Emerging Biosolids Treatment Technologies Fact Sheet

New technologies for treating wastewater and biosolids are continually being developed. Some of these technologies arise in response to regulatory, economic, or social issues affecting current solids management practices. Others arise from modifications or enhancements of existing technologies. Most take years of research, development, and testing to be ready for the municipal market, and often, several more years before they are accepted as proven processes within the industry.

THICKENING AND DEWATERING PROCESSES

Thickening and dewatering processes remove water from sludge and biosolids, making them easier and less expensive to further process and transport.

Membrane Thickening

Identification of Process and Scientific Basis

Membrane thickening is the result of the development and implementation of membrane bioreactors for secondary wastewater treatment. Thickening basins are filled with waste activated sludge (WAS), which is concentrated by the withdrawal of water through the pores of the membranes. The WAS can be thickened to 4% total solids or greater. The tank is typically aerated to maintain aerobic conditions and reduce membrane clogging and blinding. Modules of membranes may either be tubular or sheet, and the thickener can be operated as a batch or continuous-flow process.

Process Description

Membranes are composed of two basic materials: organic polymers and inorganic materials such as ceramics. Organic polymer-based membranes are typically used for municipal wastewater treatment and are formed from either modified natural cellulose acetate materials or synthetic materials. Modules are of the following types: tubular, hollow-fiber, spiral-wound, plate-and-frame, and pleated cartridge filters. The type of module selected will depend on the desired application.

Some membrane thickeners are designed with the membranes immersed in the reactors. In other applications the membranes are located in a separate stage or compartment. Any type of membrane can be used in either application. One issue with this system is the potential for membrane fouling, which is the systematic accumulation of suspended solids, colloids, precipitates, and macromolecules on the membrane surface or inside the pores. Fouling will reduce membrane permeability. Techniques to control membrane fouling include chemical washing and cleaning and air-scour and permeate back-pulsing to prevent cake layer formation.

Membrane thickening systems can require less space than other systems. Membrane units are flexible and can handle varying flow rates with the addition or subtraction of units as necessary. Solids levels must be maintained so that membranes remain immersed. Throughput limits are set by the physical properties of the membrane. Typically, peak design flows should be no more than 1.5 to 2.0 times the average design flow. Membranes should be used in an aerobic environment to achieve separation of liquid from biomass. Anaerobic environments have plugged membranes too quickly in the past. Therefore, aerobic environments are needed for oxygen mixing.

Technology Prognosis

The potential for this technology appears good. Although the number of installations are limited, it is likely to grow as the technology becomes more widely known. Some of the manufacturers supplying this technology include Enviroquip, Inc., Infilco Degremont, Mitsubishi International Corp., US Filter/MEMCOR, Veolia Water Solutions and Technologies, and GE Power and Water, Inc.

Electro-Dewatering

Identification of Process and Scientific Basis

The objective of electro-dewatering is to enhance conventional dewatering performance using an electric current. The principle of electro-dewatering is the movement of a polar liquid through a membrane or other porous structure under the influence of an applied electric field. When applied to dewatered sludge cake, a flow of ions migrates from the anode to the cathode. This movement drags water molecules out of the biosolids. Electro-dewatering is used in conjunction with conventional dewatering to remove surface and interstitial water around and inside the floc, thereby enhancing the removal of free water.

Electro-dewatering is based on the principle of electro-osmosis, which describes the movement of a polar liquid through a porous media. With electro-osmosis, the rate of flow of water through a porous media is proportional to the voltage gradient and cross-sectional area.

Electro-osmotic permeability is not dependent on particle size and remains constant for different materials that support electro-osmosis. Therefore, electro-osmosis offers an advantage over hydraulic flow (mechanical dewatering) when applied to materials such as wastewater solids, which are typically comprised of colloidal sized particles (Decker *et al*., 2006). During the application of direct current, cations in the sludge are attracted to the cathode. Movement of the cations helps carry water towards the cathode (*i.e.*, electrophoresis), where it can be released from the sludge (McKay *et al.,* 2007).

Technology Prognosis

This technology should have a good opportunity to continue to progress and develop. It has demonstrated favorable results at the Achille Gagnon Wastewater Treatment Plant (WWTP) in Victoriaville, Quebec, Canada, since 2005. As the number of installations increases and equipment and system improve, it should be a candidate for consideration in enhancing dewatering performance. Manufacturers include Elcotech Technologies, Inc., Waste Technologies of Australia, and Ashbrook-Simon Hartley, Inc.

Geotextile Tube Dewatering

Identification of Process and Scientific Basis

Geotextile tube dewatering is a low-maintenance, cost-effective dewatering solution using tubes made from a high-strength polypropylene fabric similar to that used for belt filter presses. The concept is for free water in sludge to filter through the fabric, leaving the dewatered biosolids in the tube. Dewatered solids within the bag can be allowed to sit for optimum dewatering before transporting the solids to beneficial use or disposal. Hydrostatic loading of the biosolids and constriction of the fabric apply pressure to the biosolids. The tubes need to be placed in a location where the drained water can be collected for treatment.

Technology Prognosis

This technology appears to be best suited for dewatering applications at small treatment facilities. Dewatering of solids stored in lagoons may be a niche application as well. Use in medium and large facilities could prove difficult because of logistics and space requirements of this technology. Increased use of this technology is expected in the future.

THERMAL PROCESSES

Supercritical Water Oxidation

Identification of Process and Scientific Basis

Supercritical water oxidation (SCWO) is a process for thermal oxidation of the organics in wastes. It has been used to treat a broad range of aqueous organic wastes such as polychlorinated biphenyls (PCBs), pesticides, cyanide wastewater, as well as wastewater residuals. The process involves increasing the temperature and pressure of the aqueous waste in a reactor to oxidize the organic compounds. The process is also known as supercritical wet-air oxidation, supercritical wet oxidation, and hydrothermal oxidation.

Technology Prognosis

Several challenges are associated with implementation of a full-scale SCWO system. The high temperatures and pressure warrant specialized equipment and safety procedures. In addition, the equipment must be able to withstand

the corrosive conditions created by the process. Special alloys may be required to address this issue. Salt precipitation can also create scale buildup that can impede flow through the reactor vessel and heat exchanger (Yesodharan, 2002). Research into SCWO has demonstrated the potential for the process, but additional work with larger scale systems will be needed. As additional projects are brought online, solutions to these obstacles will likely be identified, and long-term viability of the process can be assessed.

Sludge-to-Fuel

Identification of Process and Scientific Basis

Several different proprietary configurations have been developed and tested for converting municipal sludge to a carbon-rich fuel. These processes use high pressure and heat to convert the organic matter in sludge into a carbon-rich material (carbonization). The carbonized sludge can be readily dewatered or dried to generate a product that can be used as a fuel.

The processes involve pressurizing the solids above the saturated steam pressure to prevent boiling when heated above the normal boiling point. This eliminates the loss of thermal energy through evaporation and minimizes the additional thermal energy requirement. The solids are then heated to alter the molecular structure of the solids slurry, and carbon dioxide gas is removed from the solids. This reduces the mass of solids by approximately 40% and reduces the affinity of the solids to water. The resulting “carbonized” waste is then cooled, depressurized, and dewatered.

Technology Prognosis

The first full-scale facility has experienced difficulties during startup and has not been able to operate continuously. Plant modifications were being made at the time this document was prepared. It will take time before it is known if this process is viable. The complexity of the process will likely require specialized expertise to implement and operate the system. If full-scale operation proves to be successful, the prognosis for this technology should be good, especially for areas with high population density that generate the large quantities of biosolids needed for the process to be cost-effective.

Plasma-Assisted Thermal Oxidation

Identification of Process and Scientific Basis

Plasma-assisted thermal oxidation is a proprietary process that uses a low-power plasma arc torch to sustain the oxidation process in a rotary kiln. Plasma arc technology is designed to oxidize biosolids at temperatures lower than that of conventional combustion systems, which is projected to improve the energy efficiency of the combustion process. Hydro Québec, Canada’s largest electric utility, developed and patented the plasma-assisted sludge oxidation (PASO) process in 1997 for treating solid wastes from pulp and paper mills. In 2001, Hydro Québec licensed the production and marketing of the system to Fabgroup Technologies, Inc., a Montreal-based custom-metal equipment manufacturer (Metro Wastewater Reclamation District, 2006). Fabgroup Technologies has three manufacturing plants and has been in operation more than 50 years.

Plasma oxidation uses electricity to highly ionize a gas (air or inert gas) to produce a high-temperature plasma. Plasma oxidation is similar to pyrolysis in that it requires little excess oxygen. The process has been used to generate high temperatures (> 1600°C) for the destruction of specialty wastes, such as medical and military wastes.

Technology Prognosis

Application of an emerging technology to the treatment of municipal biosolids typically requires demonstration or full-scale facilities to identify process, design, and cost issues that must be addressed in the future. Fabgroup Technologies put into operation a large-scale PASO process in Valleyfield Québec in late 2008. This large facility will be invaluable in identifying any design and operational issues and potential system costs.

Vitrification

Identification of Process and Scientific Basis

Vitrification is the melting of minerals within the biosolids to create a glass-like product that can be beneficially used as an aggregate. It has been used to process and stabilize industrial and hazardous wastes and municipal sludge. The

melting process sequesters metals and destroys most volatile organic compounds. The U.S. Environmental Protection Agency (EPA) used soil vitrification as part of a Superfund site cleanup (EPA, 2001). During the process, organic matter is thermally destructed at temperatures of approximately 1400°C (2550°F) or greater. Synthetic combustion air, which is a mixture of 90% pure oxygen and recycled exhaust gas, is added to support the high temperature process (Dorn *et al*., 2007). In contrast, conventional sludge combustion in a fluid-bed furnace operates at approximately 850°C (1562°F). The resulting molten glass is cooled rapidly in a water quench chamber to create the glass aggregate. Exhaust gas is separated and subject to emissions control requirements that will vary based on local regulations and the specific process implemented.

Technology Prognosis

Vitrification has proven to be a feasible treatment process for biosolids. Japan has successfully used the technology since the 1980s. The complexity of the system and its high energy use are a few factors that have adversely affected acceptance and implementation in the U.S. Minergy's proprietary GlassPack system was designed to address the high energy consumption through the use of extensive energy recovery systems. A full-scale system has been constructed and the owner and manufacturer are working to resolve operational and maintenance issues that have prevented the system from operating reliably.

Chemical Drying for Higher Quality Fertilizer Production

Identification of Process and Scientific Basis

Chemical drying is a process that incorporates wastewater biosolids in the production of an organic/inorganic ammonium sulfate fertilizer. Chemical drying produces a value-added biosolids product that is high in nutrient value. In chemical drying, biosolids are added to other traditional fertilizer components and, because of chemical exothermic reactions, a significant percentage of the contained water is removed before later physical thermal drying. In this process, the biosolids are only a small fraction (5% to 30%) of the dry weight of the resulting fertilizer product.

Chemical drying occurs when dewatered biosolids, sulfuric acid, and ammonia are mixed in a pressure vessel. The exothermic reaction drives off water, and an organic ammonium sulfate fertilizer is produced. The reaction occurs at 135°C to 150°C (275°F to 302°F) at pressures of 207 to 480 kPa (30 to 70 psi). The high temperature/pressure process meets the standards of the EPA for Class A pathogen reduction.

Technology Prognosis

Chemical drying has been proven to be a feasible treatment process for biosolids. The complexity of the technology and the need to market the product as a high-end fertilizer will likely require the system suppliers to also operate facilities and market the product.

CHEMICAL PROCESSES

Neutralizer Process

Identification of Process and Scientific Basis

Chemical stabilization of wastewater treatment plant sludge has been used since the 1970s. One emerging chemical stabilization process is the Neutralizer process, a proprietary process supplied by BCR Environmental. The process, which uses chlorine dioxide for stabilization, is a chemical batch process that can treat raw, aerobically digested, or anaerobically digested WAS to produce Class A biosolids. It requires thickening to approximately 4% total solids to minimize the volume entering the chemical process tanks. Tests carried out at Tulane University, New Orleans, showed that this process, which provides complete disinfection of the sludge, is effective against helminth eggs, bacteria, bacterial spores, and viruses (Reimers *et al*., 2006).

Technology Prognosis

The Neutralizer process has been demonstrated to disinfect sludge to produce Class A biosolids on a full-scale basis at small WWTPs. The final product can be land applied or used as a commercial fertilizer.

EMERGING TECHNOLOGIES STILL UNDER DEVELOPMENT

Nutrient-Rich Algae

The constituents in wastewater also have energy recovery potential, but little has been done beyond the research stage at this time. The nutrient-rich effluent can be used to grow algae. The algae can be harvested and used to generate fuel feed stocks. Sunnyvale, Calif., harvests algae and codigests the algae with other solids to generate biogas. This is emerging technology that still requires research and development.

Microbial Fuel Cells

A new technology emerging from laboratory research is the microbial fuel cell. A small amount of electricity is released during microbial transformation of both carbon and nitrogen compounds in wastewater during treatment. New advances in nanotechnology allow this energy to be recovered. This is an emerging technology and there are no full-scale applications yet, but it looks promising.

Nitrous Oxide Capture From Biological Nitrogen Removal for Power

Biological nitrogen removal processes are based on microbial conversions that release nitrous oxide as a byproduct. It may be possible to capture the nitrous oxide emitted from these processes and burn the nitrous oxide to generate additional power or electricity. This technology is also in the research stages and has not been applied at any treatment facility.

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