EDITORIAL

Retrospective and Perspectives of Thermophilic Anaerobic Digestion: Part II

A few points seem worth mentioning about thermophilic anaerobic digestion (TAD) in addition to the editorial in the February issue of Water Environment Research.

Costs are a particularly complex issue because there are so many possible variations in the context in which TAD is conducted. The context, in turn, influences process configuration. Single-stage operation in a continuous mode is obviously the simplest process. If disinfection is the primary concern and if the parameters guarantee disinfection, the single-stage process is likely to be the most economical. On the other hand, a few plants that were not primarily concerned with disinfection successfully established two-phase processes that achieved satisfactory levels of volatile solids destruction and gas production. Any evaluation of a process using TAD would require several years of stable operations to make meaningful comparisons with mesophilic processes. These should be made under similar operational conditions and include parameters such as energy consumption, gas production, solids destruction, chemical usage, maintenance requirement, hauling costs, and other factors.

An interesting development for improving gas production is the addition of other wastes to wastewater sludge. For two-phase plants with low-fiber waste streams, such as those combining wastewater sludge with fats and greases and other food waste, good results have come from a highly loaded first phase, favoring acid-tolerant acidogen organisms, followed by a more lightly loaded second phase, favoring methanogens. Many of these systems run only one of the phases at a thermophilic temperature, with the other one mesophilic. On the other hand, an extreme thermophilic initial stage, at approximately 70°C, appears particularly effective in breaking down plant fibers, after which a thermophilic phase at approximately 55°C produces methane. This was observed in research on high-fiber waste streams, as in some plants in Europe that combine manure with wastewater sludge. Evidently, a process like this would be expected to guarantee disinfection easily.

The possibility of using an extreme thermophilic phase for a high-fiber waste stream is not merely an empirical observation but is based on experiments to identify the active organisms in digesters at different temperatures. For example, at 55°C a large fraction of methane production comes from organisms that split acetate ions into methane and carbon dioxide, but at 65°C these organisms were replaced by organisms that oxidize acetate into hydrogen and carbon dioxide. At either temperature, other organisms take some of the carbon dioxide and hydrogen from any source (either oxidation of acetate at the higher temperature or other reactions, such as those that use water as an oxygen source for converting longer-chain fatty acids into acetate) and use them to produce methane and water, but this reaction is particularly important at the higher temperature because the acetate oxidation reaction depends on rapid consumption of the hydrogen that this oxidation produces. This research is expected to lead to methods of manipulating cultures to enhance gas production and solids destruction.

Additional years may be needed for this research to produce results that are operationally useful, in part because so much remains to be learned about these organisms. Methanogens resemble bacteria under a microscope and are like bacteria in being prokaryotes, but they are archaea, a domain of life that was only recognized in the 1970s as being distinct from true bacteria. Methanogens are approximately as different biochemically from bacteria as either type of microorganism is from the eukaryotic cells in humans and all multicellular organisms. Compared to the biochemical differences between, for example, humans, trees, and fungi, which are large by familiar standards, these differences are much larger. For example, the lipids in archaeal cell membranes are formed of glycerol bonded to isoprene polymers that have methyl groups as side branches. It is believed that this structure makes these membranes especially resistant to the extreme conditions in which many archaea live. Previously unknown groups of archaea are still being identified, and research continues to reveal how much is unknown even about groups of archaea that have been recognized for a long time. This includes the methanogens, all of which are thought to be descended from a common ancestor, and are thought to date from early in the history of life.

Many further aspects of the microbiology of TAD are under investigation or have been recently studied, including the microbial population distribution within the granules that form in a digester; the importance of close physical proximity among different types of microorganisms so that they can exchange metabolic products; and changes over time in the relative distributions of different genera that perform the same reaction, such as producing methane from hydrogen and carbon dioxide.

Biosolids disinfection by TAD also deserves further investigation so that plants will be able to produce the highest quality biosolids at the lowest cost. These may be expected to produce practical results sooner than the work toward culture manipulation. Brief allusions to some of these topics appeared near the end of the editorial in the February issue:

- More needs to be understood about regrowth during postdigestion. At this point it is not clear if regrowth in thermophilically digested biosolids is a general problem or related to plant-specific conditions of postdigestion solids handling. It has also been suggested that biosolids dewatering may stimulate the reactivation of fecal coliforms that were injured during thermophilic digestion. Fundamental investigations are required to determine the causes of regrowth.
- The lower limits of time and temperature at which Class A pathogen limits can be met at the last points of plant control have yet to be determined. Alternative 1 for Class A disinfection in the federal regulation (40 CFR Part 503) specifies legally acceptable combinations of time and temperature for disinfection of biosolids in a batch digester. This time–temperature relationship was primarily developed from experiences in the food industry, but the few recent full-scale experiences seem to indicate that batch disinfection of the biosolids can be achieved at lower temperature and/or in a shorter period.
- A related question is to try to find parameters of a continuous single-stage thermophilic process that guarantee meeting one of the alternative sets of the Class A pathogen reduction requirements. Because most plants operate single-staged continuous mesophilic digesters, conversion to a similar process configuration at a thermophilic temperature would be relatively easy to implement. The least expensive approach would be to demonstrate disinfection in a continuous process under Alternative 3 of 40 CFR part 503. However, as Alternative 3 may be deleted from future regulations, the long-term option for a continuous process may be Alternative 6: demonstrating equivalency to processes to further reduce pathogens. This would require extensive full-scale investigations.
- Odor is one of the primary public concerns regarding the land application of biosolids, but odor studies need much more research. Issues include the following: (1) though it is sometimes assumed that thermophilic anaerobic digestion produces more odorous biosolids than mesophilic operations, there are no quantitative studies to our knowledge that support this assumption; (2) rapid temperature changes in stable thermophilic digesters may cause elevated production of odorous compounds such as hydrogen sulfide and mercaptans, but the dynamics of this transitional situation are unknown.

As noted in the February editorial, the need to achieve Class A disinfection to meet regulatory requirements has ended the days when TAD was an answer in search of a problem. However, expected further changes seem likely to shift the focus of TAD implementations back from disinfection to solids destruction and gas production. Even though increasing quantities of biosolids for land application not only meet the Class A disinfection standard, but the more stringent "Exceptional Quality" standard (not only Class A disinfection, but also meeting standards for low metals content and low attraction to potential disease vector organisms), public opposition to land application is causing more areas to be designated as "red zones", where biosolids are forbidden to be applied, no matter how high their quality. Such a legal environment of diminishing options for disposal evidently rewards achievement of greater solids destruction. Thermophilic anaerobic digestion seems likely to increase in importance as a way for wastewater treatment agencies to achieve the flexibility needed to meet the challenges of the future.

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