The conditions under which the supply of waste heat from the generators will need to be supplemented by other sources

6.3 Notes and Comments

A. Having an acid-generating phase followed by a methane-generating phase produces faster digestion than a single-phase system because the differing metabolic needs of acidogens and methanogens can be satisfied better in separate phases.

B. When conditions are optimal for each kind of digestion, thermophilic digestion is much faster for the same degree of volatile solids reduction than mesophilic. Alternatively, thermophilic gives a greater degree of reduction for the same time.

C. As methanogens require an alkaline pH (7.4-7.6), and acidogenesis precedes methanogenesis, feeding volatile solids at a sufficiently high rate ensures that the acidogens will produce enough acid to inhibit methanogenesis.

D. Hence, establishing the acid phase in a system with completely separate acid and gas phases is easy; the challenge is to maintain the alkalinity of the gas phase high enough to buffer the acidity of the inflow from the acid phase.

E. The high production of volatile fatty acids in the thermophilic phase inevitably makes it a source of odors unless it is carried out in a digester with a fixed cover, like the ones at Terminal Island.

DRAFT

F. Establishment of a stable thermophilic population for Option 1 would occur faster if a seed culture could be obtained from an operating thermophilic digester. Also, room temperature (20°-25°C) is in effect refrigeration for organisms that need temperatures of 45°-60°C for growth, so transport or storage of a seed culture for several days or weeks would not impair viability. However, significantly accelerating bacterial population establishment in a digester the size of the ones at Terminal Island using a seed culture from offsite probably would require one or more tank trucks or railroad tank cars of inoculum, so this does not appear to be a cost-effective possibility.

G. Recent evidence (Ward, et al., 1999) indicates that pasteurization or thermophilic digestion followed by digestion at mesophilic temperatures results in the development of a population of anaerobic bacteria that kills *Salmonella* and fecal coliforms, so that sludge digested by a thermo-meso process is not only disinfected but is resistant to subsequent contamination by pathogens.

H. A preliminary calculation indicates that operation of one of the Terminal Island digesters half full at 55°C will increase the heat loss through its walls by at least 50%, compared to the present mesophilic operation.

I. Many authors (e.g., Aitken and Mullenix (1992); Streeter, et al. (1997); Volpe, et al.) report experiences that argue for heating a digester to its thermophilic operating temperature as quickly as possible (preferably several degrees per day).

J. Since present meso digestion is carried out in Digesters 3 and 4 with Digesters 1 and 2 idle, the obvious course is to establish the new process in Digesters 1 and 2. This would allow the whole system for Digesters 3 and 4 to be shut down once the thermo process was established.

6.4 Questions

A. What would constitute infringement of Dague's TPAD patent, and who is the owner now that he is dead?

B. Would gas production in the meso digester be enhanced under Option B if hydrogen-rich gas from the thermo digester were injected, according to the chemistry described by Vossoughi, et al. (1999)? Would the cost of this modification be a significant consideration?

DRAFT

References

Aitken, A., and Mullenix, R. W.(1992) Another look at thermophilic anaerobic digestion of wastewater sludge, Wat. Env. Res., 64, 915-918.

Environmental Engineering Division, Los Angeles Bureau of Sanitation (1998) Class A Biosolids Program, Aug. 7 presentation

Han, Y., and Dague, R. R.(1996) Heat control, Op. Forum, ???(6), pp. 19-23

Huyard, A., Ferran, B., Audic, J. M., Dieterien, J., Adamick, J., and Noel, T., A challenge for the two phase anaerobic digestion: to produce class A biosolids and meet PFRP equivalency

Metcalf and Eddy, Inc. (1979) Wastewater Engineering: Treatment, Disposal, Reuse (2nd ed.), New York: McGraw-Hill Book Company

Peddie, C. C., Tailford, J., and Hoffman, D., Thermophilic anaerobic sludge digestion -- taking a new look at an old process, WEF 10th Annual Residuals and Biosolids Management Conference, Denver CO.

Streeter, M. D., Dague, R. R., and Main, R. E.(1997) Evaluation of a Field Application, Temperature-Phased Anaerobic Digestion, *Proc. 70th Ann. Conf., Wat. Env.Fed.*, Oct 18-20, Chicago, IL.

Volpe, G., Rabinowitz, R., Peddie, C. C., and Krugel, S., Class A (high grade) sludge process design for the Greater Vancouver Regional District (GVRD) Annacis Island wastewater treatment plant

Vossoughi, M., Alemzadeh, L., Borghei, M., Farhadian, M., and Kashfeeolani, M. (1999) Producing Methane from Organic Industrial Waste using a Fixed Bed Anaerobic Reactor, preprint

Ward, A., Stensel, H. D., Ferguson, J. F., Ma, G., and Hummel, S.(1999) Preventing Growth of Pathogens in Pasteurized Digester Solids, Wat. Env. Res., 71, 176-182.