ENGINEERED DESIGN AND CONSTRUCTION
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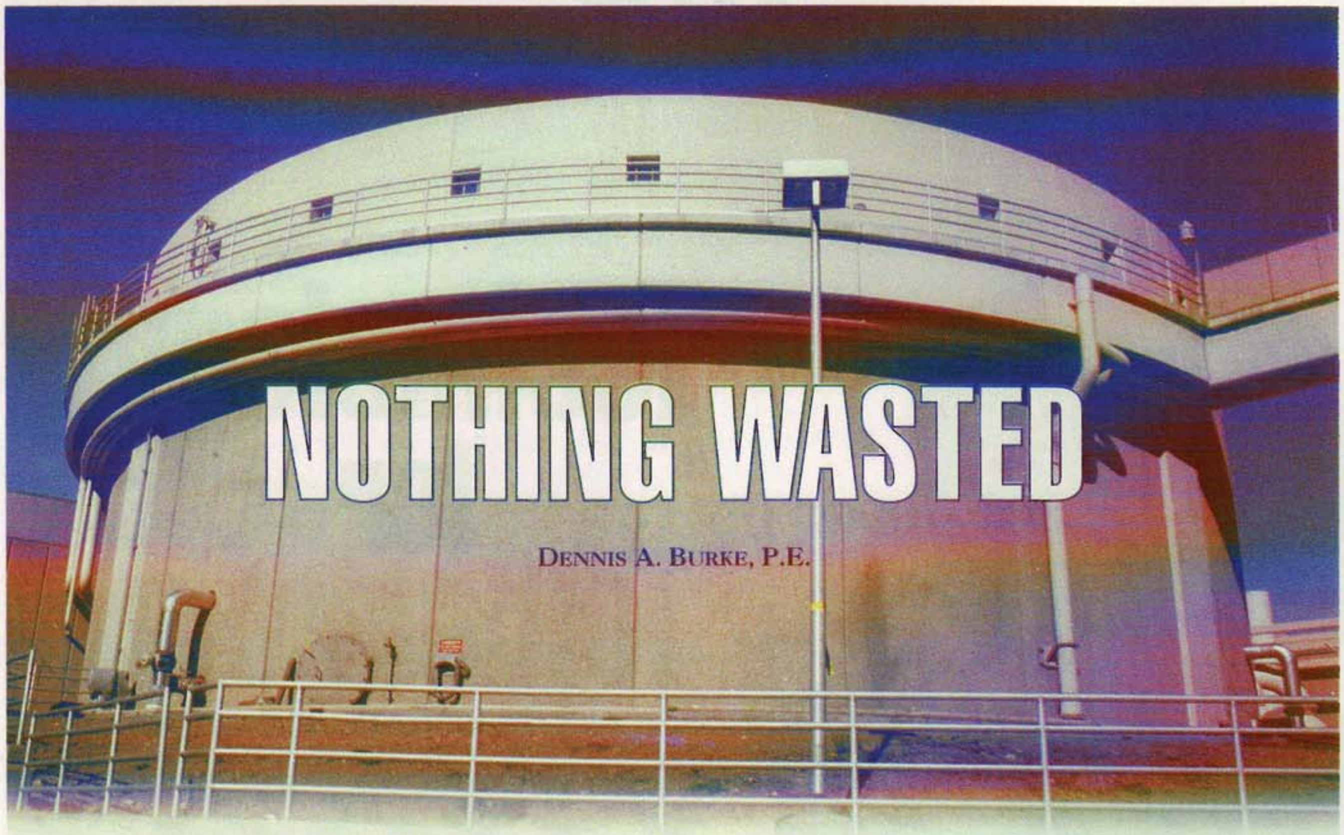
CIVIL ENGINEERING

Technology for Tomorrow



IN IDAHO, ANOXIC GAS FLOTATION DIGESTERS REMOVED NUTRIENTS FROM POTATO SLURRY WASTE AND RECYCLED THEM AS FERTILIZER. THE PROCESS PRODUCED EXCESS ENERGY.

NOTHING WASTED

DENNIS A. BURKE, P.E.

A new recovery process mines a mother lode of resources from organic waste slurries.

Anoxic gas flotation (AGF), a promising new waste treatment process, can turn up to 95% of organic slurry waste into valuable natural gas and fertilizer while producing energy.

A pilot AGF treatment plant used at two potato processing facilities in eastern Idaho was able to convert 95% of concentrated raw potato slurry waste into gas and soluble products. With hydraulic retention times as low as one day, the AGF process recovered 85% of the phosphorus and 23% of the nitrogen in the potato slurry to produce a large quantity of pipeline-quality (36,500 kJ/m^3) natural gas.

The six-month pilot test was the outgrowth of a successful laboratory-scale AGF test performed by Cyclus EnviroSystems, Olympia, Wash. The recipient of a small-business innovative research grant, Cyclus tested AGF as a means of increasing the efficiency of anaerobic digestion in slurry waste treatment.

Most organic waste is produced as slurry, including animal manure, pulped solid municipal waste, pre- and postconsumer food waste, remnants from food processing plants, primary sludge and waste biological sludge from municipal and industrial processing facilities.

Current slurry waste disposal methods vary in desirability and efficiency. Primary and secondary food processing waste is often dewatered and fed to animals. Animal manure is commonly stored in holding lagoons until weather conditions permit land application, which enriches the soil and converts slurry nutrients into future crops. Land application, however, requires both dry weather and the presence of crops to absorb nutrients. Too heavy an application or application prior to rainfall can lead to runoff that pollutes surface and groundwater. In many cases, the large tracts of land necessary to meet nitrogen and phosphate application limitations simply are not available, underscoring the need to reduce the amount of waste that is applied to land.

ANAEROBIC STABILIZATION

Municipal primary and waste-activated sewage sludge can also be applied to land but must first be stabilized to reduce putrid waste (for example, food waste) and the concentration of pathogenic organisms. Aerobic and anaerobic digestion are the most common methods of stabilization. Using conventional methods, both processes typically convert 40% to 50% of sludge mass to carbon dioxide or methane gas, reducing the amount of material that must be transported from the treatment site for land application.

Large quantities of energy are consumed in all stabilization processes except anaerobic digestion, which produces more energy than it consumes by converting a large quantity of waste to methane gas. The methane can power an engine generator, creating electricity as well as providing waste heat for the anaerobic process. This minimizes environmental impact and the consumption of limited resources.

MAKING A BETTER DIGESTER

While more economical and environmentally sound than other methods, the efficiency of anaerobic digestion traditionally has been hampered by waste slurry digesters that operate at low substrate loadings and consequently require large tanks. Because anaerobic bacteria are not easily separated and retained, operators can increase loading in conventional digesters only by raising the influent feed concentration.

Increasing the feed concentration by prethickening the influent solids produces higher concentrations of ammonia, sulfide

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and other by-products of anaerobic decomposition that inhibit bacterial activity and efficiency.

The ideal process for treating waste slurries would include small anaerobic reactors that retain bacteria within the system. The retention of biomass would allow higher loadings and more complete conversion of organic waste to soluble and gas products.

The conventional anaerobic digestion process loses a large quantity of bacteria in digester effluent. To replace the lost bacteria, a portion of all influent waste is converted into new anaerobic bacteria. The cycle of constant loss and replenishment reduces the efficiency of the process. The high loss of organic matter and bacteria in the conventional process limits the conversion rate of volatile solids to gas and soluble products to about 50% or 60%.

A number of systems have been developed to separate and maintain biomass within anaerobic reactors, including plate separators, gravity thickeners and a variety of membranes. However, none of the systems has substantially increased digester loading or process efficiency.

Some improved reactors retain biomass as pellets or films that provide enough retained bacteria to degrade soluble waste rapidly. Loading in such reactors is increased by reducing the hydraulic retention time rather than increasing the influent concentration, making digesters compact and efficient.

Although upflow anaerobic sludge blanket reactors, anaerobic sequencing batch reactors and a variety of anaerobic filters have been used successfully on a commercial scale throughout the world, they are not suitable for the high-rate anaerobic treatment of waste slurries. Slurry solids must be removed by primary treatment or converted to dissolved organic acids prior to high-rate anaerobic processes.

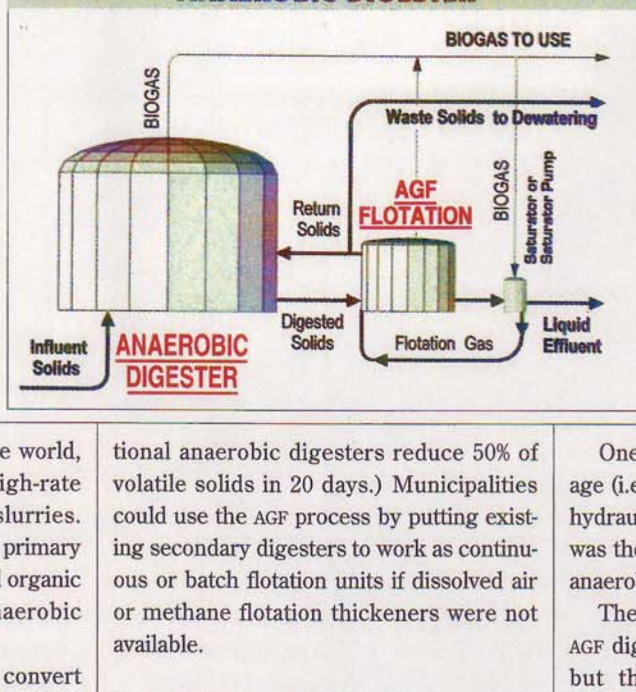
Unfortunately, processes that convert solids to organic acids generally are difficult to operate and control, while primary treatment—removal of solids from the waste stream—reduces the energy and nutrient resources that could otherwise be recovered through anaerobic digestion.

In 1991, Cyclus introduced the patented AGF process for the separation and retention of biomass within an anaerobic reactor. The AGF process relies on dissolved methane gas flotation, similar to the dissolved air flotation thickening process used in many waste treatment facilities. A tranquil process that does not inhibit bacterial consortia, dissolved methane gas flotation concentrates and retains biomass delivered to the digester. Improved biomass retention eliminates the need to prethicken solids before digestion and decreases hydraulic retention time without promoting biomass washout.

In a laboratory test, Cyclus found that postthickening in conjunction with biomass recycling substantially increased the capacity and efficiency of conventional anaerobic digesters. Biogas flotation has low capital and operating costs. When used in conjunction with polymer, the AGF process concentrates bacteria in quantities substantially greater than the influent solids.

The laboratory demonstration showed that during hydraulic retention of primary and waste-activated sewage sludge over 76% of the influent volatile solids could be converted to methane gas and soluble constituents in as little as 10 days. (Conventional anaerobic digesters reduce 50% of volatile solids in 20 days.) Municipalities could use the AGF process by putting existing secondary digesters to work as continuous or batch flotation units if dissolved air or methane flotation thickeners were not available.

ANAEROBIC DIGESTER



OUT OF THE LAB, INTO THE FIELD

The Washington State Department of Energy, in Olympia, Wash., and the King County Department of Natural Resources, in Seattle, funded a pilot plant at a facility operated by the latter in Renton, Wash., under the supervision of James Kerstetter and Stan Hummel. The pilot plant, which opened in June 1995 and operated until July 1996, included an AGF digester and also had a conventional anaerobic digester that was operated in parallel as a control. Both digesters received the same prethickened (6% solids) slurry of primary and waste activated sewage sludge.

During the 11-month pilot test, the hydraulic retention time in the conventional digester was 20 days while the hydraulic retention time in the AGF digester varied from five to 20 days. Both digesters operated at 35C.

During a six-day hydraulic retention, the AGF digester achieved greater solids destruction than did the conventional digester during a 20-day hydraulic retention time. In a hydraulic retention time of 19 days, the AGF digester converted 74% of volatile solids to gas and soluble products.

In a conventional digester, the solids retention time equals the hydraulic retention time. The AGF digester was able to achieve a solids retention time more than three times longer than the hydraulic retention time, in effect increasing the capacity of the anaerobic digester to 3.5 times its conventional size. The longer solids retention time resulted in greater conversion of solids to gas and soluble constituents. The AGF digester achieved volatile solids loadings as high as 11.0 kg chemical oxygen demand (COD) per cubic meter per day on a continuous basis, compared with values of no greater than 3.8 kg COD per cubic meter per day in the conventional control digester. The AGF digester achieved peak loadings as high as 20 kg COD per cubic meter per day.

One factor limiting the maximum leverage (i.e., the ratio of solids retention time to hydraulic retention time) of the AGF process was the accumulation of fixed solids in the anaerobic digester.

The volatile solids concentration of the AGF digester remained relatively constant, but the concentration of fixed solids increased substantially, from 20,000 to 35,000 mg/L. Because a portion of the fixed solids had to be removed from the digester each day to maintain an optimal concentration, the maximum solids retention time clearly was governed by the accumulation of fixed solids in the digester. After the test, Cyclus developed and patented methods to remove a significant portion of the fixed solids from the digester, increasing the maximum leverage achieved by the process.

The pilot operation demonstrated the benefits of retaining the biomass through postthickening, as opposed to prethickening the influent solids. Postthickening and recycling biosolids allowed substantially greater loadings than prethickening. Even at hydraulic retention times as low as five days, the biosolids were well stabilized and odorless. The concentrated solids removed from the flotation unit as waste biosolids were charge neutralized, and as a result required very little additional polymer during dewatering, approximately 30% less than in a conventional anaerobic digestion belt press dewatering system.

During operation of the pilot plant, the hydrolysis rate of particulate solids was extremely rapid: organic sludge was completely converted to gas and soluble products within 24 hours. The hydrolysis rate was directly proportional to the biomass retained in the system.

The high rates of particulate matter conversion to gas and soluble products indicated that the digesters could operate in detention times considerably less than five days. With the AGF process, the capacity of existing municipal digesters could be tripled or even quadrupled with very little capital expenditure.

POTATO SLURRY

In the early part of 1996, the Idaho Association of Commerce and Industry agreed to continue the pilot test operation at the J.R. Simplot potato processing plants.

The association's primary interest was the development of a cost-effective system to remove nutrients from potato slurry and reduce the quantity of land needed for treated waste disposal. Because it could treat potato slurry waste at a high rate without the need to remove particulate solids prior to treatment and it produced a clean, clear effluent free of particulate matter, the AGF process offered a potential means of removing and recovering phosphate and nitrogen nutrients from potato slurry as an inorganic fertilizer.

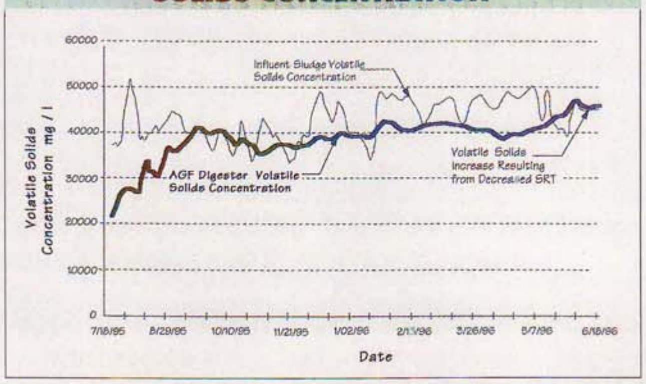
The pilot plant treated the raw slurry waste from a plant that processes french fried potatoes. Operating in an anaerobic contact stabilization mode with a contact digester, solids holding digester, AGF separator and nutrient recovery unit, the process converted 97.5% of the waste to gas and soluble products in detention times as low as 12 hours.

Less than 5% of the influent waste was concentrated to an odorless residual organic slurry having the consistency and appearance of soil. Thirty percent of the nitrogen and most of the phosphate were removed. Cyclus investigated methods of recovering the nutrients as a marketable inorganic product, but did not implement them.

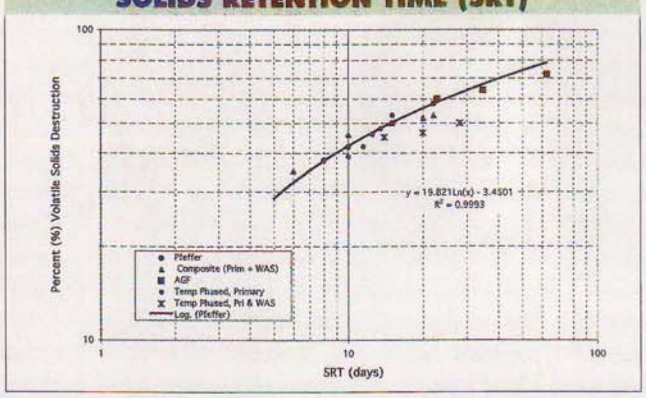
In late 1996, the pilot plant was moved to a potato flake processing plant in eastern Idaho. The raw potato flake waste was a concentrated slurry with a COD concentration as high as 20,000 mg/L as well as high nitrogen and phosphate concentrations.

During the six-month operation, the pilot plant converted over 95% of the waste to gas and soluble products in hydraulic retention times of less than one day. As the pilot test progressed, Cyclus fine-tuned the integrated nutrient recovery system, eventually retrieving 95% percent of the phosphate and 22% of the nitrogen as magnesium-ammonium-phosphate, a highly valued inorganic fertilizer commonly called struvite.

AGF DIGESTER VOLATILE SOLIDS CONCENTRATION



VOLATILE SOLIDS DESTRUCTION VERSUS SOLIDS RETENTION TIME (SRT)



The pilot plant results confirmed that high-rate anaerobic processes can treat concentrated waste slurry in small reactors with low detention times and produce a clear, clean, odorless effluent.

Over the past year, pilot and laboratory studies have established that the process produces high-quality biogas, much of which is of pipeline quality. Cyclus has developed a more efficient process for the removal of inorganic solids as a separate stream to increase the maximum solids retention time and destruction of volatile solids. The company has also investigated the potential recovery of nutrients as pellets for commercial agricultural use.

The King County Department of Natural Resources is planning to construct a full-scale AGF facility in Seattle to increase the capacity of its anaerobic digesters and the rate of volatile solids destruction. The sanitation districts of Orange County are planning to construct a large pilot facility to recover nutrients, produce pipeline quality gas and minimize biosolids discharge. In addition, several large food processing plants are planning facilities to convert their slurry waste to gas and energy rather than continuing to discharge their waste into the municipal system.

The AGF process has the potential to solve the nation's food, animal waste and municipal solid waste disposal problems. Many communities are struggling to meet their municipal solid waste recycling goals. In order to meet those goals, putrid waste, such as the food fraction of municipal solid waste, must be recycled. The many municipal anaerobic digesters throughout the country represent a tremendous resource for converting food and other putrid waste to energy. If the capacity of those anaerobic digesters could be increased to three to four times their current capacity, without affecting treatment plant effluent quality, large quantities of energy and nutrients could be produced at a minimal cost. ▼

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