PROCESSES TO PRODUCE DISINFECTED BIOSOLIDS AT HYPERION TREATMENT PLANT

R. Iranpour*, H.H.J. Cox, S. Oh, R. Palacio, M.A. Starr, S. Fan, T. Minamide, J.E. Mundine

City of Los Angeles Bureau of Sanitation, 12000 Vista del Mar, Playa del Rey, CA 90293; Corresponding author: *phone (310) 648-5280, email riz@san.lacity.org

ABSTRACT

This paper describes Phases III, IV and V of full-scale testing at the City of Los Angeles Hyperion Treatment Plant (HTP) of the production of Exceptional Quality (EQ) biosolids (U.S. EPA Part 503 Biosolids Rule) by thermophilic anaerobic digestion. The tests were conducted after complete conversion of HTP to thermophilic operation and insulation and electrical heat-tracing of the post-digestion train. The Phase III process contained two stages, both of which were operated in a continuous mode. Pathogens (*Salmonella* sp., helminth ova and enteric viruses) in silo and farm biosolids were non-detectable, whereas fecal coliform densities were in general below the Class A limit of 1000 MPN/g dry wt. The Phase IV process was a two-stage continuous/batch process that complied with the time-temperature relation for batch treatment, defined in Alternative 1 of the Part 503 Biosolids Rule. The batch stage provided 16 hours holding at a temperature of 56.6^0C. Farm biosolids produced by this process did not contain fecal coliforms or *Salmonella* sp., thus providing full compliance with the Class A pathogen reduction requirements. However, an increase of the production of methyl mercaptan was observed when the temperature was raised to meet the minimum temperature of 56.3^0C at 16 hours holding. Subsequently, the digester temperatures were lowered to minimize potential odor nuisance to HTP neighbors. As the time-temperature relation for batch treatment would not be met, Phase V tests were conducted to evaluate compliance with Alternative 3 of the Part 503 Biosolids Rule (extended pathogen monitoring). Although the temperature of the thermophilic digesters was reduced, biosolids at HTP's silos and at the farm for land application showed non-detectable levels of *Salmonella* sp., helminth ova and enteric viruses, whereas fecal coliform densities were about 100 times less than the Class A limit.

KEYWORDS: Class A, Exceptional Quality biosolids, thermophilic anaerobic digestion, disinfection, full-scale, continuous operations, continuous-batch operations

INTRODUCTION

Early investigations on thermophilic anaerobic digestion at the City of Los Angeles Hyperion Treatment Plant (HTP) date back to the work of Garber, who had the main objective of improving solids destruction and gas production by increasing the digester temperature (Garber, 1954; Garber et al., 1975). More recently, interest in thermophilic anaerobic digestion has been renewed by an ordinance in Kern County, California, which

banned the land application of Class B biosolids as of January 1, 2003. In anticipation of this ordinance, the City of Los Angeles in 1999 initiated a program to investigate and implement thermophilic anaerobic digestion at its plants for the production of Exceptional Quality (EQ) biosolids (Iranpour et al., 2005a). Production and land application of biosolids in the U.S. is regulated by the U.S. EPA in 40 CFR 503, commonly referred to as the Part 503 Biosolids Rule (U.S. EPA, 1993). EQ biosolids meet the Class A pathogen reduction requirements and can be land applied without site restrictions (U.S. EPA, 1994).

Pilot-scale tests at HTP (Phases I and II) demonstrated the reduction of fecal coliform and *Salmonella* sp. densities to below the Class A limits in a designated thermophilic battery of six digesters, which treated approximately 20% of the plant's feed sludge (Iranpour et al., 2004a; 2005a). The recurrence of fecal coliforms (Class A limit of 1000 MPN/g dry wt) in post-digestion biosolids during these pilot tests, however, caused non-compliance with the Class A pathogen reduction requirements in the Kern County ordinance. Fecal coliform recurrence was tentatively attributed to: a) contamination of thermophilically digested biosolids by mesophilically digested biosolids; b) a large drop of the biosolids temperature in the thermophilic post-digestion train, which could have facilitated the reactivation and/or growth of fecal coliforms (Iranpour et al., 2002a; 2004b). It was therefore decided to insulate and heat-trace HTP's post-digestion train between the digesters and silos at the Truck Loading Facility.

After completing the conversion of HTP to thermophilic operation and the insulation of the post-digestion train, several full-scale tests were conducted to demonstrate compliance with the local and federal standards for EQ biosolids. In this contribution, the following tests will be discussed:

- Phase III: two-stage continuous process for compliance with Alternative 3 in 40 CFR 503.32.
- Phase IV: two-stage continuous/batch process for compliance with Alternative 1.
- Phase V: two-stage continuous/batch process for compliance with Alternative 3.

U.S. EPA REGULATIONS

The general requirement for Class A biosolids is that either the fecal coliform (indicator) density needs to be less than 1000 MPN/g dry wt or the *Salmonella* sp. (pathogen) density needs to be less than 3 MPN/4 g dry wt. In addition, one of six Alternatives in 40 CFR 503 Section 32 should be used. These Alternatives specify treatment conditions or requirements for additional monitoring. Thermophilic anaerobic digestion may comply with Alternatives 1, 3, 4 or 6:

- Alternative 1 specifies the required time and temperature for disinfection of biosolids. Although not specifically defined in the regulations, it is usually understood that the time-temperature requirement needs to be met in a batch process to guarantee a certain holding time for all sludge particles.

- Alternative 3 can be used for continuous processes or other processes that do not meet the time-temperature requirement of Alternative 1. Alternative 3 requires additional monitoring of viable helminth ova and enteric viruses (non-bacterial pathogens) and monitoring of process parameters. If destruction of both non-bacterial pathogens to below their limit of detection has been demonstrated, the process is considered to be Class A as long as operation is in the parameter range during which complete destruction was achieved.
- Alternative 4 can be used for undefined processes. The requirement is that helminth ova and enteric viruses need to be non-detectable in each batch of biosolids leaving the plant. This alternative is not feasible for plants that produce and transport biosolids on a continuous basis.
- If a process has been demonstrated to achieve the Class A pathogen reduction requirements, Alternative 6 provides the opportunity of seeking equivalency as a Process to Further Reduce Pathogens (i.e., "recognized" Class A processes, which are included in Alternative 5) as decided by the Pathogen Equivalency Committee. This requires extensive testing to demonstrate the equivalency.

MATERIALS AND METHODS

Hyperion Treatment Plant: HTP is the main wastewater treatment facility for the City of Los Angeles, servicing an area of about 1500 km^2 and a population of about 4 million. The treatment process consists of preliminary screening and enhanced primary treatment, a pure oxygen secondary activated sludge process, conventional and egg-shaped digesters, solid bowl centrifuges for sludge dewatering, and biosolids handling and storage. The average daily flowrate is 350 mgd. The plant produces approximately 700-800 wet tons of biosolids per day, the vast majority being land applied in Kern County. Post-digestion biosolids handling at HTP consists of screening, centrifuge dewatering, transport of digested sludge and concentrated biosolids through pipes with Able pumps, and biosolids storage in silos for a maximum of one day. Prior to the tests described herein, the entire post-digestion train between digesters and silos was insulated and provided with electrical heat-tracing to reduce heat losses during post-digestion biosolids handling.

Phase III process: This process was tested in August/September, 2002, when the conversion of HTP to thermophilic operation still was in progress (Figure 1). The first stage contained 15 thermophilic digesters (90% of the plant's total feed sludge) at an average temperature of 54.4^0C and a mean hydraulic retention time (HRT) of 10.9 days. Approximately 10% of the sludge was digested in 6 mesophilic digesters at an average temperature of 35.2^0C and a mean HRT of approximately 39 days. Digested biosolids from mesophilic and thermophilic digesters were mixed in two blending digesters at a mean HRT of 1.3 days and an average temperature of approximately 51.4^0C.

Phase IV process: The tests were conducted in October, 2002, after conversion of all egg-shaped digesters to thermophilic operation (Figure 2). The first stage contained 16 digesters that were operated in a continuous mode at an average temperature of 57.5^0C

and a HRT of on average 10.5 days. The second stage contained four digesters that were operated in a batch mode to comply with the time-temperature requirement of Alternative 1. The guaranteed holding time was 16 hours, which required a temperature of at least 56.3^0C. Continuous measurements indicated that the minimum temperature in any of the batch digesters during the entire test period was 56.6^0C.

Phase V process: This process was the same as the one in Phase IV (Figure 2), but the digester temperatures were lowered. As the time-temperature requirement of Alternative 1 would not be met, tests were conducted in November, 2002, to demonstrate compliance with Alternative 3. The average temperature in the first stage (16 digesters) was 52.7^0C at a HRT of 9.9 days. The holding time in the second stage was 16 hours, but at a holding temperature of 52.6^0C.

Sampling procedures: Biosolids samples from the silos at the Truck Loading Facility (sampled just before loading onto the trucks) and at the farm (sampled immediately after unloading) were collected in sterile bottles. Sample collection and preservation were according to procedures as described in Part 9020 of *Standard Methods* (APHA et al., 1992) and by U.S. EPA (1999).

Analytical methods: Total solids and densities of fecal coliforms and *Salmonella* sp. in biosolids were determined according to Parts 2540G, 9260 and 9221E.2 of *Standard Methods* (APHA et al., 1992), respectively. Helminth ova and enteric viruses were determined according to the methods by U.S. EPA (1987) and ASTM (1992), respectively.

RESULTS

Phase III: Preliminary testing of the Phase III process in August, 2002, demonstrated that the biosolids temperature at the silos was on average 50.4^0C. This was only 1^0C less than the average temperature in the second stage digesters, which can be attributed to insulation of the post-digestion train. Without insulation, during pilot-scale tests with a thermophilic battery and dedicated post-digestion train, the temperature in silo biosolids dropped by almost 12^0C as compared to the digester temperatures (Iranpour et al., 2004b; 2005a).

Additional tests were conducted in September, 2002, providing the following results:

- The Class A limit for fecal coliforms in biosolids at the silos and the farm was met in 95% (two exceedances) and 88% (one exceedance) of the samples, respectively. These exceedances could be related to a relatively low biosolids temperature (Figure 3).
- The Class A limit for *Salmonella* sp. was met in all farm biosolids samples. It should be noted that *Salmonella* sp. never exceeded the Class A limit in any of the tests, nor was recurrence of *Salmonella* sp. ever observed during post-digestion.

- Helminth ova and enteric viruses were detected in primary sludge, but the densities of these non-bacterial pathogens in farm biosolids were reduced to below their Class A limits (non-detect).

Phase IV: The Phase IV process was the configuration originally planned for HTP to demonstrate compliance with local and federal requirements for EQ biosolids. The biosolids at the farm were sampled daily over a period of 2 ½ weeks. These tests demonstrated that *Salmonella* sp. and fecal coliforms in farm biosolids consistently were below the Class A limit (non-detect) (Figures 4a and b). Helminth ova and enteric viruses were also below the Class A limit (non-detect) in composited samples of farm biosolids. Although compliance with the Kern County and federal regulations was demonstrated for the first time with HTP fully in thermophilic operation, a large increase of odorous emissions from thermophilic operations was observed when the digester temperature was rapidly raised to meet the time-temperature requirement of Alternative 1 at a holding time of 16 hours (Iranpour et al., 2005c). Analysis of the digester gas showed a sharp increase of the production of methyl mercaptan. Digester temperatures were subsequently reduced in order to prevent an increase of odorous air emissions.

Phase V: These tests were necessary because the time-temperature requirement of Alternative 1 would not be met after lowering the digester temperature, hence, demonstration of compliance with Alternative 3 was required. One week of daily testing in November, 2002, demonstrated that *Salmonella* sp. (Figure 5a) and fecal coliforms (Figure 5b) were below the Class A limit (non-detect) in biosolid samples taken at the farm. Likewise, viable helminth ova and enteric viruses were below the Class A limit (non-detect) in composited samples of farm biosolids.

DISCUSSION & CONCLUSIONS

Phase III process: This process in general met the Class A pathogen requirements of Alternative 3 in the Part 503 Biosolids Rule. The one exceedance observed for the fecal coliform density in farm biosolids was considered not to be significant as an indicator of the disinfection efficiency because the Phase III process achieved reduction of all pathogens (*Salmonella* sp., viable helminth ova, enteric viruses) to below the limits for Class A biosolids. These results are remarkable and better than at first expected from a continuous process that was operated below the target temperature of about 55^0C, received large amounts of fecal coliforms from the mesophilic digesters, and had a minimum average residence time in the digesters.

Phase IV process: This process complied with the time-temperature relation of Alternative 1 for batch treatment, therefore, meeting the Class A limits for fecal coliforms and pathogens by this process was expected. The elevated production of methyl mercaptan was a drawback, because it is a volatile sulfur compound with a low odor threshold (approximately 1 ppb). Minimization of odor emissions is a top priority for the City of Los Angeles and, in general, one of the major challenges in promoting public acceptance of production and land application of biosolids. Hence, it was decided to

reduce the digester temperature with the rationale that the Phase III tests were conducted at a lower temperature, while still achieving the Class A pathogen reductions but without unacceptable odor emissions from thermophilic operations.

Phase V process: This process complied with the Class A requirements of Alternative 3 by achieving complete destruction of fecal coliforms, *Salmonella* sp. and enteric viruses, whereas helminth ova were non-detect in both the digester inflow and farm biosolids. Thus, this process met federal and local requirements for EQ biosolids and the City of Los Angeles received Kern County's permit for land application of HTP's EQ biosolids four days before the ban on Class B biosolids became effective.

Fecal coliform recurrence in post-digestion biosolids: Fecal coliform recurrence in biosolids, causing exceedance of the Class A limit, was observed during pilot-scale tests (Iranpour *et al*., 2004a; 2005a). This resulted in non-compliance with the Kern County ordinance, which is more strict than the federal regulations by requiring that the Class A limits for fecal coliforms and *Salmonella* sp. both be met. During these full-scale tests, fecal coliform densities in farm biosolids were either below the Class A limit (Phase III) or non-detectable (Phases IV and V). This can probably be attributed to complete conversion of HTP to thermophilic operation (elimination of contamination by mesophilically digested biosolids) and insulation and electrical heat-tracing of the post-digestion train (maintaining a biosolids temperature greater than 50^0C during post-digestion processing) (Iranpour *et al.*, 2004b, 2005b).

REFERENCES

APHA, AWWA and WEF (1992). *Standard Methods for the Examination of Water and Wastewater.* American Public Health Association/American Water Works Association/Water Environment Federation, 18th edition, Washington, D.C.

ASTM (1992). *Standard Practice for recovery of viruses from wastewater sludges.* Annual Book of ASTM Standards: Section 11 – Water and Environment Technology, ASTM, Philadelphia, PA.

Garber, W. (1954). Plant-scale studies of thermophilic digestion at Los Angeles. *Sew. Ind. Wastes* **26**, 1202.

Garber, W., Ohara, G.T., Colbaugh, J.E., Haksit, S.K. (1975). Thermophilic digestion at Hyperion Treatment Plant. *J. Water Pollut. Contr. Fed.* **47**, 950.

Iranpour, R., Oh, S., Cox, H.H.J., Samar, P., Taylor, D., Mohamed, F., Hagekhalil, A., Kearney, R.J. (2002a). Effects of dewatering on bacteria inactivation: Centrifuge simulation and field tests at the Hyperion Treatment Plant. *Proceedings Water Environment Federation 75th Annual Technical Exhibition and Conference*; Sep 28 – Oct 2, 2002, Chicago, Illinois; Water Environment Federation: Alexandria, Virginia.

Iranpour, R., Cox, H.H.J., Alatriste-Mondragon, F., Starr, M. (2004a). Pilot-scale tests on disinfection of biosolids by thermophilic anaerobic digestion at Hyperion Treatment Plant. *Proceedings 10th World Congress on Anaerobic Digestion*; Aug 29 – Sep 2, Montreal, Canada; International Water Association: London, UK.

Iranpour, R., Cox, H.H.J., Fan, S., Abkian, V., Kearney, R.J. (2004b). Solving fecal coliform growth/reactivation in biosolids during full-scale post-digestion processes. *Proceedings 10th World Congress on Anaerobic Digestion*; Aug 29 – Sep 2, Montreal, Canada; International Water Association: London, UK.

Iranpour, R., Cox, H.H.J., Oh, S., Fan, S., Kearney, R.J., Haug, R.T. (2005a). Thermophilic anaerobic digestion to produce Class A biosolids; Initial full-scale studies at Hyperion Treatment Plant. *Water Environ. Res.* (in press).

Iranpour, R., Cox, H.H.J., Fan, S., Kearney, R.J., Haug, R.T. (2005b). Full-scale Class A biosolids production by two-stage continuous-batch thermophilic anaerobic digestion at the Hyperion Treatment Plant. *Water Environ. Res.* (accepted).

Iranpour, R., Cox, H.H.J., Oh, S., Fan, S., Haug, R.J., Kearney, R.J. (2005c). Short-term and long-term effects of increasing temperatures on the stability and the production of volatile sulfur compounds in full-scale thermophilic anaerobic digesters. *Biotechnol. Bioeng.* (accepted).

U.S. EPA (1987). *Occurrence of pathogens in distribution and marketing municipal sludges.* EPA 600/1-87-014.

U.S. EPA (1993). 40 CFR Part 503: The standards for the use and disposal of sewage sludge. *Federal Register* **58**:9248-9404.

U.S. EPA (1994). *Plain English Guide to the EPA Part 503 Biosolids Rule*. EPA/832/R-93/003.

U.S. EPA (1999). *Environmental Regulations and Technology: Control of Pathogens and Vector Attraction in Sewage Sludge*. EPA/625/R92/013.

Figure 1. Phase III process diagram.

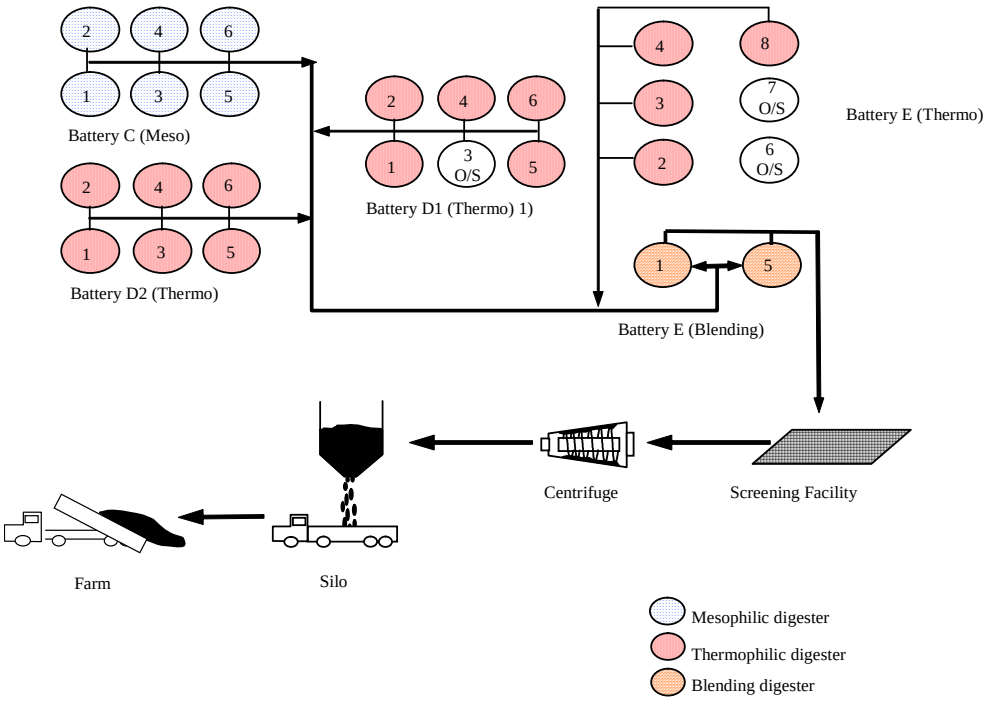

Figure 2. Phases IV and V process diagram.

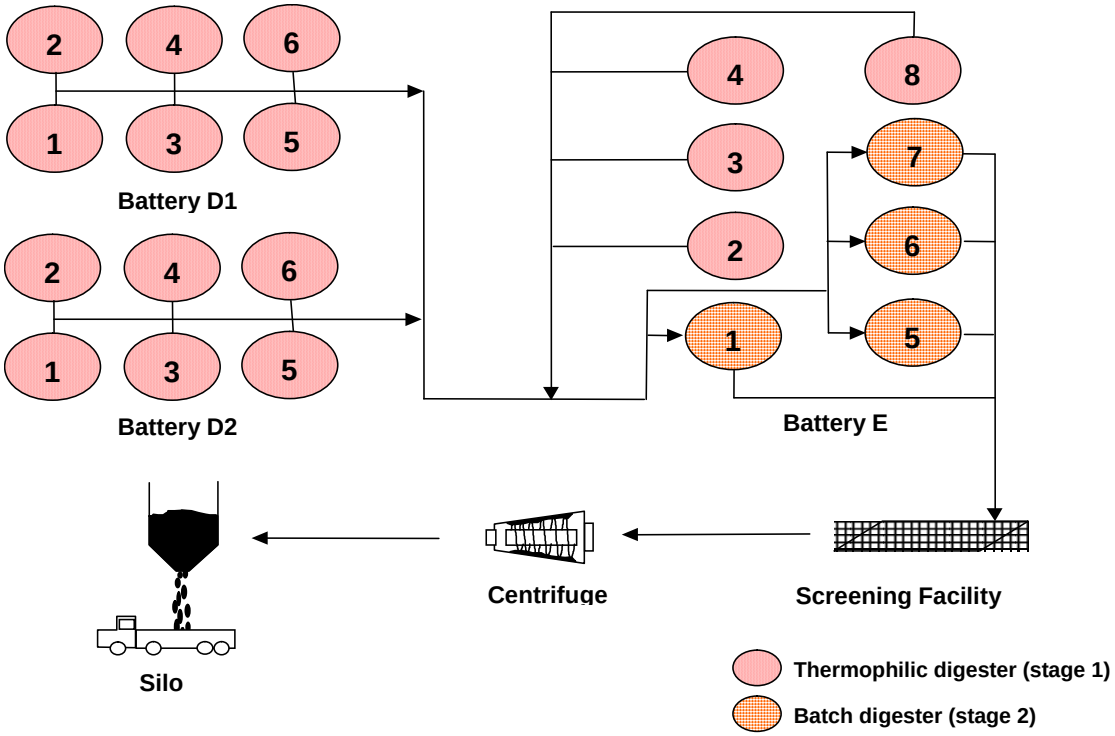

Figure 3. Phase III – Fecal coliform densities in silo and farm biosolids.

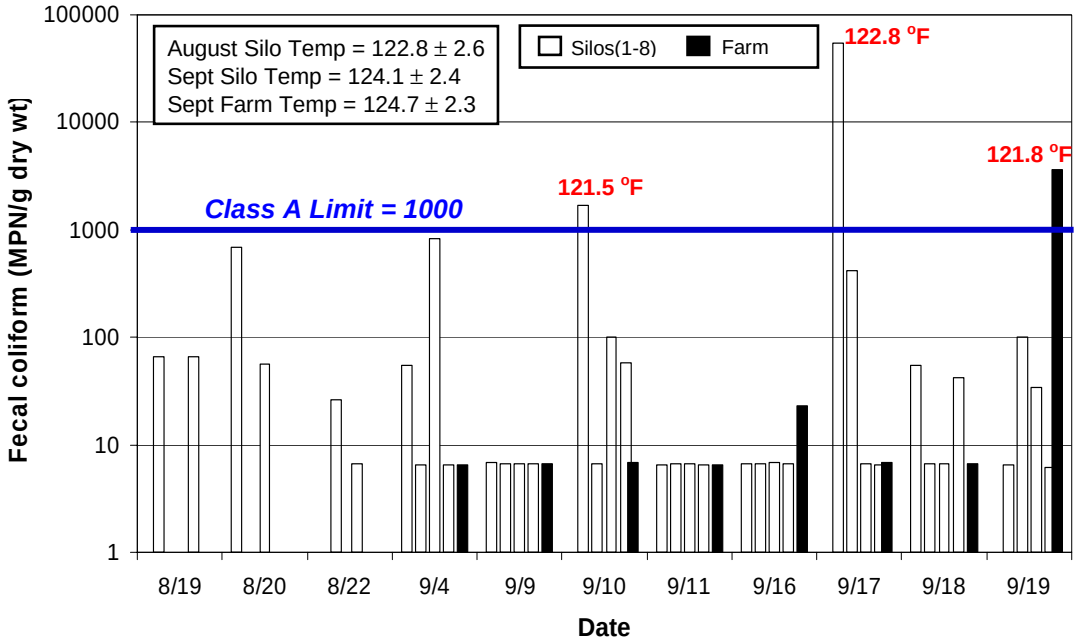

Figure 4. Phase IV – Densities of *Salmonella* sp. (A) and fecal coliforms (B) in farm biosolids.

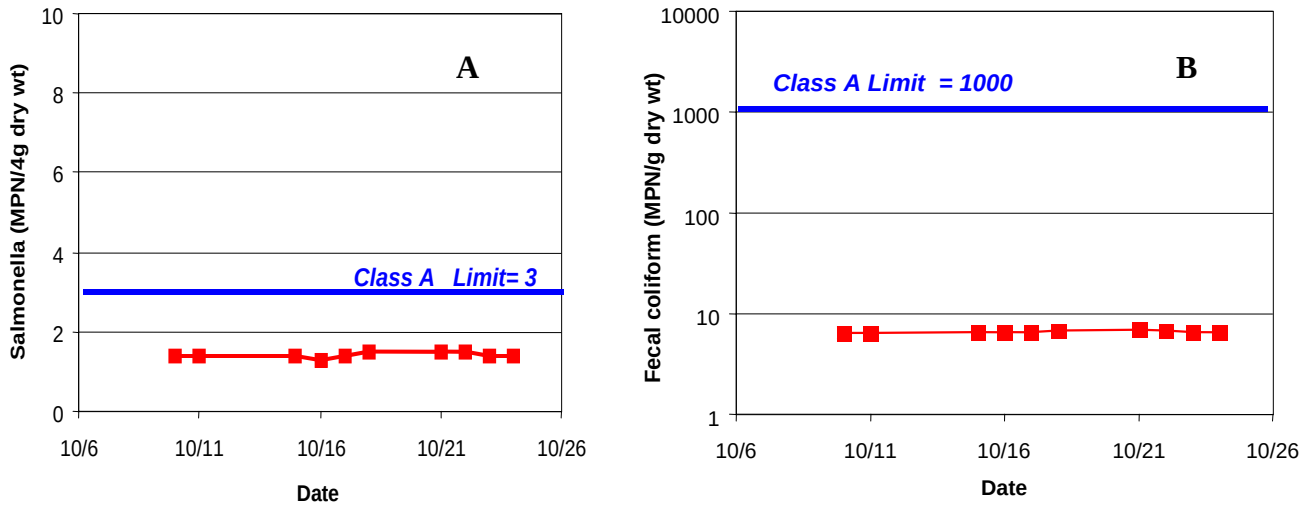

Figure 5. Phase V – Densities of *Salmonella* sp. (A) and fecal coliforms (B) in farm biosolids