Advances in the State of Biosolids Management Practice Fact Sheet

IMPROVING PERFORMANCE

Manufacturers, researchers, and practitioners are continuously looking for ways to improve the performance of solids management equipment and processes. The drivers for this vary, for example, improved performance can provide a manufacturer with a competitive marketing edge, while for a utility it usually means lower costs. In addition to economics, regulatory factors, public perception, and technical constraints can all drive efforts to improve the performance of equipment and processes. Performance improvements have been a focus for all aspects of solids processing, from thickening and dewatering through stabilization. Although it is not possible to discuss all the performance improving enhancements that have been implemented in recent years, some highlights are presented here.

Dewatering

One process that has seen significant focus in recent years is dewatering because it has such a significant effect on downstream processes, such as transportation, drying, and incineration, and the wastewater treatment process as well. Dewatering equipment manufacturers as well as ancillary support system suppliers have developed several features that are intended to improve dewatering performance. For example, the Louisville Metropolitan Sewer District has recently tested a polymer control and solids monitoring system that is projected to reduce polymer requirements by 10% while slightly improving capture efficiency and total solids concentration.

Belt filter presses are one of the main dewatering technologies in use in the industry because of their low cost, simplicity, and performance. However, belt press installations generally require an operator to monitor operations on a frequent basis. Automation of polymer feed and remote cameras have helped to reduce operator attention requirements, but other dewatering technologies have proven to be better suited for unattended operation.

Centrifuges are one example. The torque on a centrifuge can be set to maintain the cake solids within a narrow range. With polymer feed automated, an operator only needs to periodically check the centrifuge equipment. Centrifuge controls packages are designed such that if a unit experiences problems, such as undue vibrations, the system initiates an automatic shutdown sequence to prevent damage to the machine.

Centrifuge dewatering has long been the choice of many utilities, especially large ones, because of their high throughput and good performance. One drawback has been the power consumption, which on an average running basis can be 5 to 10 times greater than other systems. Manufacturers have been able to improve energy efficiency through the use of improved designs, with reductions in power consumption by as much as 40% over older design. Chicago Metropolitan Wastewater Reclamation District recently replaced 16 older model centrifuges for thickening with higher efficiency units to help reduce their overall power consumption (Jamjun, 2008).

Another dewatering advancement is the 3-belt filter press. This technology uses independent belts in one machine to decouple the thickening and dewatering process. This system is well suited for plants that don’t have primary treatment and produce thin waste activated sludge (WAS). The decoupling allows for optimization of both steps and maximizes throughput. Continued advancement of these types of dewatering and ancillary support systems could have far-reaching impacts. Improved dewatering will help reduce overall costs, reduce fossil fuel consumption for processing and transportation, and reduce solids being recycled through the liquid treatment process.

Anaerobic Digestion

Anaerobic digestion, a widely used solids stabilization process, has also been the focus in recent years. Improved digestion can reduce the volume of solids that must be transported and increase biogas production for energy recovery. Some improvements can also reduce the volume of digester tankage required, saving space and costs.

Advancements in anaerobic digestion performance include:

- **WAS Conditioning –** Several new pretreatment technologies focus on lysing the WAS cell walls and making WAS more readily degradable during digestion. More discussion of these processes is included in the section on solids minimization.
- **Thermal Hydrolysis –** New thermal treatment technologies are available for WAS or for combinations of primary solids and WAS.
- **Two-stage Processes –** Anaerobic digestion is a multistage biochemical process that has traditionally been accomplished in a single stage mesophilic (~35°C to 37°C) process. The use of a two-stage process comprised of an acid phase (acidogenisis) followed by a gas phase (methanogenisis) has been shown to enhance volatile solids destruction and improve process control. There have been several different configurations of this two-phase process, including some that incorporate a thermophilic (50°C to 60°C) acid phase to enhance pathogen reduction and other process parameters.
- **Thermophilic Digestion –** There are numerous benefits to a thermophilic operation, including increased volatile solids destruction, increased biogas production, shortened solids residence time, and the potential to meet Class A pathogen reduction requirements. However, there is an increased heat demand as a result of the higher operating temperature; increased ammonia loading in the dewatering sidestream as a result of greater volatile solids destruction; increased polymer demand for dewatering; and added equipment and operational requirements. Continued improvement of the anaerobic digestion process will benefit utilities in many ways, including making the most use of existing facilities.

Aerobic Digestion

Aerobic digestion has long been used for biosolids stabilization, especially at small to medium-size facilities. Although the conventional process is capable of sufficiently stabilizing the solids to meet Class B pathogen reduction and vector attraction reduction criteria, it can be difficult if process conditions are not optimum. In addition, aeration consumes significant power. Over the last decade research has shown that modifications to the process, including prethickening, tanks in series, and incorporation of aerobic–anoxic operation can improve stabilization performance and reduce energy needs (WEF-MOP 11, 2008). In addition to conventional aerobic digestion, some system suppliers have focused on optimizing a variation of the process to provide a system capable of meeting the Class A pathogen reduction criteria more energy efficiently. This process, autothermal thermophilic aerobic digestion, has been in use for years, but difficulties controlling the process and resulting odors have limited its use. Advancements in the technology have resulted in some new installations of the process in locations such as in Middletown, Ohio.

Incineration

Multiple hearth incinerators were once the standard for solids incineration. Although the technology worked well for years, fluidized bed incineration systems offer a substantial improvement. Emissions from fluid bed systems are significantly less due to the improved combustion process and fluid beds are also more energy efficient. The Northeast Ohio Regional Sewer District recently evaluated replacing the existing multiple hearth furnaces with new fluid bed furnaces and concluded the following (Dominak, 2009):

- A 98% reduction in energy requirements could be achieved, saving approximately $1.0 million/year.
- Electric power could be generated saving from $0.4 to $1.6 million/year.
- With power generation, approximately 30,000 metric tons of greenhouse gases (CO_2 equivalent) could be eliminated.

Reducing Operations Requirements

Budget pressures have forced most utilities to look for ways to reduce operator requirements. One approach is to use system automation. Improvements in instrumentation, controls, and Human-Machine-Interface software have led to significant improvements in the automation of biosolids processing. A detailed discussion of all the process and instrumentation improvements in the industry that have led to increased automation is not possible for this document. Automation of Wastewater Treatment Facilities (WEF-MOP 21,

2006) contains extensive background information related to process and instrumentation controls. However, some biosolids processing systems have proven to be better suited for automation than others. Following are a few examples.

Low Temperature Thermal Drying

Thermal drying to create a value-added product has seen steady growth in the U.S. since the mid-1990s. However, most of the systems installed used high temperature processes (480+°C) and complex materials handling systems that required continuous operator attention. Over the last 5 to 7 years, many of the dryer system manufacturers have developed low temperature (120°C to175°C) belt dryers that have less complex materials handling systems. Installations in Europe have demonstrated the systems can be operated on a continuous basis while only being attended during a single shift. Safety monitoring systems and controls are configured to automatically shut the systems down in the event of operations problems. The low temperature of the systems helps reduce the risk associated with unattended operation. While there are just a few belt dryer installations in the U.S., several new facilities are in development and it is expected that some of these facilities will evaluate unattended operation.

Solids Minimization

Solids minimization processes are a specialized subset of the processes and technologies discussed previously in the Improving Performance section. Solids minimization processes are designed to reduce the mass of solids for further processing, use, or disposal. In most situations, reducing the mass of biosolids will be favorable to the triple bottom line (economics, social, and environmental) of a biosolids management program. There are numerous processes and approaches to solids minimization now available or under development. These include the enhanced digestion processes already discussed, as well as processes that target a reduction in WAS production or improving the degradability of WAS.

Reduction of WAS production is often related to the wastewater treatment process and these processes are discussed in detail elsewhere (Sandino and Whitlock, 2010). This section will focus on the WAS pretreatment processes that are intended to enhance the degradability of the WAS because enhanced degradation can lead to increased biogas production and other benefits besides solids reduction.

There are several emerging WAS treatment technologies that may improve the digestion process. Most of these technologies lyse (rupture) the bacterial cells that make up WAS. Rupturing the cell walls releases the soluble organics that were protected by the cells. The release of soluble organics in the feed sludge to an anaerobic digestion process should help increase volatile solids destruction, increase biogas production, and improve product dewatering characteristics. The methodology for rupturing the cells varies depending on the proprietary process considered. Some of the methods used include:

- High temperatures to weaken the cell walls followed by a large pressure drop to rupture the walls (thermal hydrolysis)
- Chemical treatment to weaken the cell wall followed by a large pressure drop to rupture the walls
- Pulsed electric fields
- High-intensity ultrasound waves

As previously noted, many of these technologies are emerging and have not been demonstrated on continuous full-scale basis. (Lei *et al*., 2010) These authors described a modeling framework that appeared to closely compare to observed field results. Their model indicated that WAS treatment processes that only lyse WAS cells offered limited benefit for overall solids reduction or increases in biogas production. Conversion of the non-biodegradable organic fraction to more readily degradable fractions demonstrated greater benefits in enhancing anaerobic digestion performance (greater volatile solids destruction and increased biogas production rates).

ENERGY EFFICIENCY AND CONSERVATION IN BIOSOLIDS TREATMENT

Power for water and wastewater treatment can comprise more than 40% of a municipality's total power usage (Parry, 2010). Energy costs are projected to increase at the rate of 2.4% per year for the next 25 years and U.S. energy consumption is expected to increase 14% over this same time period (WERF, 2010). As fossil fuels become scarce and concerns over greenhouse gases grow, utilities are striving to become better stewards of our energy resources. In addition to costs and environmental concerns, there are regulatory and

social drivers that are encouraging energy conservation at all levels. One example is the Metropolitan Water District of Greater Chicago's goal of reducing energy consumption by 10% by 2013 (Jamjun, 2008). Many other utilities have implemented similar goals.

Although aeration for liquid treatment processes is usually the largest power consumer for wastewater treatment, the power demand for solids processing can be significant (Reardon, 2010). Solids conveyance and processing equipment, including pumping, dewatering, and digester mixing/aeration, can use large motors and contribute significantly to total power consumption. Manufacturers are continuously working to develop more energy-efficient equipment and utilities are more closely evaluating technologies based on energy requirements. Energy consumption can be the deciding factor in equipment selection. Recent developments in energy conservation for biosolids management are discussed below.

Digestion Mixing

Both aerobic and anaerobic digestion systems require mixing. Conventional aerobic digestion uses aeration blowers to mix and maintain aerobic conditions. Traditional aerobic digestion systems have been operated with full aeration for oxygen supply and mixing. As previously noted, research and operations over the last decade have shown that use of aerobic–anoxic operation can significantly reduce energy consumption and provide process benefits.

The energy associated with mixing varies for anaerobic digesters. With growing interest in codigestion and increasing the solids concentration of the feed, more mixing energy is being designed into some new systems. One emerging technology that is being watched by the industry is the linear motion mixer. Depending on the mixing system being compared to it, the linear motion mixer uses only 5% to 25% of other mixing systems.

Design Approach

In addition to technology improvements, design approach will impact energy consumption. Oversizing of equipment often results in energy inefficiencies. Planners and designers can size for staging of facilities and equipment to optimize energy efficiency and accommodate growth.

FULL RECOURCE RECOVERY

Nutrients in biosolids have long been used to the benefit of agriculture. However, there is growing interest in expanding the recovery of the resources in biosolids beyond conventional agricultural uses. Drivers for this include increasing fuel costs, public policies aimed at reducing greenhouse gases, and regulations requiring greater nutrient removal from wastewater. Examples of some related developments are given below.

Biosolids as Biofuels

In addition to cost, environmental concerns are continually encouraging conservation of fossil fuels to help reduce the emission of greenhouse gases. These drivers have contributed to an evolving industry focused on using biosolids as a biofuel.

Biosolids are rich in energy. Unprocessed biosolids have the heat value of a low-grade coal. Biogas from anaerobic digestion, which is approximately 60% methane, can be cleaned to create a biomethane product with an equivalent heat value of natural gas.

Biogas from anaerobic digestion has long been used for power generation (cogeneration) at large wastewater treatment plants through combustion of the gas in engine generators. Historically, the costs of the engines and relatively low electric power costs have made this an economical option only for the very large utilities. But over the last decade, initiatives from the U.S. Environmental Protection Agency (EPA), Department of Energy, and the manufacturers have led to the development of more efficient engines that are designed for use with biogas. The increased efficiency and rising electric power costs are making cogeneration more viable for medium sized facilities.

Developments in microturbines and fuel cells are rapidly making cogeneration potentially economically viable for smaller treatment facilities. Electric power is only one benefit from cogeneration. Heat can be recovered from the power producing systems and used in a variety of ways. For example, dryer manufactures have recently developed lower temperature systems that can use this recovered heat to dry biosolids.

Other uses for the heat include building and process heating. Some utilities have actually used their assets (specifically anaerobic digesters) to

accept and process high-strength wastes and produce more gas. In fact, high-strength waste products such as grease, food processing waste, and biodiesel byproducts are finding their way into anaerobic digestion systems and are significantly boosting biogas production.

Another approach uses dried biosolids as a substitute for coal. Dried biosolids have been used as a substitute for coal in electric power production in Europe and in cement production in both Europe and the U.S. (Garcia, 2010). Several U.S.-based power utilities are currently investigating the impacts of using dried biosolids as a coal substitute. Recent testing by Colorado Springs Utilities demonstrated their dried undigested biosolids have a heat value almost equivalent to that of a sub-bituminous (Powder River Basin) coal used in one of their power plants.

Nutrient Harvesting

As effluent limits for nutrients become more stringent, concentrations of nutrients increase in biosolids. One concern with this is the growing fertility imbalance between nitrogen and phosphorus in the biosolids. Biosolids application in traditional agriculture has been based primarily on nitrogen concentrations and corresponding crop demand for the nitrogen. But researchers and practitioners have realized this often results in an overapplication of phosphorus compared to crop requirements. Increasing phosphorus concentrations in biosolids exacerbate this problem. Some states have implemented phosphorus indices that limit application rates for biosolids based on phosphorus levels in the soils and biosolids (http://extension.missouri.edu/publications/DisplayPub.aspx?P=G9181).

Typically, biosolids application rates based on phosphorus levels are extremely low and difficult to achieve. Appliers may have to apply at agronomic nitrogen rates and then not apply to the same site for several years to allow the crops to use the excess phosphorus, if this is accepted by the state agencies. This will increase transport distances and increase the land based requirements for land application programs. Increased phosphorus concentrations in the sludge prior to anaerobic digestion are also causing maintenance issues for utilities through increased struvite formation. Struvite is a chemical precipitate (magnesium ammonium phosphate) that typically is formed during the anaerobic digestion process. It can cause plugging of pipes in digester heat exchangers or adversely affect downstream piping and dewatering equipment. Utilities are spending significant time and money removing the precipitate from pipes and equipment.

One solution to these issues is to harvest the phosphorus before it ends up in the biosolids, and then use the phosphorus as a specialized fertilizer. Not only will this help the wastewater industry, it will help reduce waste of phosphate, a valuable natural resource that some researchers forecast could be exhausted by the end of the century (http://www.nhm.ac.uk/research-curation/research/projects/phosphate-recovery/Nordwijkerhout/Parsons.pdf).

There are several proprietary systems being marketed as struvite recovery systems. These processes typically remove ammonia and phosphorus as a struvite precipitate from biosolids processing sidestreams. The resulting product can be marketed as a specialty fertilizer. Full-scale facilities have recently been developed in Tigard, Ore., and Edmonton, Alberta.

VALUE-ADDED PRODUCTS – RESOURCE RECOVERY

Although land application of liquid and dewatered biosolids has proven to be a reliable, cost-effective management practice for many utilities, some utilities have found the need to create value-added products for beneficial use. Value-added biosolids products are typically EPA Class A, Exceptional Quality biosolids. Some of the drivers for creating value-added products include difficulties in locating and permitting conventional agricultural land application sites, social objections to the conventional biosolids products (liquid and cake), and costs. Developing value-added products can provide numerous advantages to utilities, including:

- Opening up new markets and outlets that may result in revenue from sale of the product.
- Potentially reducing total weight to be transported, which will reduce truck loads and fuel consumption.
- Public acceptance and support of biosolids as a fertilizer, soil amendment, or biofuel.

- Opening up options for public/private ventures for facility financing and operations.

Composting is one of the most widely used processes for creating a value-added product. There are numerous approaches and systems designed for composting and manufacturers are continually developing new systems to improve the efficiency of the process, reduce odor emissions, and reduce labor requirements. The resulting product is best used as an organic soil amendment as opposed to a fertilizer, but it does offer fertilization benefits as well. Common users include nurseries, landscapers, soil blenders, public parks and road departments, and contractors. Both public and private organizations have had good success operating biosolids composting facilities.

Another value-added product produced by heat drying was used by only a few large utilities up until the mid-1990s, but now is more widely used. In recent years, manufacturers have developed small-capacity systems that make the technology more affordable to plants in the <10 MGD range. Increasing energy costs over the last 5 years have slowed development some, but it has also encouraged development of drying projects using recovered energy sources such as biogas or waste heat from cogeneration. Several manufacturers have developed low temperature drying systems that are well suited for energy recovery applications. Dried product has been marketed globally as a fertilizer (Milwaukee Metropolitan Sewerage District's Milorganite http://www.milorganite.com/home/) used as a conventional agricultural fertilizer, used as a base for chemical fertilizer production, and as a biofuel for cement production.

A relatively new approach to creating a value-added product uses a commercial manufacturing process to create a high-value fertilizer. In the early 2000s, a company in Helena, Ark., demonstrated on a large scale the viability of using biosolids as a feedstock in the manufacturing of fertilizer using a refurbished chemical fertilizer manufacturing facility. Individuals associated with that early successful process have now developed commercially available systems that are targeted toward processing biosolids into a high-value ammonium sulfate granular fertilizer. The process uses standard pugmill and thermal drying equipment and includes the addition of nutrients. The resulting product is very dry (greater than 99%), hard granule of 2 to 3 millimeters (mm) in size, having a nitrogen-phosphorus-potassium (N:P:K) nutrient content of 15:2:0, along with significant micronutrients, such as sulfur and iron, and a high organic content.

REDUCING PROCESS AND PRODUCT ODORS

Odors from biosolids and biosolids treatment processes can adversely affect the ability of a utility to beneficially use the product. Despite all its nutrient and fuel value, odors can create such a stigma about the product that the end users will not accept it.

New research that can inform the management of odor problems includes finding that:

- Odor production correlates with concentrations of total volatile organic sulfur concentrations (TVOSC) and TVOSC concentrations can be used as an indicator of the effectiveness of odor-reducing measures.
- Centrifuge-induced shear can increase TVOSC levels. Operational parameters can be adjusted to reduce shear and significantly reduce TVOSC levels, with minor drop in performance. Other dewatering technologies did not create the shear and increase odors of the product.
- Longer solids retention time (SRT) during anaerobic digestion can reduce TVOSC levels.

Advanced digestion and digestion enhancements (WAS conditioning) show better reduction of TVOSC levels in comparison to conventional mesophilic digestion. In addition to this research, practitioners have made advancements in controlling and treating odor emissions from biosolids processing. Use of new dewatering technologies with containment is one example of steps being taken to better control odors. New high-velocity virtual stack dispersion fans can help with cost-effective treatment of large volumes that have relatively low odor concentration.

GOING BEYOND COMPLIANCE

As evidenced by previous discussions, the public does not necessarily consider mere compliance with regulations to be adequate. The National Biosolids Partnership (NBP) Biosolids Management

Program (BMP) [based on an environmental management system (EMS)] was born from this fundamental concern. In addition to the NBP program for wastewater organizations, a new biosolids land appliers certified program has been developed for personnel by the Association of Boards of Certification (ABC) and California Water Environment Association.

NBP BMP

The BMP is a voluntary program that uses a flexible framework to help public and private sector organizations improve the quality of their biosolids management programs. The BMP framework is designed to accommodate all types of biosolids management practices and is based on elements that encompass all levels of a program, including policy-making, management planning, program implementation, measurement and corrective action, and management review (http://www.wef.org/Biosolids/page.aspx?id=7554&ekmensel=c57dfa7b_127_0_7554_3). Organizations that achieve BMP recognition are committed to the use of best management practices and conform to the NBP's Code of Good Practice.

One of the key features of the BMP program is the use of third-party audits to improve the credibility of the biosolids program with the public. The audits also help participants identify areas of strength as well as areas of weakness that can be improved upon. It should be noted that while the NBP program was developed primarily to focus on environmental and social issues, the program can also offer financial benefits to participants in terms of improved and more efficient operations.

ABC and California Water Environment Association Certification Programs

Some states, such as North Carolina and Colorado, require certification of land application operators. The purpose of these requirements is to further the knowledge base of the operators, help them understand the requirements and their basis, and improve regulatory compliance. The ABC and California Water Environment Association offer certification programs for land application professionals.

Public Outreach

Although most wastewater treatment facilities operate behind fences, biosolids management programs are highly exposed to the public. Land application, distribution and marketing, and other practices are dependent on the public's acceptance and participation in the program. Biosolids managers and staff must be cognizant that their daily actions can have a profound impact on the success of the program. For this reason, utilities are implementing training programs to help operations staff better manage interaction with the public, especially the news media. Certification programs, such as the NBP BMP and state certification programs previously discussed, can help to improve biosolids programs and, in so doing, their image as well. These programs help utilities establish protocols to improve management practices and reduce compliance issues. The use of independent third-party auditors is intended to increase the public's comfort level that a utility is following the established best management practices and meeting or exceeding all regulatory requirements.

Diversification of Outlets

Diversification of outlets for biosolids products is becoming more common in the industry. Diversification improves program flexibility and reliability, and may even reduce program costs. For example, the City of Los Angeles uses land application (two separate contracts) for the majority of its biosolids, but also composts and recently implemented a demonstration project using deep well injection technology for ultimate energy recovery. Other utilities with diversified management programs include Hampton Roads Sanitation District (composting, incineration, and land application), Kansas City (incineration and land application), and the Austin Water Utility (composting and land application). Despite the benefits of diversification, it can increase staffing requirements, the level of training and documentation required, and monitoring and recordkeeping requirements.

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