Solving fecal coliform growth/reactivation in biosolids during full-scale post-digestion processes

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Abstract Fecal coliform recurrence has been observed at the City of Los Angeles Hyperion Treatment Plant during pilot-scale experiments with a designated thermophilic battery of six anaerobic digesters, while other digesters were still at a mesophilic temperature. Several lab and full-scale experiments indicated the following possible causes of the growth/reactivation of fecal coliforms in post-digestion: a) contamination of thermophilically digested biosolids with mesophilically digested biosolids; b) a large drop in the biosolids temperature between the centrifuges and silos, which could have allowed the reactivation and/or growth of fecal coliforms. These were resolved by the full plant conversion to thermophilic anaerobic digestion and design modifications of the post-digestion train.

Keywords Class A biosolids; disinfection; fecal coliforms; reactivation/growth; thermophilic anaerobic digestion

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Introduction

In response to a Kern County, California, ordinance requiring land application of exceptional quality (EQ) biosolids as of January 1, 2003, the City of Los Angeles initiated a multi-phase research program for implementing thermophilic anaerobic digestion at the Hyperion and Terminal Island Treatment Plants (Shao *et al.*, 2002; Iranpour *et al.*, 2005a, b). EQ biosolids must meet the Class A pathogen reduction requirements in the U.S. EPA Part 503 Biosolids Rule: the *Salmonella* sp. (pathogen) density needs to be below 3 MPN/4 g dry wt or the fecal coliform (indicator) density needs to be below 1000 MPN/g dry wt (U.S. EPA, 1993, 1994).

In most tests on thermophilic anaerobic digestion, disinfection of the biosolids has usually been demonstrated in samples only from the digester outflow (Watanabe *et al.*, 1997; Ghosh, 1998; Wilson and Dichtl, 1998). However, pilot-scale testing at Hyperion Treatment Plant (HTP) demonstrated the recurrence of fecal coliforms in biosolids during post-digestion (Iranpour *et al.*, 2003a, 2005a, b). Fecal coliform densities strongly increased in biosolids after the dewatering centrifuges, causing exceedance of the Class A limit in biosolids in the silos at the truck loading facility and at the farm for land application. These are the last points of plant control for compliance with the federal Class A standards.

According to federal regulations, the recurrence of fecal coliforms does not affect compliance if the Class A limit for the density of *Salmonella* sp. is still met. This is not the case in the ordinance in Kern County, as it requires that both Class A limits for fecal coliforms and *Salmonella* sp. be met. Consequently, the recurrence of fecal coliforms in post-digestion biosolids would cause non-compliance with the Kern County requirements for EQ biosolids (Iranpour *et al.*, 2004). There are several potential causes for the recurrence of fecal coliforms. These include growth of fecal coliforms that survived treatment, reactivation of injured fecal coliforms, and contamination by external sources. This study describes laboratory and field experiments for investigating the potential causes of fecal

coliform recurrence with the overall objective of developing preventive strategies for implementation at plant-scale to obtain disinfected biosolids at HTP.

Materials and methods

Hyperion Treatment Plant

HTP is the largest wastewater plant operated by City of Los Angeles with a daily flow of $1.3 \times 10^6\,m^3$/day. HTP has 20 egg-shaped digesters of $9450\,m^3$ each and produces on average 800 wet tons of biosolids per day. During initial pilot-scale studies, a battery of six thermophilic digesters with a dedicated thermophilic post-digestion train was tested for the production of EQ biosolids. Thermophilic operations (20% of the plant's sludge) were isolated from mesophilic operations (80% of the plant's sludge). Figure 1 presents a schematic of the thermophilic digestion process (continuous-batch) and the post-digestion processes (screening, centrifuge dewatering, silos, transport to the farm). Operation of the thermophilic digesters during the pilot-scale tests has been described in detail by Iranpour *et al.* (2005b).

QA/QC plant walk-throughs

Several QA/QC plant inspections were made between digesters and silos at the truck loading facility to identify potential sources of contamination in the dedicated thermophilic post-digestion train.

Laboratory regrowth tests

Experimental details of these tests have been described (Iranpour *et al.*, 2002). Biosolids were collected from various locations in the post-digestion train, incubated under controlled laboratory conditions and regularly sampled for the fecal coliform density. Selected samples were first spiked with fecal coliforms prior to incubation.

Laboratory simulation of centrifuge dewatering

Biosolids from the digester outflow were divided in four portions and centrifuged in the laboratory with the following additions: a) digester outflow biosolids (blank); b) blank with high pressure effluent (HPE); c) blank with Mannich polymer; d) blank with HPE and Mannich polymer. The additions of Mannich polymer and HPE were in the same

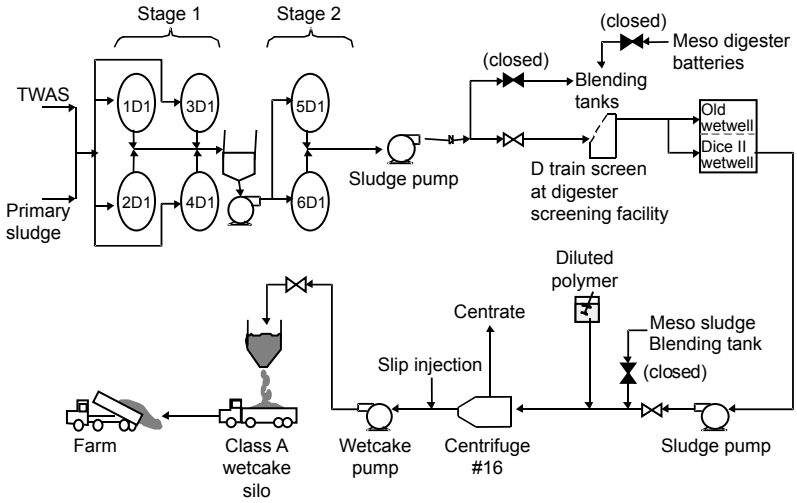

Figure 1 Pilot-scale setup of thermophilic anaerobic digestion and post-digestion at HTP

ratios as in plant operations. After centrifugation, the biosolids were tested for fecal coliform regrowth during incubation in the range 25–55 °C.

Analytical procedures

Analytical procedures for determining the densities of fecal coliforms and *Salmonella* sp. were according to the requirements by U.S. EPA (1993).

Results and discussion

Fecal coliform and *Salmonella* sp. profiling in post-digestion train

Salmonella sp. were never detected in biosolids sampled at all locations between the digester outflow and the farm. The fecal coliform density was below the Class A limit in biosolids including dewatering centrifuges, but exceedances were observed in silo biosolids at the truck loading facility and in farm biosolids (Figure 2A).

QA/QC plant walk-throughs

This investigation confirmed that the thermophilic battery and its post-digestion train were most likely isolated from mesophilic operations. However, contamination by mesophilically digested biosolids could not be entirely excluded because of the length of the

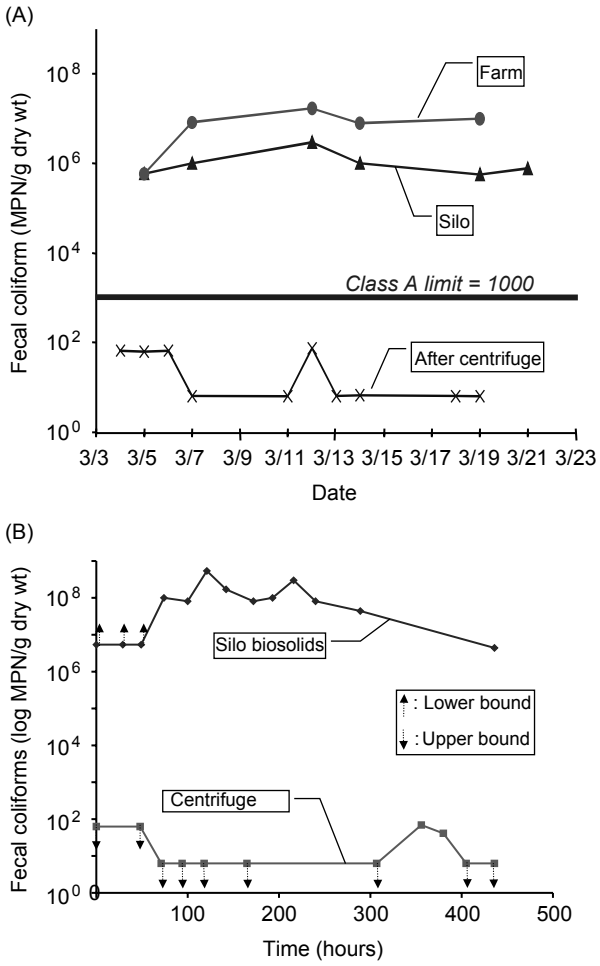

Figure 2 (A) Fecal coliform densities in post-digestion biosolids during pilot-scale tests. (B) Fecal coliform regrowth tests (21 °C) with centrifuge and silo biosolids

train and the presence of many connections between mesophilic and thermophilic operations. Analysis of several samples from different locations in Figure 1 showed that fecal coliforms were not detected in HPE and Mannich polymer added before the dewatering centrifuges and in several HPE additions between the centrifuges and the silos as slip injection to reduce friction during transport.

Laboratory regrowth tests

Figure 2B demonstrates, at initial time, that biosolids from the dewatering centrifuge contained a low number of fecal coliforms, which further declined during subsequent incubation at ambient temperature in the laboratory. In contrast, at the initial time, silo biosolids already contained fecal coliforms that exceeded the Class A limit, which further increased by about two orders of magnitude during incubation.

Laboratory simulations of centrifuge dewatering

No significant growth of fecal coliforms was observed after centrifugation of blank (digester outflow biosolids, results not shown). Likewise, there was no significant growth when HPE, Mannich polymer or a combination of HPE and Mannich polymer were added to the blank prior to centrifugation (results not shown). The results were the same for incubation temperatures in the range 25–55 °C. The simulations in the laboratory, therefore, could not confirm the role of centrifuge dewatering in the recurrence of fecal coliforms observed at plant-scale. One possible explanation could have been that the total solids contents in biosolids centrifuged in the laboratory was only 10%, whereas biosolids centrifuged in the plant contain about 30% biosolids.

Effect of temperature on fecal coliform regrowth

In biosolids from the digester outflow, fecal coliform densities were very low and did not increase during incubation at 25–45 °C (<5 MPN/g dry wt, results not shown). In addition, the fecal coliform density rapidly declined when digester biosolids were spiked with fecal coliforms (results not shown). In centrifuge biosolids, however, the fecal coliform density rapidly increased after spiking and incubation at 25–45 °C (Figure 3A). The declining density in digester outflow biosolids can possibly be attributed to the production of inhibitory metabolites during anaerobic digestion, such as volatile fatty acids, ammonia, bacteriocins, etc. (Ward *et al.*, 1999; Iranpour *et al.*, 2000), although molecular methods for detection may provide a better understanding of the fate of fecal coliforms (Rittman, 2002; Iranpour *et al.*, 2003b). In contrast, centrifuge biosolids were capable of supporting fecal coliform growth and/or reactivation of injured fecal coliforms at temperatures in the range of 25 to at least 45 °C. Further tests in the laboratory and the plant demonstrated that fecal coliforms in post-digestion biosolids could be prevented by maintaining a biosolids temperature of approximately 50 °C and higher.

During the pilot tests at HTP, a large drop in the biosolids temperature occurred along the post-digestion train dedicated to the thermophilic battery, in particular between the dewatering centrifuges and the silos: digester outlet 52.6 °C; centrifuge outlet 48.2 °C; silo at truck loading facility 41.0 °C; farm 40.3 °C. This decline was thought to be a significant factor contributing to the recurrence of fecal coliforms in post-digestion biosolids, because biosolids temperatures at the silos and the farm were below the minimum temperature of 50 °C that would prevent growth and/or reactivation of fecal coliforms.

Solving fecal coliform regrowth

After the tests described above, HTP completed the conversion of the plant to thermophilic operation of all digesters. In addition, the post-digestion train between the

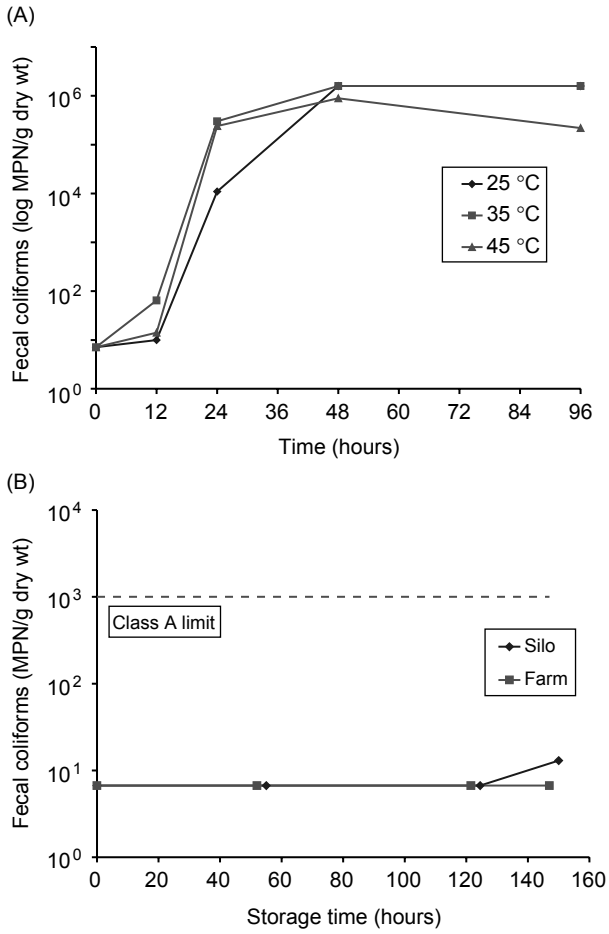

Figure 3 (A) Fecal coliform regrowth tests (25–45 °C) with spiked centrifuge biosolids. (B) Fecal coliform regrowth tests (21 °C) with silo and farm biosolids after post-digestion design modifications and full plant conversion

digesters and the silos at the truck loading facility was insulated and provided with electrical heat-tracing to prevent the large drop of the biosolids temperature in post-digestion. Subsequent tests demonstrated that fecal coliforms were not detected ($<5-10$ MPN/g dry wt) in silo and farm biosolids. In addition, fecal coliforms were not detected in regrowth tests with incubation of silo and farm biosolids at ambient temperature for over 140 hours (Figure 3B).

Conclusions

These experiments indicated that the fecal coliform recurrence in post-digestion biosolids during pilot-scale testing at HTP could have been caused by a combination of: first, Contamination of thermophilically digested biosolids by mesophilically digested biosolids, although many efforts were taken to isolate the thermophilic train from mesophilic operations. And secondly, a large drop of the biosolids temperature during post-digestion processing, which could have allowed the growth of fecal coliforms and, if present, the reactivation of fecal coliforms that were injured during thermophilic anaerobic digestion.

Fecal coliform recurrence was resolved by the complete conversion of HTP to thermophilic anaerobic digestion (elimination of contamination by mesophilically digested

biosolids) and the insulation and electrical heat-tracing of the post-digestion train (preventing the large drop of the biosolids temperature).

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