EASY DOES IT

Rapid temperature increases in thermophilic anaerobic digesters apparently produce more volatile sulfur compounds, while gradual increases maintain a more balanced culture

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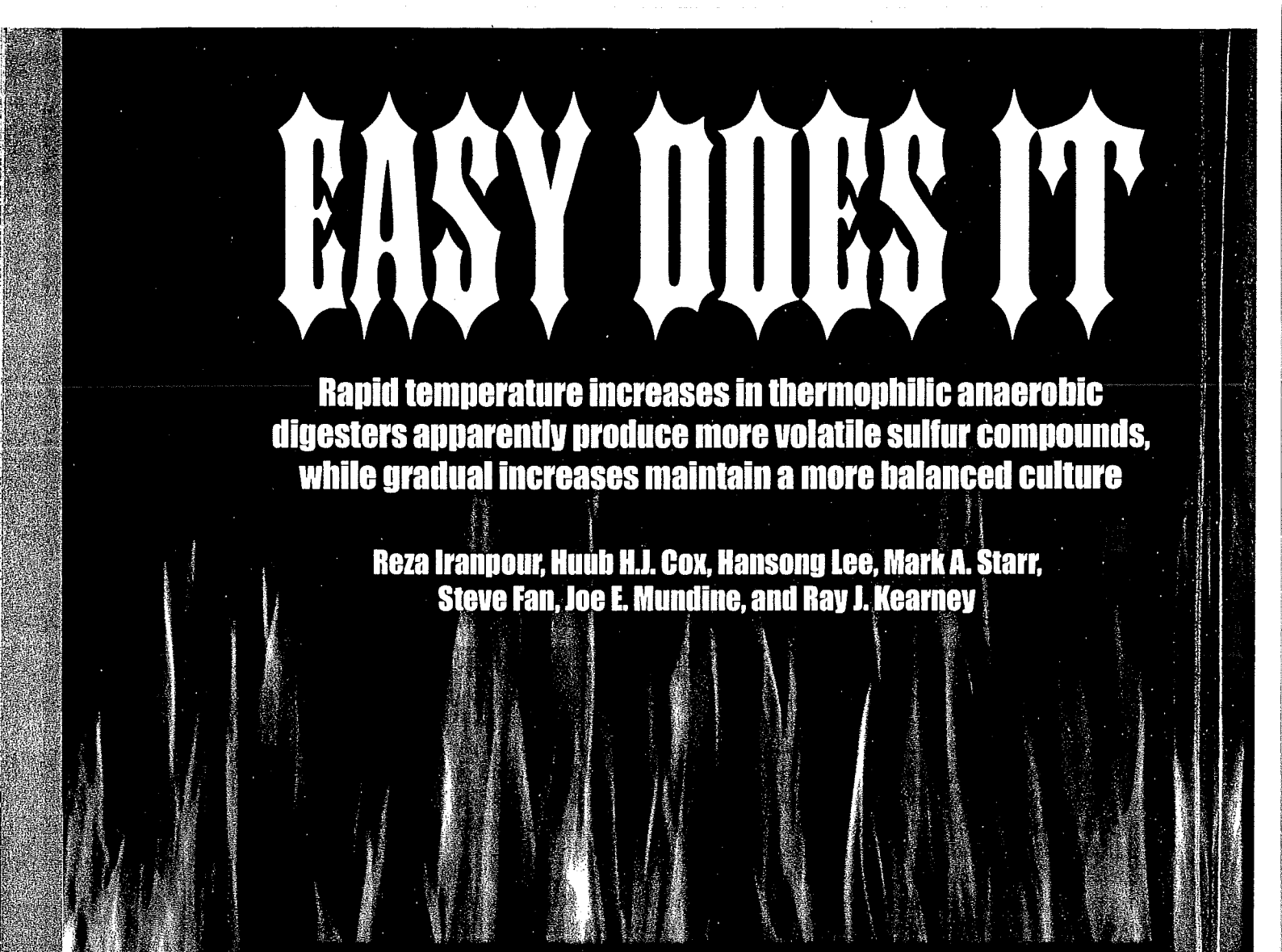


The rate at which digester temperature is increased can affect digester odors. This is what was found during a study at the Hyperion Treatment Plant (Playa del Rey) and Terminal Island Treatment Plant (San Pedro) in southern California.

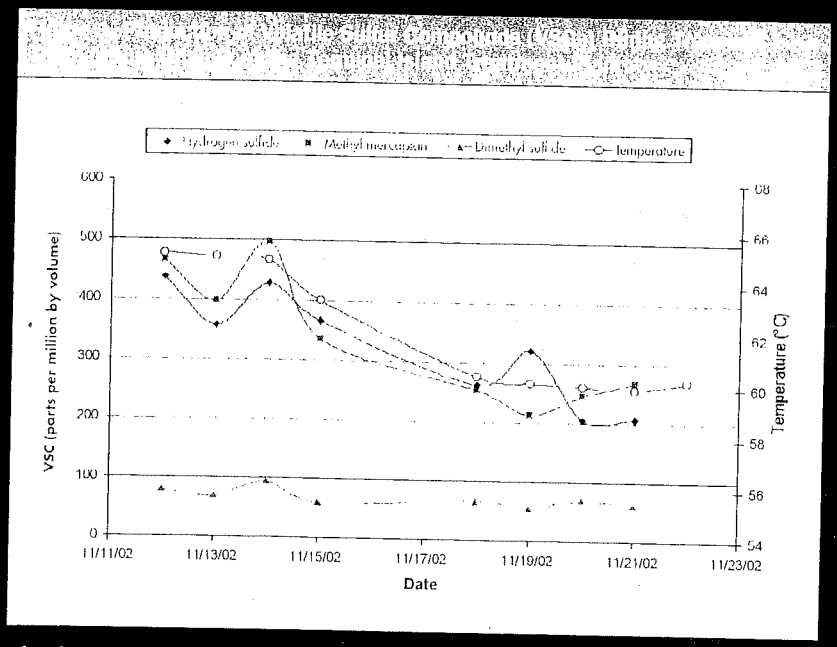
To comply with the Class A requirements in 40 *CFR* Part 503 for eliminating pathogens in biosolids, the City of Los Angeles' Bureau of Sanitation converted the digesters at Hyperion and Terminal Island to thermophilic operation. The bureau implemented a single-stage sequencing-batch process for the Terminal Island digesters and a two-stage continuous-batch process at Hyperion. Because Hyperion's batch digesters were operated a few degrees below the temperature defined by the time–temperature requirements specified in Part 503, Sec. 32, Alternative 1, their temperature was increased rapidly to evaluate operation under this alternative. Although Terminal Island's digesters already were operating according to the time–temperature requirements of Alternative 1, their temperature was increased rapidly to evaluate whether this change would prevent fecal coliform bacteria from recurring in biosolids after digestion.

Effects of Rapid Temperature Changes

Terminal Island. Terminal Island has four 5000-m^3 egg-shaped digesters, which are fed a mixture of primary sludge and thickened waste activated sludge (WAS) at a total feed rate of 570 m^3/d. Three digesters are operated in a single-stage sequencing-batch process to meet the time–temperature requirements for Class A biosolids spelled out in Part 503, Alternative 1 — that is, a temperature of at least 55°C for 24 hours. Each digester is operated on a 3-day cycle of sludge feeding, holding, and withdrawal. About 11% of digester volume is withdrawn or fed in each cycle, resulting in an overall average hydraulic retention time (HRT) of about 26 days.

Between Oct. 28 and Nov. 7, 2002, Terminal Island raised the temperature in Digester 1 from about 59°C to 65.5°C and held it there for about 10 days to see whether the added heat would prevent fecal coliform bacteria from recurring in the resulting biosolids downstream of the digesters. Then the plant lowered the temperature to about 58°C over 2 weeks.

It was found that rapidly increasing the digester temperature significantly changed the production



of volatile sulfur compounds (VSCs) and digester performance. Hydrogen sulfide and methyl mercaptan concentrations in digester gas increased to about 450 ppm (by volume) and about 500 ppm, respectively (see Figure 1, above). Dimethyl sulfide concentrations were not significantly affected by digester temperature, and carbonyl sulfide, ethyl mercaptan, 2-propyl mercaptan, and 1-propyl mercaptan were not detected.

The concentration of volatile fatty acids (VFAs) in digester biosolids samples also jumped from between 60 and 250 mg/L to about 1000 mg/L. The total alkalinity was not significantly affected by digester temperature; it remained between 1650 and 1850 mg/L. Therefore, the ratio of VFA to total alkalinity increased from about 0.1 to a maximum of 0.55.

Volatile solids destruction decreased and the methane content of digester gas dropped from about 60% to about 42%. Digester parameters rapidly returned to normal values when the temperature decreased.

Hyperion. Hyperion has three new batteries (D1, D2, and E) of 9500-m^3 egg-shaped digesters (20 total). The average feed consists of 11,300 m^3/d of primary sludge and 3000 m^3/d of thickened WAS. The digesters are operated in a two-stage process. The first stage uses 16 digesters operated in a continuous mode. Average HRT in the first stage during these tests was about 10 to 12 days. The second stage uses four digesters operated in a batch mode with a 32-hour cycle of sludge feeding, holding, and withdrawal. Up to 70% of the total capacity of each digester is fed or withdrawn during each cycle.

Because the holding time is 16 hours, a temperature of at least 56.3°C is required to meet the time–temperature requirement of Part 503, Alternative 1. So, in late September and early October 2002, the plant rapidly increased the temperature of the first-stage digesters from about 54°C to around 58°C, and then held them between 57°C and 58°C for 3.5 weeks in October.

Unfortunately, odor complaints from nearby residential areas also increased in October, so the plant dropped the temperature in all digesters to about 53°C, and staff made plans to have the digesters meet Part 503, Sec. 32, Alternative 3 instead, which specifies testing of the biosolids for a wider range of pathogenic organisms.

The odor complaints coincided with a strong increase of VSC levels in digester gas. At about 58°C, concentrations of methyl mercaptan and

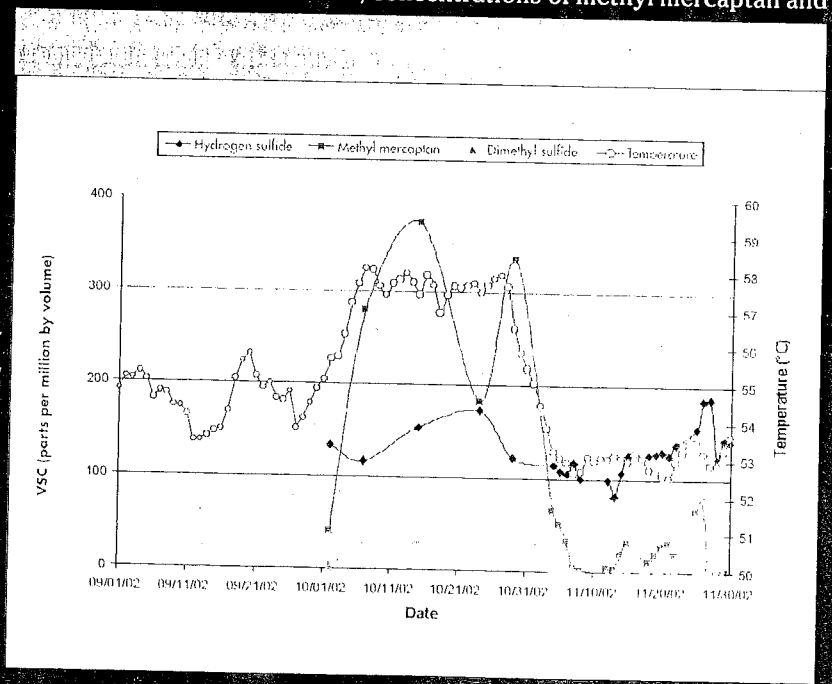
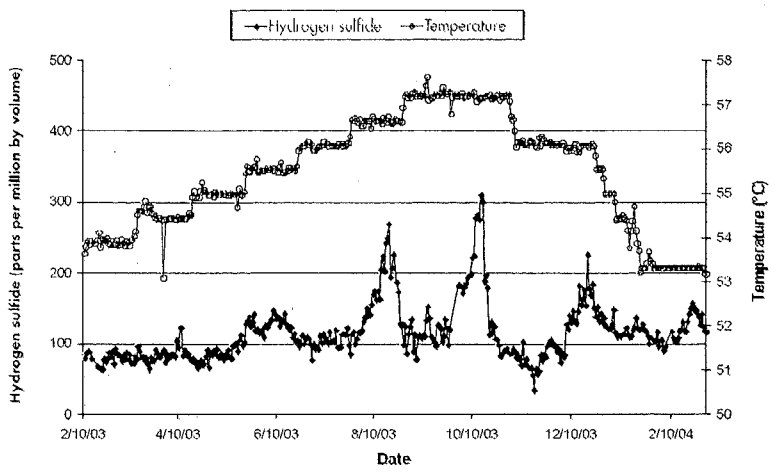


Figure 3. Production of Hydrogen Sulfide During Steady-state Test at Hyperion Treatment Plant (Digester 1D1).



dimethyl sulfide increased sharply from near zero to about 370 and 40 ppm, respectively (see Figure 2, p. 59). When the plant reduced the temperature to about 53°C, concentrations of both gases dropped sharply. The hydrogen sulfide concentration, on the other hand, remained between 100 and 200 ppm regardless of temperature.

Average VFA concentration also correlated with digester temperature (on a delayed response), increasing from about 400 mg/L to more than 1000 mg/L as the temperature increased to 58°C, and dropping as the temperature dropped. But overall digester performance — VFA-to-alkalinity ratio, volatile solids destruction, and methane production — seemed to be unaffected. Total alkalinity remained between about 3000 and 3700 mg/L, and the VFA-to-alkalinity ratio increased to a maximum of about 0.33 at higher temperatures. Methane and carbon dioxide concentrations in digester gas also remained stable.

Effects of Gradual Temperature Changes

To further evaluate the effects of temperature changes on digester performance, Hyperion slowly increased the temperature of Digester 1 in Battery D1 (Digester 1D1) from about 54°C in February 2003 to about 57°C in September 2003 (0.55°C per month). The temperature in the other digesters was kept constant.

Overall, Digester 1D1 performance was about the same. Although hydrogen sulfide production increased at temperatures greater than 56.1°C (see Figure 3, left), its concentration in digester gas was controlled by injecting more ferrous chloride. Methyl mercaptan and dimethyl sulfide concentrations in digester gas were low and stable until 56.1°C. They started to increase at 56.6°C, rising slowly and irregularly until they suddenly spiked to peak concentrations of around 4 and 20 ppm by volume, respectively, at 57.2°C (see Figure 4, below).

VFA and alkalinity concentrations changed simultaneously over several months, but these changes seem to be related to seasonal changes in plant loading, because they occurred in both Digester 1D1 and Digester 2D1, even though the latter remained at about 53.3°C. And because VFA and alkalinity concentrations changed together, the VFA-to-alkalinity ratio in Digester 1D1 remained well below 0.1 (see Figure 5, right). Meanwhile, the composition of digester gas in terms of methane and carbon dioxide remained steady.

Figure 4. Production of Methyl Mercaptan and Dimethyl Sulfide During Steady-state Test at Hyperion Treatment Plant (Digester 1D1).

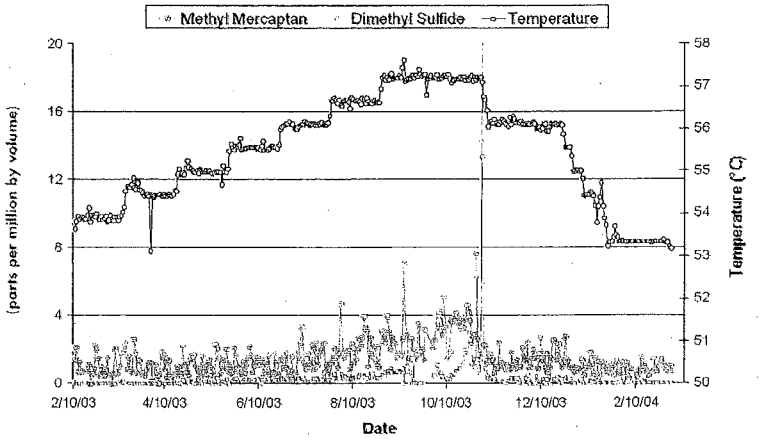
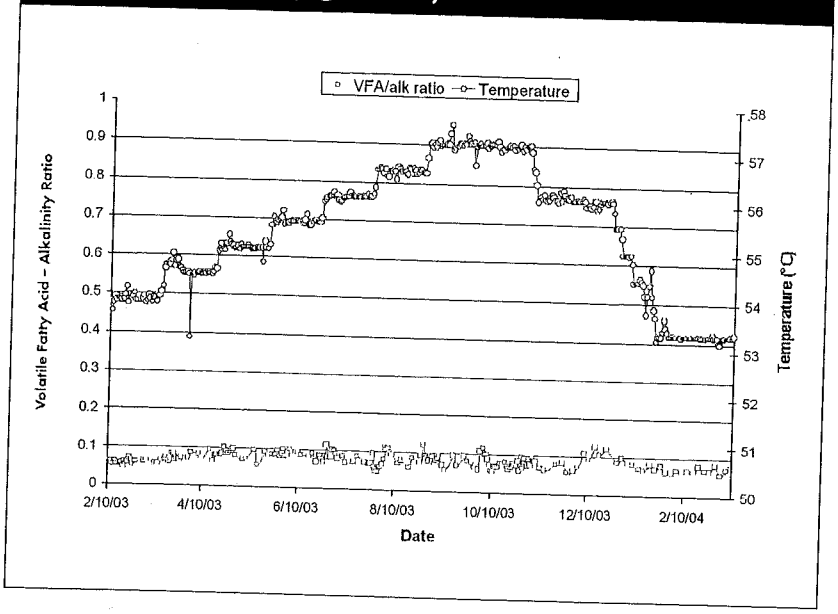


Figure 5. Ratio of Volatile Fatty Acid to Alkalinity During Steady-state Trial at Hyperion Treatment Plant (Digester 1D1).



Fast Not Always Good

Hydrogen sulfide, methyl mercaptan, and other VSCs are critical components in odor emissions from thermophilic operations because they are easily detected — even at low parts-per-billion concentrations. VFA production also may contribute to increased odor emissions. Although researchers only analyzed VFA in biosolids, the elevated production and volatilization of VFA probably caused higher concentrations in air emissions.

Test results suggest that, to avoid odor problems, thermophilic digester temperature should be increased gradually. Researchers hypothesized that raising digester temperature rapidly may not have given microbial populations sufficient time to adapt. A gradual increase may maintain the culture in a balance that keeps odors acceptably low and maintains a healthy digester performance. At Hyperion, increasing the temperature at a rate of 0.55°C per month was successful, but other rates could be tested. The results of the steady-state test with Digester 1D1 at Hyperion suggest that the best performance is obtained at temperatures no greater than about 56.1°C.

Test results also showed that methyl mercaptan concentrations in digester gas correlated with temperature changes. Hydrogen sulfide concentrations also varied with temperature at Terminal Island, but increased only slightly at the highest temperatures during gradual changes at Hyperion. Therefore, if a thermophilic digester needs to be operated at a higher temperature, researchers suggest that the temperature be increased gradually until the threshold at which odorous compounds begin to increase.

Further Study on Microbes

Other researchers have noted a complex mechanism by which microbial populations in anaerobic digesters form and degrade VSCs. The accumulation of VSCs may result from an imbalance between the microbes that produce them and those that degrade them. In particular, methanogens are believed to catalyze not only the methane formation from VFAs, but also the biodegradation of methylated VSCs such as methyl mercaptan. So, the loss of methanogenic activity during rapid temperature increases could cause two effects:

- less methane production from VFAs, thereby causing VFAs to accumulate in the digester, and
- reduced VSC demethylation, thereby causing methyl mercaptan and dimethyl sulfide to accumulate in digester gas.

The stable digester performance observed soon after digester temperature was reduced may indicate that these microbial imbalances are reversible. A better understanding of the mechanisms of VSC production and degradation may provide a basis for developing strategies to reduce or control these problems during thermophilic operations. So, more studies are needed to define the effect of temperature on the activities, diversity, and densities of microbial communities — for example, acetotrophic and hydrogenotrophic methanogens, sulfate-reducing bacteria, and others — in full-scale digesters.

At the Hyperion Plant, which is operated by the Bureau of Sanitation, City of Los Angeles, ***Reza Iranpour****, Ph.D., P.E., is the maintenance planning manager;* ***Huub H.J. Cox****, Ph.D., and* ***Hansong Lee****, P.E., are engineers;* ***Jeff Beller*** *is the assistant division manager of the Environmental Monitoring Division;* ***Mark A. Starr****, P.E., is an engineering manager; and* ***Steve Fan****, P.E., is the plant manager.* ***Joe E. Mundine*** *is the executive officer of the Bureau of Sanitation.* ***Ray J. Kearney*** *is a consulting sanitary engineer (Los Angeles, Calif.).*