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Wastewater Edition

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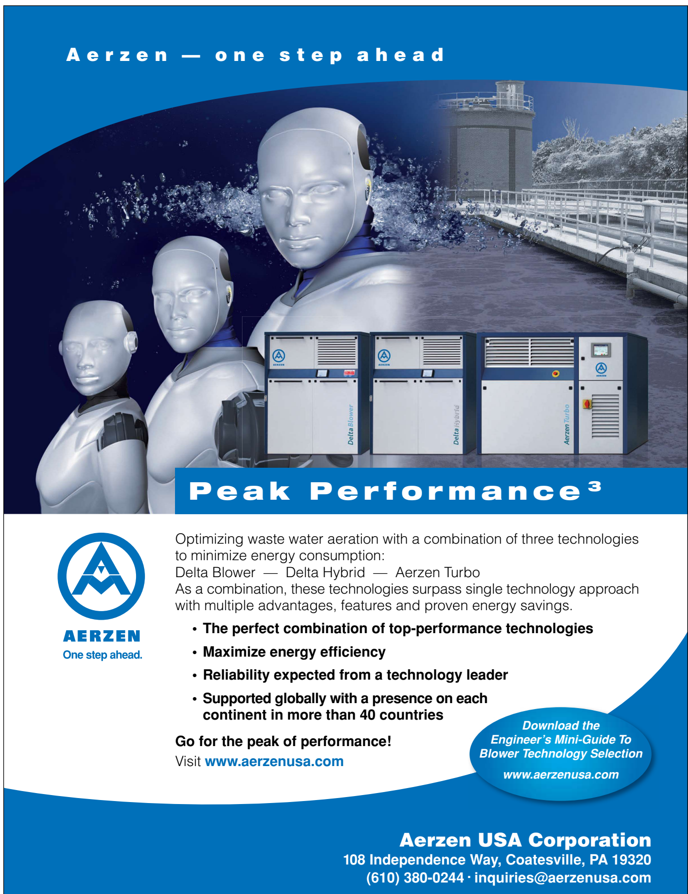

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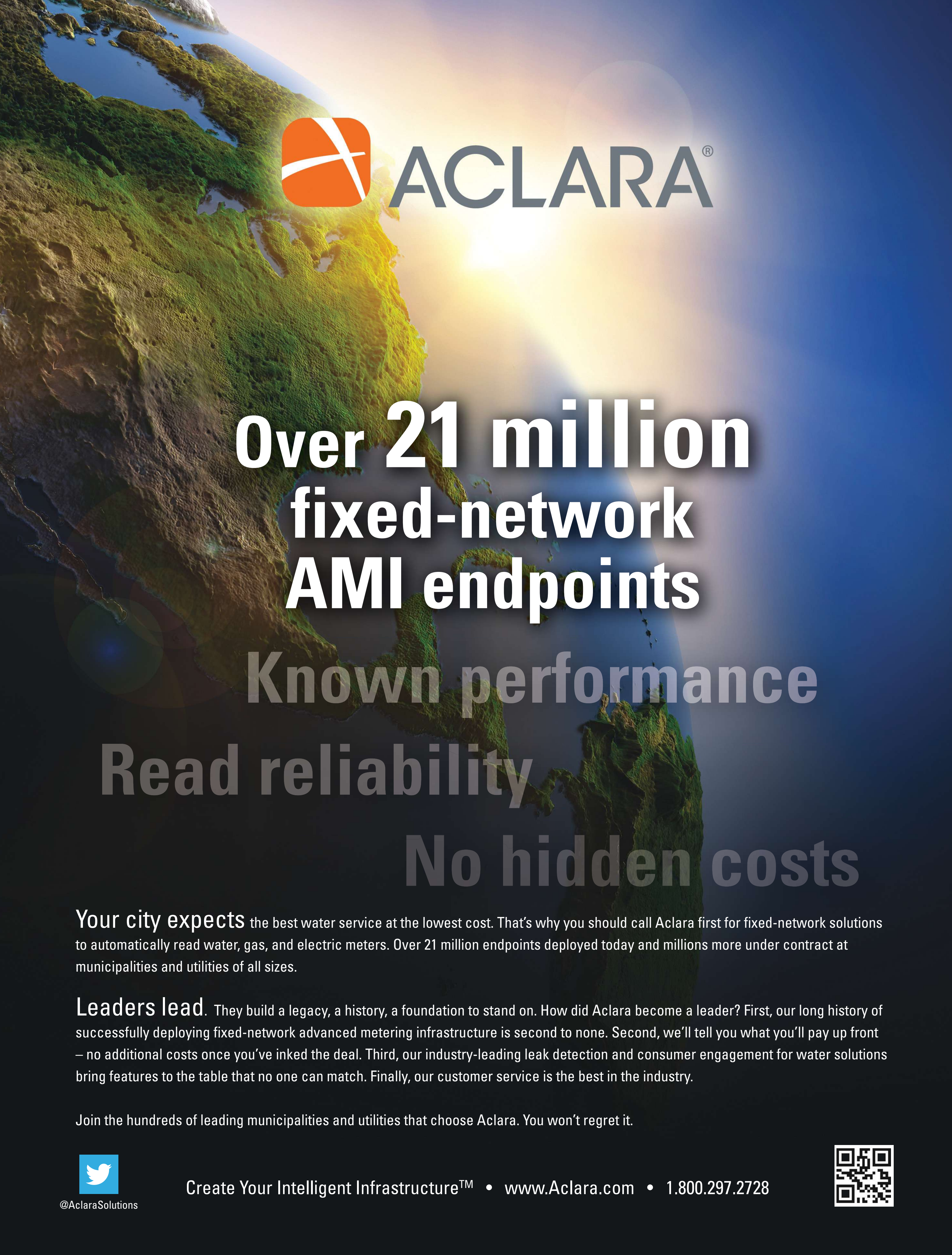
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Wicked Awesome Remediation

July 13, 2013 in Boston was a day more than 50 years in the making, as the long-suffering Charles River was opened for recreational swimming. Infamous for its heavy pollution, the river had become the butt of many a joke, and deservedly so. It sounds like jest to say that anyone who fell in the river was advised to go to the hospital for a tetanus shot, but that was exactly the case. After receiving a "D" grade for water quality by the U.S. EPA in 1995, the Charles began a steady road to recovery that resulted in a "B+" in 2011. And this summer, after half a century, it was once again open to swimmers — and swim they did.

This is a success story that bucks the trend for most urban waters. The U.S. Geological Survey (USGS), in the very same week the Charles River reopened to swimmers, reported that stream health deteriorated in the vast majority of agricultural and urban areas. Their study noted the following statistics:

- Two-thirds of U.S. estuaries can no longer support healthy fish communities due to nutrients and dead zones.
- 42 percent of the streams were poor or degraded compared to regional reference conditions.
- 80 percent of urban waterways contain at least one pesticide detrimental to aquatic life.

But, again, this is a success story. Urban and agricultural conditions, though difficult, are not death sentences for streams. The USGS study points out that nearly one in five of the streams situated in urban/agricultural areas was in relatively good health, despite contending with the challenges of land and water-use development that often lend themselves to poor water quality. For the Charles River to be the exception — of all places, with its history — is a monumental upset (to draw on sports parlance).

It was also quite a comeback. The Charles was once considered "an open sewer," according to a 2011 news article from the *Beacon Hill Times.* And yet the purpose of the article was to announce that the river had just won the "largest environmental prize in the world," the International Riverprize, beating out more than 20 worldwide contenders.

Wastewater Practices And Pollution Prevention

The Charles River was revived with a multifaceted game plan to address the root causes of the pollution. Some efforts, like eliminating combined sewer overflows (CSOs) and stormwater runoff, as well as aggressively monitoring water quality, are familiar and expected. Others, such as computer modeling and "smart sewering," indicate a more advanced approach. As a practical measure, a dam was also built to prevent salt water that derives from road de-icing, wastewater effluent, and/or faulty septic systems from entering the basin.

There was one method, however, that was highly unusual. Oysters, it seems, love to eat sewage. So, back in 2008, the Massachusetts Oyster Project shipped in 150,000 of the hungry shellfish to feast in the Charles River. Speaking of comebacks, oysters were once prevalent in the Boston area, but were wiped out due to overharvesting and industrialization in the early 1900s. Now they were brought back to save the river.

With each oyster capable of filtering 30 gallons of water per day, it was estimated that 3 million gallons of sewage could be processed every 24 hours. Nitrogen, in particular, fixes to their shells, making up about 8 percent of their total weight. Apparently thriving, the oysters are still there today — a quirky piece of a puzzle assembled rather nicely by the Charles River Watershed Association and its partners.

In a time when many rivers and streams are becoming even more endangered, the reclamation of the Charles River is cause for celebration — particularly for that first group of swimmers on July 13. No tetanus shot required.

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Save Nutrients, Save The World

While regulations demand that wastewater treatment plants get nutrients out of the water, the world's food supply may demand more – that we recover and reuse them.

By Kevin Westerling

Nutrients are a nuisance in our environmental waters and, by extension, a nuisance to wastewater treatment plant (WWTP) operators, especially in the United States. Federal and state regulators have been steadily rolling out more — and more stringent — effluent limits on nutrients — namely, phosphorus and nitrogen. Aggressive action is certainly necessary; eutrophication caused by nutrients results in hypoxia (oxygen depletion) and harmful algal blooms that kill aquatic life and can lead to cyanosis ("blue baby syndrome") in humans. The aggressive way in which WWTPs are targeted, however, may seem unfairly strict and unbalanced considering the nutrient loadings of nonpoint sources, such as runoff from farmlands, which actually pollute receiving waters much more. But this burden taken on by wastewater utilities may also yield tremendous opportunity.

Whereas the current focus mainly lies on simple (or not so simple) nutrient removal, often at great cost to the municipality, the next (r)evolutionary step will be the recovery and reuse of nutrients, particularly phosphorus. It's a virtual inevitability since phosphorus is a finite resource that otherwise must be mined from phosphate rock. Phosphorus is vitally important because, along with nitrogen and potassium, it's an essential component of (N-P-K) fertilizer. In short, it's needed to feed the world, and it's in danger of running out … someday.

There is considerable debate as to when and how that may happen, with many factors to consider in the projection (see the sidebar on page 10 for details). Though even alarmists would admit that we're at least decades away from a phosphorus shortage, there is no denying the general direction of the trend. A finite resource coupled with a rising population, according to the basic law of supply and demand, will only create shortage and increase value. So it's feasible that wastewater plants could someday get rich from treating human waste, which is loaded with nutrients. Imagine that: urine as liquid gold! Before you balk, consider that one person's urine is enough to keep 3,000 to 10,000 square feet of farmland well-fertilized, depending on the type of crops grown.[1]

Even in its most basic forms — localized land application, for instance — the recycling of nutrients has enough value to help offset the very significant costs of sludge treatment. What opportunity might then be offered by more advanced recovery technologies, especially when considering the rising demand for fertilizer? And while the true mission of public utilities isn't to turn a profit per se, it is their mission to serve the community's needs in the most cost-effective way. Recovery and reuse of nutrients has the capability to simultaneously protect waterways from eutrophication, provide (and prolong) fertilizer production for crops, and save — or even earn — money for municipalities.

The question then becomes, why aren't more wastewater facilities doing this? Some progressive utilities in the U.S. actually are, but it is much more prevalent in Europe. Here are some of the technologies and utilities that are leading the way.

Here And Now: Turning Phosphorus Into Fertilizer

A number of companies are precipitating phosphorus from the sidestream through fluidized-bed reactor processes and recovering it as struvite, or magnesium ammonium phosphate. While this practice is more easily adopted by WWTPs that feature biological phosphorus removal and anaerobic digestion, it can also be installed (less seamlessly) at plants using chemical phosphorus removal. The recovered struvite is turned into and then sold as a slow-release fertilizer. This offsets the capital and operational costs of the process, while also reducing or eliminating disposal costs. By contrast, chemical phosphorus precipitation creates waste sludge that has little value as a fertilizer and is most often hauled off at the expense of the municipality. Furthermore, unrecovered struvite forms as scale in pipes and can reduce system capacity.

The leading company in extracting struvite and turning it into profit, as measured by WWTP installations, is Ostara Nutrient Recovery Technologies. Oregon's Clean Water Services was among the first to take the plunge at their Durham Advanced Wastewater Treatment Facility near Portland, and the success prompted them to also incorporate the technology at its Rock Creek facility in Hillsboro. Hampton Roads Sanitation District's Nansemond Treatment Plant in Suffolk, VA, has also taken advantage, as has the City of York (PA) Treatment Plant. Carried out as public-private partnerships, Ostara garners service fees and a portion of fertilizer profits to pay back the costs of installation, which can be repaid in as little as five years.

Other companies extracting struvite to make fertilizer include Multiform Harvest, employed by the City of Boise at the West Boise Wastewater Treatment Facility, and Netherlands-based DHV Water with its Crystalactor technology. The latter differs from Ostara and Multiform Harvest in that, rather than creating fertilizer pellets, Crystalactor — licensed through Procorp Enterprises in the U.S. — crystallizes phosphate on fine grain sand and has thus far been used solely for industrial wastewater treatment.

Troublesome nutrients become life-giving fertilizer.

Further Out: Electrochemical Nutrient Recovery

Although the above technologies are state of the art, science is already working on new and potentially better ways to recover phosphorus and nitrogen to make fertilizer. Current practices require the addition of magnesium — magnesium chloride ($MgCl_2$), magnesium hydroxide ($Mg(OH)_2$), or magnesium oxide (MgO) — as the limiting reagent to successfully recover struvite. Another requirement for struvite is a pH in the range of 8.5 to 9.5, which is typically achieved by adding sodium hydroxide (NaOH). In Stuttgart, Germany, however, at the Fraunhofer Institute for Interfacial Engineering and Biotechnology, a new process has been patented that makes struvite without adding magnesium or sodium hydroxide. Not only does the process save money by not using chemical salts, but also energy consumption is extremely low at just 70Wh/m^3 of wastewater.

An electrolytic cell consisting of an inert cathode and sacrificial magnesium anode is the catalyst for operation. Water cleavage splits the water at the cathode and forms hydrogen and hydroxide ions, causing an increase of pH in the wastewater that remains constant at a value of nine — in the sweet spot for struvite recovery. Oxidation takes place on

PREDICTING PEAK PHOSPHORUS – AND POTENTIAL CATASTROPHE

Maintaining an adequate phosphorus supply is a matter of life and death, and some parties, many academics among them, are calling for swift action to avoid global turmoil. The Sustainable Phosphorus Initiative, for example, was founded by scientists at Arizona State University's Global Institute of Sustainability precisely to create awareness and develop solutions for phosphorus scarcity.

The problem for those eyeing a shortage is that the world is completely dependent on phosphorus for its food supply – it being a limiting factor for crop growth (i.e. without it, crops won't grow). Unfortunately, the vast majority of the world's phosphate rock is found in just a few countries. Morocco and the Western Sahara region of Africa, according to a 2012 report from The Hague Centre for Strategic Studies (HCSS), are the sites of nearly two-thirds of all known reserves, followed by (in order, and in much smaller percentages) Iraq, China, Algeria, Syria, Jordan, South Africa, the U.S., and Russia. The report notes that 80 percent of global exports come from Middle Eastern and North African countries and that "political turmoil and social unrest in phosphate rock producer countries are likely to increase," creating an "inherently unstable" environment.[2]

Phosphate rock

Because phosphate rock is nonrenewable, formed only through the course of millions of years, the point of "peak phosphorus" – when demand surpasses production, whether by sheer use or helped along by political factors – could trigger starvation and wars. Some studies speculate that peak phosphorus will hit before midcentury, due to the demand of developing countries and "richer" diets of meat and dairy products that require up to three times the phosphorus of vegetarian diets. With European countries lacking significant phosphate rock reserves, The Hague is at least monitoring the situation.

On the other hand, the International Fertilizer Development Center (IFDC) issued a report in 2010 stating that peak phosphorus will be stalled for several centuries.[3] The International Fertilizer Industry Association (IFA) supports the IFDC's conclusion and points out that, unlike phosphate rock, phosphorus itself is a renewable resource that *can* – and therefore should – be reused within economic and technical limits.[4] On this particular point, all parties agree.

the sacrificial magnesium anode, releasing magnesium ions into the solution where they react with the phosphorus and nitrogen to form struvite.

While selling fertilizer is a nice perk for municipalities, regulations still rule the day; otherwise, fertilizer sales will be going toward EPA fines. The electrochemical process performed admirably in this regard as well, lowering phosphorus concentrations by 99.7 percent to values under 2 mg/L during long-term trials in a continuous laboratory plant. The next step is testing the process in the real world, which is currently taking place with mobile pilot plants at municipal WWTPs. If all goes well, it will be yet another option in a burgeoning sector of the wastewater industry.

As the need for nutrient recovery continues to grow, so too does the technology. Now it's just time for wastewater treatment professionals to hop on board and help save the world. ■

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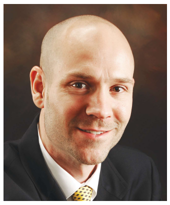
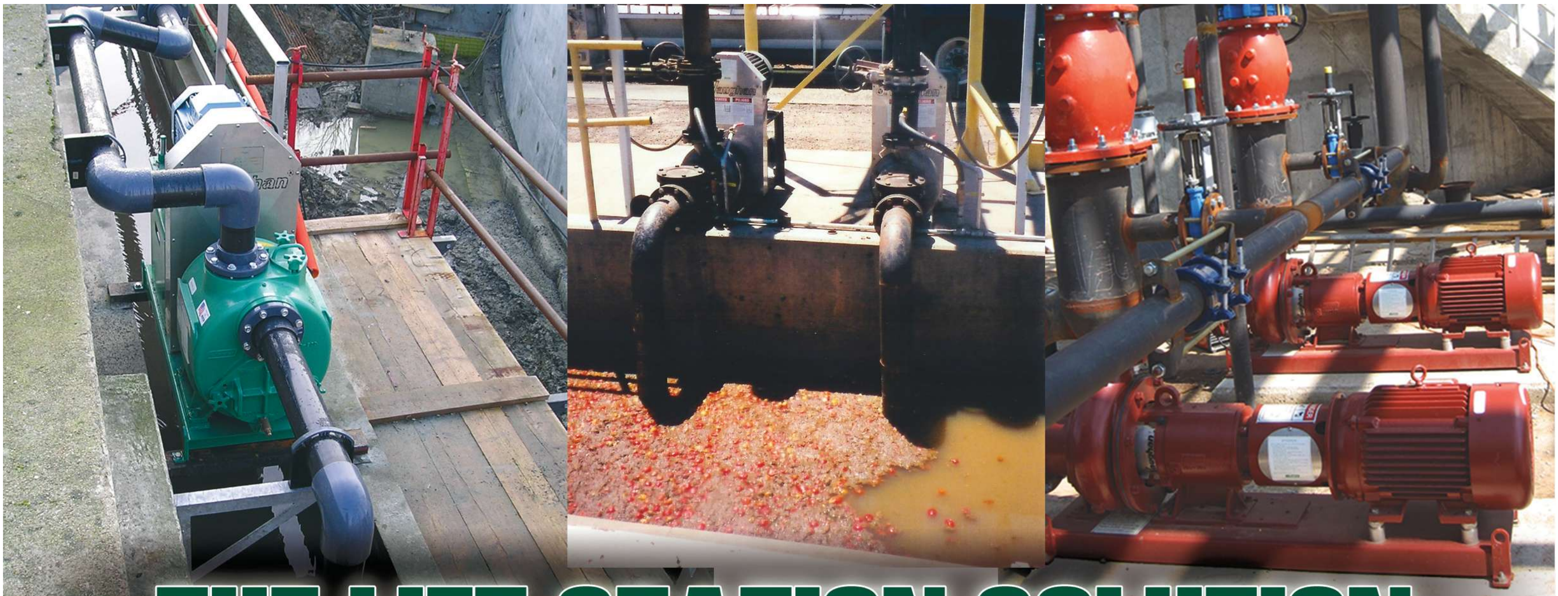


Kevin Westerling has served as the editor of Water Online, the Internet's premier source for water and wastewater solutions, since 2008. Kevin's education includes a bachelor's degree in English literature, a minor in journalism, and certification as a web content developer. He can be reached at editor@wateronline.com.



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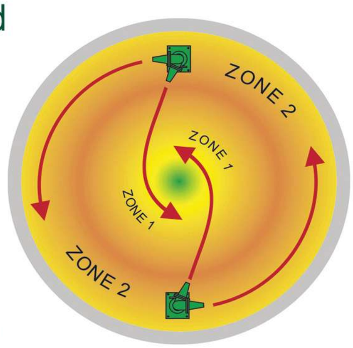

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Three Approaches To Controlling Odor In Wastewater Treatment Ponds

Due to their ability to circulate a precise horizontal cross-section of water, long-distance circulators can solve odor problems in equalization ponds, anaerobic ponds, and deep-water industrial ponds.

By Joel Bleth

Solving odor problems in wastewater treatment ponds should begin with a few investigative questions: How was the pond designed? Has the operation of the pond changed over the years? What is the purpose and operational theory of each pond, and have ponds been added or closed? Why are odors apparent on some days and not others? Understanding these "hows" and "whys" will provide clues to successfully solving odor problems in a variety of wastewater treatment plants.

All organic material contains sulfur, a chemical element that is necessary to sustain life. Sulfur in the aerobic digestion process is converted to odorless sulfate in the presence of oxygen. Sulfur in anaerobic digestion becomes sulfide and exists in several forms, from hydrogen sulfide to mercaptins, or thiols. The odors associated with sulfides are equally as diverse, ranging from the smell of garlic to rotten eggs and worse. Wastewater treatment plant operators may rate the odors coming from their plants from mild to offensive, depending on the number of complaints received from nearby residents.

Operators have several options for trying to deal with pond odors, from increasing the aeration to applying chemicals to the water or perfume to the air. But often these solutions are expensive and not totally effective.

Another alternative — long-distance circulators or mixers — has emerged as an economical, effective solution for controlling odors in many wastewater ponds. These mixers are installed on the pond's surface and consist of a solar-powered or grid-powered motor, an axial flow impeller that pulls water up from the intake to the surface where it is spread out at 360 degrees, an adjustable-depth intake hose, and a power-control system.

Long-distance circulators are different from any other reservoir equipment in that the adjustable intake takes advantage of the manner in which water forms thin horizontal layers in ponds and allows a precise, horizontal cross-section of water to be circulated throughout the entire pond footprint. This circulated zone can be indexed to the top of the pond, such as a setting to circulate just the top X feet of the pond, or the intake hose can be set to circulate the entire depth of the pond regardless of how full the pond is. This article discusses how this unique characteristic allows long-distance mixers to control odors in three types of wastewater treatment ponds:

1) Equalization ponds
2) Anaerobic ponds
3) Deep storage industrial ponds

Equalization Ponds: Keep The Pond Well-Mixed And Aerobic

An equalization pond in front of a wastewater treatment plant acts as a shock absorber by temporarily holding excess inflow during rain events until the water can go through the treatment plant.

For example, an equalization basin may be designed to hold 8 million gallons of water when full at eight feet deep, but normally to be operated with 2 million gallons in the pond at a depth of 3 to 4 feet, with 1 million gallons per day entering the pond and going through to the treatment plant. During a heavy rain, the equalization pond may quickly fill to the depth of 8 feet and then, a few days later, be back down to 3 feet.

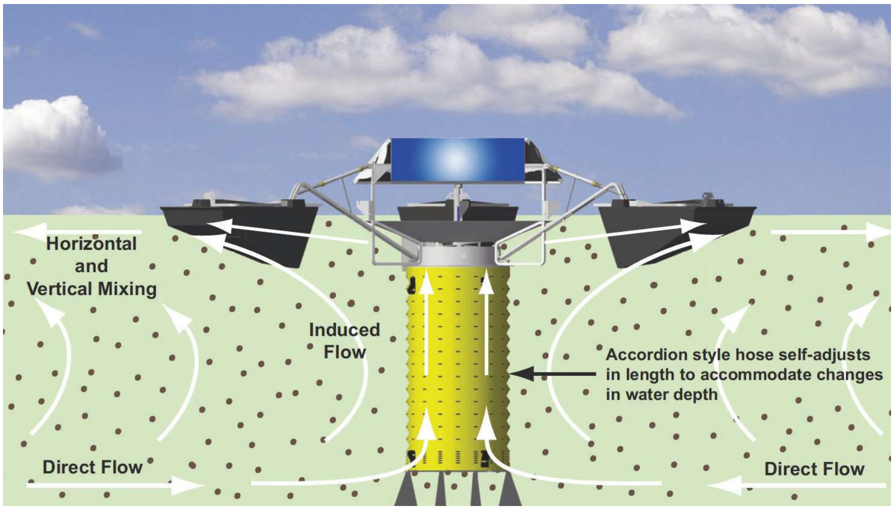
As illustrated at right, in this type of pond, without thorough mixing, the organic solids entering the pond will tend to settle to the bottom, and, over time, the anaerobic digestive process at the bottom can create ongoing odor problems. But by keeping the solids and water thoroughly mixed, the solids move on to the plant instead of settling to the bottom, and the detention time of both the water and the solids is too short for the anaerobic process to ever pick up any momentum and create an odor problem.

In these ponds, the unique design of a long-distance circulator, set with the intake hose all the way to the bottom of the pond, will automatically allow full mixing of the pond as it goes through these depth changes, without any adjustment being needed and without damaging the bottom of the pond in any way.

Anaerobic Ponds: Odor-Cap An Anaerobic Pond

Some wastewater treatment ponds, such as waste sludge storage ponds in activated sludge systems, are purposely designed for anaerobic digestion and thus produce sulfides and odors continuously throughout most of the pond depth. To eliminate odors emanating from these ponds, operators can

Equalization Pond



By keeping the solids and water thoroughly mixed, the solids move on to the plant instead of settling to the bottom.

maintain an oxygenated layer of water at the surface of the pond, sometimes called an "odor cap." When sulfide gas bubbles rise toward the surface of the pond, they are instantly oxidized to nonodorous sulfate as they pass through the oxygenated odor cap.

A thin odor cap at the top of the pond, even 1-inch thick, is all that is required to neutralize sulfide odors. But a thin odor cap can be disturbed by wind, which would then let odors escape, so usually it is best to have a 1- to 3-feet thick odor cap.

Some floating aerators, such as brush aerators, have a shallow, mostly horizontal mixing effect, and these are often the best type of aerator to use to create an odor cap on an anaerobic pond. However, because they generally send out a turbulent flow which reaches several feet deeper than desired, they can bring deep BOD (biochemical oxygen demand) material up into the odor cap zone, which causes oxygen depletion. For that reason, and also because these aerators push water in only one direction, oftentimes several machines are needed for each pond in order to supply enough oxygen to maintain the odor cap, which leads to higher capital and operating costs.

As illustrated below, floating circulators are ideal for creating an odor cap on top of the pond, because their intake hoses can be set for a shallow water depth, usually 1 to 3 feet, and because one machine will circulate to the edge of the pond in all directions. Consequently, only one machine is usually needed per pond. Circulators maintain the oxygen in the odor cap through two mechanisms, (a) capture of photosynthetic oxygen during the daylight hours, and (b) surface re-aeration during the nighttime hours. Since the machine is not bringing up any BOD loading from deeper water, because there is no turbulence, usually there is no problem in maintaining oxygen in the odor cap 24 hours per day.

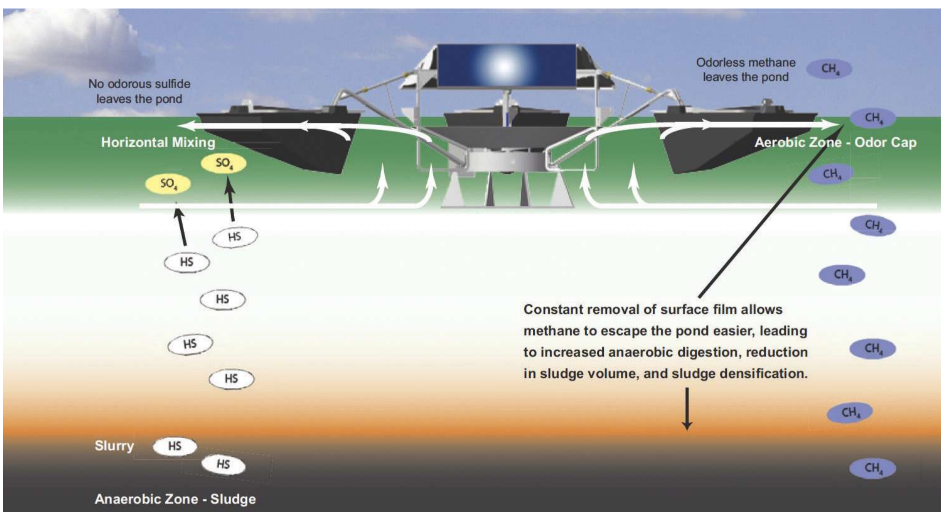
Whatever the situation, circulators can be a viable tool in both aerobic and anaerobic pond types.

Regardless of what type of equipment is used to create and maintain an odor cap on an anaerobic pond, three practices are crucial to proper odor control in an anaerobic pond:

1. Inflow to the pond should be kept below the odor cap so that the influent BOD does not use up the oxygen in the odor cap. If the odor-control plan calls for a 3-foot-thick odor cap at the top of the pond, the inflow should be brought in horizontally at 4 feet deep or deeper. If an old pond is converted to sludge storage and the horizontal inflow pipe is not deep enough, then add a baffle or 45-degree elbow with a short pipe extension so that the inflow water does come in below the odor cap. And in ponds where the influent water enters vertically at the bottom of the pond, place a deflector, similar in shape to a card table, over the influent pipe to deflect incoming water into a horizontal pattern, instead of allowing it to shoot up to the surface of the pond.

2. Similarly, the effluent should also be drawn off the pond from below the odor cap. This prevents the oxygenated water that composes the odor cap from being drained off the pond. If an old pond is being converted to use for sludge storage and it has a skimming outlet pipe, devise an antiskimming baffle, or 45-degree elbow and short pipe extension, to allow water

Anaerobic Pond



Only the top 2 or 3 feet of the pond are mixed, effectively "capping" the anaerobic waters below.

Diagnosing odor problems in wastewater treatment plants can be intriguing and begins with a thorough investigation of the plant, its processes, and purposes.

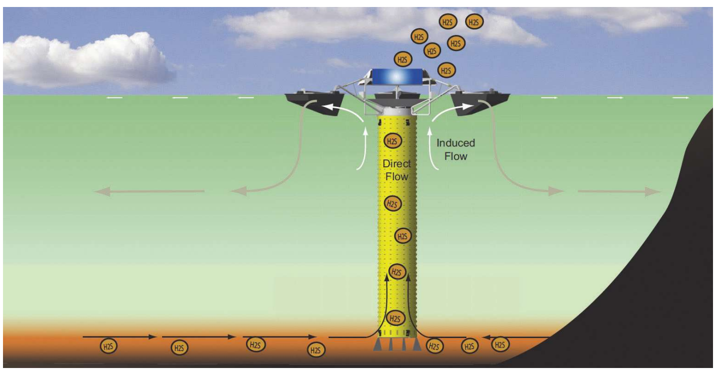
leaving the pond to come from below the odor cap.

3. Finally, the influent to the pond, which contains the BOD for anaerobic digestion, cannot be hot water. Hot water will float across the top of the pond, and the BOD in it will use up the oxygen in the odor cap. For this reason, odor capping is difficult in some industrial treatment applications, such as beef processing, where the influent is hot wash-down water. Often these plants use hot water that is high in BOD. For those ponds, aerobic digestion of all influent is one solution, or the pond can be covered to achieve odor control.

Deep Industrial Pond: Constant Degassing In An Anaerobic Pond

Some industrial wastewater ponds can be quite deep, 30 to 50 feet, for example, and may contain mostly mineral- and salt-based wastewater, such as boiler blow-down water from a power plant. Mining ponds and oilfield wastewater ponds can also have this problem.

Deep Industrial Pond



Deep, dense water, along with hydrogen sulfide, is continuously drawn up to the surface of the pond and depressurized. Sulfides vent into the atmosphere at the distribution dish.

In these ponds, the sulfate comes in with the water and other minerals, as opposed to being released during digestion of organic material. In the anaerobic environment at the bottom of the pond, some sulfate is converted to sulfide and trapped in the cold, high-salt, high-density water at the bottom of the pond. Then, when the pond turns over and goes into a full mixing mode, particularly in the fall and during some spring nights, a huge amount of sulfides can be released into the air.

As illustrated above, in these ponds, an effective odor-control strategy is to place one or more circulators in the pond, depending on pond size, with the intake hose all the way to the bottom of the pond. The deep, dense water with the dissolved hydrogen sulfide is continuously drawn up to the surface of the pond and depressurized, and the sulfides vent into the atmosphere at the distribution dish (see diagram). Because water in ponds is found in thin, horizontal layers, usually one machine set at the deepest part of the pond will remove sulfides across the bottom of the entire pond. The sulfide smell is usually noticeable right at the machine, but not at shore. Then, when the pond turns over from time to time, there is no odor event because no sulfides remain on the bottom water.

Conclusion

Diagnosing odor problems in wastewater treatment plants can be intriguing and begins with a thorough investigation of the plant, its processes, and purposes. What is the theory of the pond's design and how is it operating? How do the inflows and outflows work? Why and when are the odor problems occurring?

Just as each plant is unique, each solution is unique, but many pond odor problems, and solutions, will fall into one of the three categories mentioned above.

Whatever the situation, circulators can be a viable tool in both aerobic and anaerobic pond types. They can often be installed and operated at a fraction of the cost of other methods, yet operate compatibly with existing aeration systems. And in industrial applications in the U.S., the solar-powered machine qualifies for a 30 percent investment tax credit and accelerated depreciation. Treatment plant operators will discover it's worth their investigative time to consider circulators — and curtail resident complaints about odors forever. ■

Joel Bleth is president and CEO of Medora Corporation, which he cofounded with Willard Tormaschy in 1998. Bleth holds degrees in engineering and law from the University of North Dakota, Grand Forks.

Tightening NPDES Guidelines: Industrial Plants Beware

Multiple methods of dealing with waste stream discharges are examined in light of the recent clampdown on industrial processes.

By Brad Buecker

I began my career in the power industry in 1981 at a coal-fired plant in the Midwest. At that time, U.S. EPA National Pollutant Discharge Elimination System (NPDES) guidelines focused upon a small core of primary impurities in wastewater discharge streams. These included total suspended solids (TSS), oil and grease (O&G), pH, and free chlorine (or other oxidizing biocide). A common guideline is shown below in abbreviated form.

Table 1: An abbreviated NPDES example

Constituent	Monthly Average (Limit Or Range)
Free Available Chlorine	0.2 mg/L
O&G	10 - 15 mg/L
pH (range)	6.0 - 9.0
TSS	30 mg/L

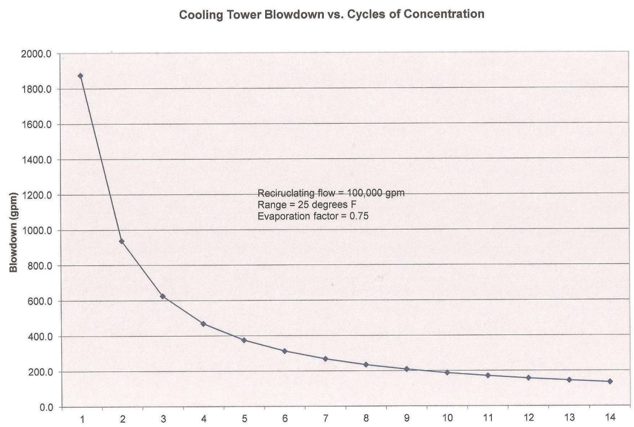
My former plant, like many other plants then, utilized once-through cooling, so these limits were often easy to achieve. The majority of problems arose at coal-fired power plants from the discharge of coal-pile runoff ponds and wet-ash disposal ponds. The constituents in these streams that required the most oversight tended to be TSS and pH, but straightforward methods were available to control this chemistry.

The Times They Are A'Changin'

In the power industry, the development of shale gas combined with the perceived "war on coal" has led to the rapid planning and installation of simple- and especially combined-cycle units for new power generation. But due to pending 316b water regulations, which are designed to protect marine life from destruction in cooling water intakes, all of the many combined-cycle RFPs I have seen in the last two years specify a cooling tower or, in some instances, an air-cooled condenser.[1] For other heavy industries, cooling towers are also quite common. The key point in this regard is that new NPDES guidelines are focusing upon many additional impurities besides those outlined in Table 1 and where the concentrating nature of cooling towers can put tower blowdown in violation of new guidelines. While it is well-known that the EPA is preparing new regulations, some states have already implemented stricter guidelines, examples of which are outlined next.

A general parameter that is appearing in new NPDES regulations is total dissolved solids (TDS). This has very important consequences for cooling tower operation. Consider an example provided by new friends at a power plant in one of our southern states. Prior to this year, the plant's NPDES permit only called for monitoring of TDS. The new permit will impose an average monthly limit of just slightly over 1,000 mg/L. Due to the very nature of cooling-tower operation, the impurities in the makeup increase in concentration due to evaporation of water from the tower. Say, for instance, that the makeup water contains on average 400 mg/L TDS. If the wastewater guideline is 1,200 mg/L, the tower cycles of concentration (COC) are limited to three. The effects of COC on blowdown volume are quite evident in the figure below. The larger discharge volume at lower COC can create problems in locations where the discharge quantity is also regulated, a situation that has quite notably arisen in California.

Figure 1: Effect of cycles of concentration on blowdown per conditions shown on the chart.



While it is well-known that the EPA is preparing new regulations, some states have already implemented stricter guidelines.

Sulfate (SO_4) is another constituent that is appearing in some new NPDES guidelines. This can be problematic with regard to process chemistry, as sulfuric acid feed to cooling-tower makeup has been a common method to remove bicarbonate alkalinity and thus minimize calcium carbonate ($CaCO_3$) scaling in the condenser and cooling system.

$$H_2SO_4 + Ca(HCO_3)_2 \rightarrow CaSO_4 + 2H_2O + 2CO_2$$

Tighter regulations on sulfate in the discharge stream may eliminate this straightforward method of scale control at some plants. On a related note, phosphorus is being banned in many waste streams. Phosphorus, of course, serves as a nutrient for plant growth, and when released to open bodies of water can often initiate and propagate algae blooms. The difficulty is that a very common cooling water-treatment method relies on the use of ortho-phosphate and organic phosphates (phosphonates) for both corrosion and scale control.

Heavy metals are also on the list, with a primary example being zinc. This element was once an integral part of the phosphate/phosphonate programs mentioned above, as it assists with corrosion protection. However, zinc's use has been severely curtailed due to discharge issues. Another metal that is now appearing on NPDES permits is copper, for which the discharge limit may be below 30 or perhaps even 20 µg/L (µg/L is equivalent to parts-per-billion). At these very low limits, copper discharge can potentially be a problem from units equipped with copper-alloy condenser tubes. However, another copper source, and I am speaking here of wooden cooling towers, comes from copper compounds often utilized as a wood preservative.

Control Methods

As one might suspect, adjusting to new NPDES guidelines is not always simple or inexpensive. To make matters worse, sometimes other factors compete against any efforts. A primary example is the growing requirement to use recycle water in place of fresh water as plant makeup. Recycle water, such as tertiary-treated wastewater, can have quite variable concentrations of many impurities, in which case the wastewater discharge can also be quite variable. A snapshot analysis from a recent example shown to me by a colleague indicated 4.8 mg/L of phosphate and 15 mg/L of ammonia in that particular sample. Ammonia is appearing in discharge permits, as it can be lethal to aquatic creatures.

For plants facing tight TDS restrictions, reducing the cooling tower COC is a method to lower the dissolved solids content of the waste stream, but that technique in turn increases the discharge volume. This may or may not be a problem, depending upon the environmental authorities in charge of permitting. For new plants, this factor could be very important with regard to plant location and the quality of the water available for makeup.

The emerging restrictions on sulfate in the discharge may, in some cases, eliminate makeup water acid treatment as a scale-control mechanism. An alternative method to reduce the threat of calcium carbonate scaling, albeit at considerable expense and increased system complexity, is makeup water cold-lime softening. This technique will lower both the calcium and bicarbonate alkalinity of the stream, but not without proper operator control and monitoring of the unit. A factor that may favorably influence softening for some applications is the ability to also include magnesium feed for reduction of silica. Silica chemistry is quite complex, but a general rule of thumb suggests 150 ppm as the silica limit in the cooling tower recirculating water, with possibly an upper limit of 200 ppm or so with some of the newer chemical treatment programs. This is often not an issue with surface water supplies, as these may contain only a relatively small silica concentration. However, groundwater is a fairly common source for cooling tower makeup, and some supplies, particularly in the West, may contain 30 to 50 ppm of silica. Thus, the high makeup silica will greatly limit the cycles of concentration in the tower, unless some of it is removed from the makeup.

If phosphate discharge is prohibited, one possible alternative for recirculating water treatment is an all-polymer treatment program.[2] A simple polymer, often a polyacrylate, typically is included in a phosphate/phosphonate program to act as a sequestering agent and/or crystal modifier. An all-polymer program, on the other hand, relies on what are known as co- and ter-polymers that have more than one functional group to act as sequestering agents/crystal modifiers. One helpful technology that has been enhanced over the last decade or so is that of tagged polymers. The chemicals contain a functional group that can be monitored by fluorescence or other techniques, the data from which can then be used for automatic chemical control of cooling water chemistry. Another potential option is blowdown treatment by clarification, with primary coagulant being a compound, such as ferric chloride, that will cause the phosphate to precipitate and be removed with the clarifier sludge blowdown.

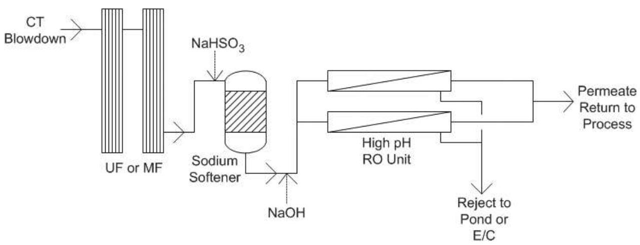
With regard to the copper issue mentioned above, for new plants straightforward solutions include no copper in the condenser and a selection other than wood for the cooling tower material. FRP (fiberglass reinforced plastic) is becoming a common choice as a tower material. For existing plants with wood towers and a copper discharge issue, the solution is more problematic. Replacement of the tower is, of course, one possibility, but obviously at considerable cost. One potential wastewater technology is treatment of the stream in a clarifier that utilizes a coagulant with sulfide active groups. This treatment method has been implemented at some coal plants for mercury (Hg) removal from wet flue gas desulfurization streams. Copper also reacts quite readily with sulfide, so this technology may represent a control technique for that element as well.

Backend Discharge Reduction

Several methods are possible to reduce the volume of plant discharge, but I would like to focus on one rapidly emerging technology, a generic diagram of which is outlined below.

One version of this process is licensed for various markets as HERO™ by such firms as Aquatech, GE,

Figure 2: Generic outline of an emerging wastewater treatment technology



and U.S. Water, while Veolia supplies their OPUS™ technologies for this purpose. Keys to the process are:

- Micro- or ultrafiltration (UF) to remove suspended solids in the waste stream
- Sodium bisulfite ($NaHSO_3$) feed to remove residual oxidizing biocides
- A sodium softener to remove calcium and magnesium
- Sodium hydroxide injection to elevate the pH above 10 (The combination of hardness removal and pH elevation keeps silica in solution.)
- Two-pass reverse osmosis (RO) treatment to recover 90 percent of the water

While the process appears straightforward, my colleagues and I have directly observed operating

As one might suspect, adjusting to new NPDES guidelines is not always simple or inexpensive.

issues with the technology in actual application. These include:

- Some standard cooling tower chemicals may foul the UF membranes.
    - The membrane manufacturer and type greatly influence this phenomenon.
    - Use of upstream multimedia filters to help remove the chemicals may be completely ineffective.
- Use of poor-quality backwash water for the UF membranes may result in scaling of the effluent surface of the membranes.

Even when the system outlined in Figure 2 operates steadily, a waste stream still remains and must be disposed. Potential solutions include:

- Deep well injection
- Evaporation pond(s)
- Thermal evaporation/crystallization
- Have the material transported off-site to a waste disposal firm

Any of these techniques may be easier said than done. Deep-well injection and evaporation ponds require environmental evaluations and the required permits before implementation. Permission may not be granted. Also, deep-well injection has its own set of technical issues, including the need to pump the material at high pressure into the well(s) and the possibility of scale formation within the well casing, particularly as temperatures increase deeper underground.

Thermal evaporation/crystallization is a proven technology, but these systems typically require a significant amount of energy, plus they can be labor- and maintenance-intensive. Some plant personnel have thus opted for the last option on the above list and have installed a large-capacity storage tank from which the wastewater can be trucked to a disposal facility.

The upshot of this discussion is that plant personnel are facing tighter restrictions on waste stream discharges (include air in this category) and thus will have to plan accordingly. ■

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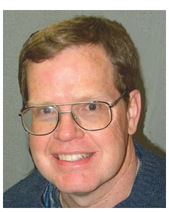

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The Good And Bad Of Wastewater Instrumentation: Pros, Cons, And Opportunities

Instrumentation is heavily pushed to achieve efficiency, but it only works when you use it correctly — and many utilities don't.

By Oliver Grievson

Wastewater instrumentation is set, especially in the U.K., to become more and more important moving forward. As the industry moves to a production mindset and the drive to reduce carbon and improve operational efficiency becomes more and more important, the water industry will be forced to adapt and keep an almost constant "eye" on what is going on. Moving forward, unless a structured approach is taken, there are a lot of pitfalls that the industry faces. This article will attempt to highlight at least a few of those pitfalls that exist.

The first question to ask when installing any instrumentation is "why?" There is always a case to install an instrument, and there is always a case not to. Any instrument has got to tell any wastewater operator something about the way the process is operating. The answer to the question could be regulatory, and it could be operational. In the U.K., the only instrument that is required by the Environmental Permit is a flow monitor, and yet a permitted plant has a lot more instruments than that. For example, dissolved oxygen monitors and power monitors (on efficiency grounds); ammonia and turbidity monitors (compliance grounds); and pressure, flow, and level monitors (operational grounds).

Moving forward, this is set to increase; final effluent monitoring and measurement of product flow through the plant (be it wastewater or sludge) will need to happen. This needs to be tempered and limited, however, to those monitors that cannot only provide "data," but "information," on the process operation. This is, of course, the first pitfall that exists and why the question of "why" needs to be asked. If an instrument is being put in place to monitor data, then the question "What am I going to do with that data?" needs to

CASE STUDY 1:
THE COST OF INSTALLATION

Consider the dilemma: You need to install a flow meter at a treatment plant, and you have a limited space to do it in. What do you do? The options are:

(a) Repair the flume — difficult to do, but not impossible — and keep the old flow meter.

(b) Install a new electromagnetic flow meter at the outfall to the plant where the flow meter is relatively cheap, but comes with some civil installation.

(c) Use a new technology where the meter is expensive, but the installation is relatively simple.

The answer that I chose was (b) as (c) wasn't available at the time and (a) looked to be impractical and expensive.

The result: The total cost was more than $150,000, with the actual flow meter costing less than $5,000. The point of the case study is that, although the instrument was relatively cheap, the installation certainly wasn't, as it involved a large hole and asbestos. The cost of installation needs to be taken into account.

be asked. The U.K. water industry produces something along the lines of 400 million pieces of data every day; 99.999 percent is for nothing, and the industry is drowning in data that it does nothing with.

Once the first question has been asked, the need for an instrument confirmed, and a home for the data decided upon, the next question is, "What do I choose, and how do I get it into place in my treatment plant?" There are numerous companies that sell instruments to the water industry, but the simple answer is that there is the right instrument for the right application. Help is almost at hand with a project by the Global Water Research Council, which is due to set up a website towards the end of the year giving impartial advice on the pros and cons of the different instrumentation types. There are, however, a few things to consider:

A complicated combination of controls can lead to confusion.

- **Type of instrument** — This very much depends upon the accuracy that is needed and the budget that is available.
- **Ease of installation** — Can you install it in your treatment plant with ease, or are major adaptations required?
- **Ease of operation** — How easy is the instrument for the operator on the ground to use? Can it be managed in 10 minutes, or does it need a Ph.D. to operate?
- **Technical specs** — Most modern instruments can provide you with a wealth of data on what it's measuring and how "happy" it is, as well as a wealth of other information. What do you, as a purchaser, actually need/want?
- **Communication** — Do you want an instrument with advanced digital communication, an Internet connection, or a simple analogue connection, or do you want it to read locally with no communication to the outside world?

There is also a second and most important pitfall to consider, and that is the installation of the instrument itself. This is vitally important because an instrument that isn't installed correctly or is installed in such a way that is not maintainable will never work. It will, in fact, cause further damage insofar as it, and instruments in general, are never trusted. This sets up an effect I refer to as "The Resistance to the Effective Use of Instrumentation" (see Case Study 2). There are many forms of this, including:

- A lack of understanding of what an instrument can do and the features of that instrument not used (for example, the power and flow calculations that can form part of a variable speed drive).
- An instrument that is badly installed, either in terms of the way it works or in such a way that it can't be maintained.

- Overdesign of the instrument or the instrumentation system — if there are too many instruments, they won't get maintained.

Presuming the right instrument has been installed and has been checked, the next thing is to operate and maintain it — surely something that the water industry is very used to. However, a system needs to be in place, especially where multiple people look after multiple things at different times. The instrument needs to be captured, tasks need to be put in place, and the right people with the right training need to do the right things. If instruments aren't maintained or the structure they are installed in kept clean, errors creep in and trust is lost. Ultimately, the instrument is lost, and the system fails — or, more dangerously, the instrument and its data are believed, and designs are prepared on the basis of erroneous data.

So What Happens When It Goes Right?

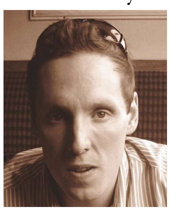
The chances and opportunities are actually endless. The old, often-quoted adage is, "You can't manage what you don't measure." It's especially true in the water industry. A more-or-less continuous measurement is required by the water industry. Instrumentation is the best means to control aspects of the treatment plant and to give operators the right information to manage the plant. It empowers the operators of treatment plant to make informed decisions about how a plant is operating.

This is all very well in theory, but what about the fact?

At the most basic level, dissolved oxygen probes have proved over the years that they are well worth the investment. The modern optical probes are relatively cheap, and with a simple control system and PLC can be used to control the dissolved oxygen in an activated sludge treatment facility at a (near-) constant fixed set-point. This is technology that has been in existence for years. The less commonly used methodology of wastewater instrumentation and control is the simple mixed liquor monitor. It can be used to measure the solids in the lanes to tell an operator if levels are going up on a daily basis (with trend analysis via the PLC/SCADA) or down (allowing decisions to made about wasting rates). At the very least, this gives a more efficient mode of operation, saving time and money in activated sludge process (ASP) control. Done in an automated way, which is the next step, this can control levels with operator supervision only and give a more consistent product in terms of liquid effluent and sludge consistency.

The most modern techniques involve the use of instrumentation for advanced process control, with the data from instrumentation used to drive models that control treatment.

Instrumentation is becoming more and more important in the global water industry as a means to reach the production mindset that the industry is seeking. It also allows for efficiencies in both environmental and financial terms, which seems to be the ultimate goal that the industry is being driven towards. ■



Oliver Grievson is currently the flow compliance & regulatory efficiency manager for the U.K. water company Anglian Water. He also runs the "Water Industry Process Automation & Control Group" (WIPAC) on LinkedIn and is a member of the Wastewater Committee of the Foundation for Water Research. His career has stretched from working in a water laboratory to managing water and wastewater facilities around the world.

CASE STUDY 2:
THE RESISTANCE TO THE EFFECTIVE USE OF INSTRUMENTATION

Exhibit A: There are a plethora of instruments at a treatment plant in the U.K. — all different, all measuring different things, all needing different maintenance. The question for the operator is, "What am I looking at? How do I maintain it?" The answer is that it's too complicated … the system fails.

Exhibit B: A single treatment plant has over 50 dissolved oxygen probes in combination with three activated sludge streams. The task for the operator is to maintain all the dissolved oxygen probes and keep the instruments working effectively. He can't — there are just too many instruments … the system fails.

Exhibit C: A probe is installed in such a way that the operator can't maintain the instrument safely. It's not safe … the system fails.

All three examples lead to a lack of trust in instrumentation. ***The result: a resistance to instrumentation.***

A New Way To Desalinate – Government Tested, Real-World Approved

Developed by the Department of Defense, capacitive deionization (CDI) removes salt from water, while conventional methods remove water from salt.

By Patrick Curran

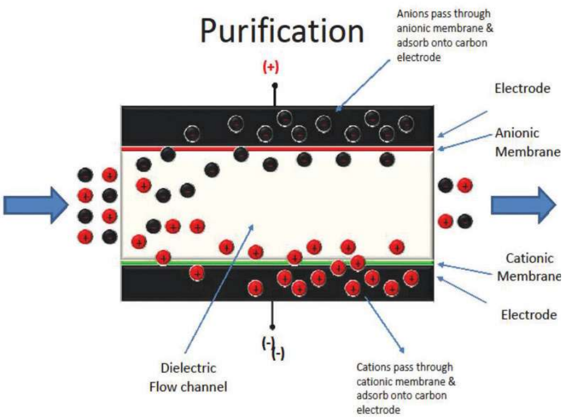
What is easier, removing 96.5 parts of something from 3.5 parts of something else or removing 3.5 parts of something from 96.5 parts of something else? All else being equal, of course it is easier to remove the lesser component from the larger. But that is not how most water desalination technologies work today. Reverse osmosis (RO) and vacuum distillation (VD) all work by removing the water from the salt water. So, how can you remove salt from water?

CDI is another example of a technology that was developed for one purpose, but found other market segments where its advantages were greater than expected.

Removing ions from solution with an electric field is a well-known method to desalinate water, and electrodialysis is a popular example. Because ions are disassociated in solution (Na+ separate from Cl-), they can move independently of one another and can be pulled towards an oppositely charged plate. Removing ions from solution as it is done with electrodialysis (ED) can be a much easier way to desalinate water versus the standard reverse osmosis or brine concentrator method of removing water from the salt water.

When the ions are removed as in ED, they must be paired up with an oppositely charged ion supplied by another flow channel within the device or the splitting of water. This pairing causes device, energy, and mass balance issues and limits the effective range of ED to a maximum of 8,000 ppm and typical range of 1,200 ppm, per the Colorado School of Mines' *Technical Assessment of Produced Water Treatment Technologies* (November 2009, pages 35-37). Also described in the report, the energy consumption is very large and capital cost per gpm higher than state-of-the-art alternatives.

CDI also removes ions from water with an electric field (see diagram below). As ions pass through the charge-specific membrane, they adsorb onto the surface of a high-surface-area carbon supercapacitor instead of pairing up with oppositely charged ions. Because of this, anions and cations are kept separate during the purification cycle. This enables CDI to remove low solubility species without fouling because the cations and anions are physically separated.



After the supercapacitor fills with ions, the polarity is switched, and the ions are pushed back into the original flow channel. Water flow is stopped, and the concentration of ions builds to more than 10X the incoming solution. Because the electric field is now opposite, the ions attempt to adsorb onto the newly charged electrode. But because of the charge-specific membranes, they are prevented from passing through and readsorbing.

Although they reside in the same small space, the electric field minimizes mixing of the anions and cations, preventing any significant precipitation. After all of the ions have been discharged, they are removed from the device, and the cycle repeats itself. By concentrating in this fashion, the recovery

Removing ions from solution as it is done with electrodialysis can be a much easier way to desalinate water versus the standard reverse osmosis or brine concentrator method.

of clean water can be as high as 95 percent. This is extremely beneficial in industries such as oil and gas that have wastewater disposal volume concerns.

By using capacitors to capture the ions instead of another flow channel, the device construction costs and energy usage are much lower. And because the flux rates (moles/min/cm2 membrane) are significantly higher, a given device can process a much higher inlet of total dissolved solids (TDS). The latest system designs for 8,000 to 10,000 ppm applications have capital costs less than 1/3 that of ED. The cost of ownership (energy, maintenance, depreciation, and disposal) is up to 70 percent less than the leading state-of-the-art technology for that particular TDS range.

The latest CDI devices can process up to and greater than 150,000 ppm of water including water with over 50,000 ppm of hardness and low solubility species such as barium(Ba)/strontium(Sr)/calcium(Ca) sulfates and calcium carbonates. Because any dissolved ions can be removed, it is also effective at removing low concentrations of heavy metals such as mercury, arsenic, selenium, uranium, etc.

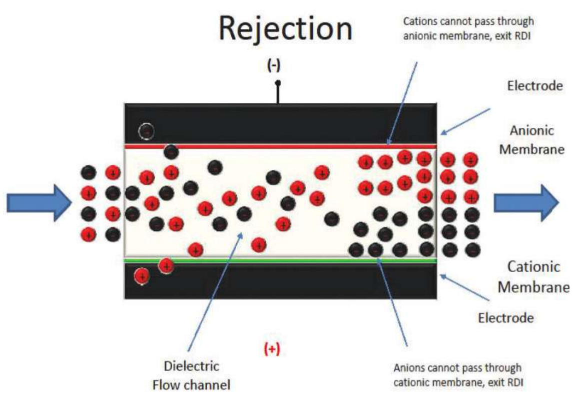
Because of the ability to process complicated high TDS waters, CDI is making inroads into industries with very difficult, highly saline waters such as oil/gas produced water, frack water, mining wastewater, flue gas desulfurization (FGD)/cooling tower blowdown, and other industrial wastewaters. This is very helpful when treating water for discharge with stringent limits such as power and greenhouse industries. In some cases, the concentrated solution is the desired product. CDI can concentrate a solution to recover high-value metals, salts, acids, and bases.

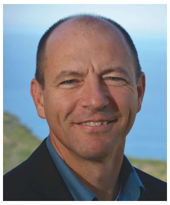
The system basis is the grouping together of large supercapacitors, similar to how RO tubes are organized. This positions CDI to be able to build high-capacity systems simply by duplicating the supercapacitors.

Pretreatment is very important for any membrane process, including CDI. The requirements for total suspended solids (TSS), organics, and iron are very similar to RO and ED due to the very thin flow channels and fouling nature of organics and ferric iron. But because of CDI's ability to capture and remove low solubility salts safely, no antiscaling chemicals are needed.

The origin of most current CDI devices is from a DARPA project from the DoD back in 2000-2004 to develop an alternative to desalination systems used to supply troops with fresh water. CDI is another example of a technology that was developed for one purpose, but found other market segments where its advantages were greater than expected.

As system design and material properties continue to improve, the economics and performance capabilities of the CDI system will continue to improve and likely surpass all existing technologies in performance. These systems are starting to penetrate various markets and will continue to make inroads over the next decade. ■





Patrick Curran, CEO and founder of Atlantis Technologies, has led the development and commercialization of many novel processes and products over his 25-year career, garnering seven issued and pending patents. He has a B.S. in chemical engineering from Drexel University.

Ultrasonic Sludge Disintegration: A 'Bubbly' Solution For Anaerobic Digestion Or BNR

'Sonicating' sludge proves to be a sound method for handling biosolids.

By Bryen Woo and James Goldhardt

One of the ongoing challenges in wastewater treatment facilities is the handling of biosolids. It has been found that the total biosolids generation continues to increase each year. In fact, the processing, treatment, and disposal of sludge for beneficial use accounts for approximately 40 to 60 percent of the total wastewater treatment plant (WWTP) expenditures. These expenditures can certainly add up over the life of a wastewater treatment plant; therefore, it is important when designing a wastewater treatment plant to have an efficient and effectively operated solids handling system. Ultrasonic sludge disintegration, by way of ultrasound, is a proven method to help mitigate this very issue.

Ultrasonic sludge disintegration is a prime application for improving the anaerobic digestion process and for biological nutrient removal (BNR) processes.

Ultrasound And The Ultrasonic Sludge Disintegration

Sound travels in waves and generates acoustic energy. The human audible frequency range is between 20 Hz and 20 kHz; anything above that is referred to as ultrasound. A sound wave, at any given frequency, has a minimum and maximum point referred to as rarefaction and compression. During the rarefaction stage, particles move away from each other into lower-density areas to create a lower pressure. In the compression stage, particles move together into high-density areas to create a higher pressure (or the opposite of rarefaction).

By way of ultrasound, acoustic cavitation can be created. When sonicating liquids (applying acoustic energy to agitate particles), the sound waves alternate between compression and rarefaction cycles, where small voids are created in the liquid, creating microbubbles. As shown in Figure 1, the bubbles will grow until they attain a volume at which they can no longer absorb any energy. At that state, the bubbles implode violently (during the compression cycle). This implosion is referred to as cavitation and, in liquids, produces an enormous amount of energy. It is estimated that these bubbles (from cavitation) have temperatures as hot as 8,900 degrees F and pressures as high as 7,250 psi.

Ultrasonic sludge disintegration uses acoustic cavitation as a means to provide the necessary physical and chemical changes in order to rupture the cell walls of sludge microorganisms. Ultrasonic energy is very effective primarily because the compression of the bubbles during cavitation is more rapid than thermal transport, allowing for a localized "hot spot" to be created. The localized hot spot allows for sludge disintegration to occur easily, as it only takes approximately 100 microseconds for cavitation to occur and less than 400 microseconds for microorganism cell walls to rupture.

Ultrasonic sludge disintegration is a prime application for improving the anaerobic digestion process and for biological nutrient removal (BNR) processes. A typical ultrasonic reactor consists of a 5-kW control power supply producing ultrasonic energy and an oscillating unit consisting of a transducer, booster, and horn that is positioned within the contacting reactor, applying ultrasonic energy to the feed sludge.

Certain criteria are needed for optimizing the ultrasonic reactor, one of which is the feed sludge type. Since primary

Figure 1: Acoustic cavitation

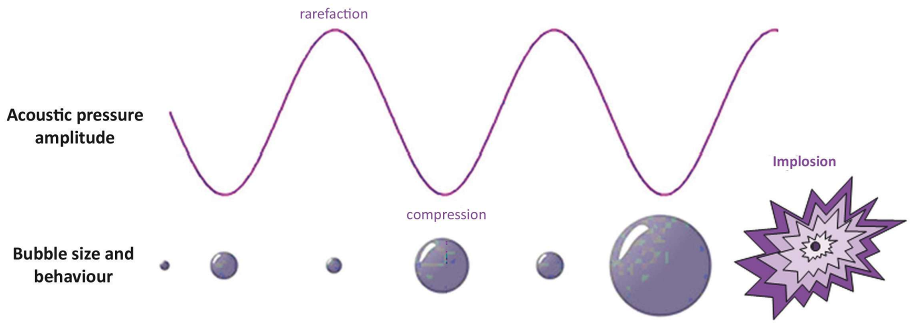
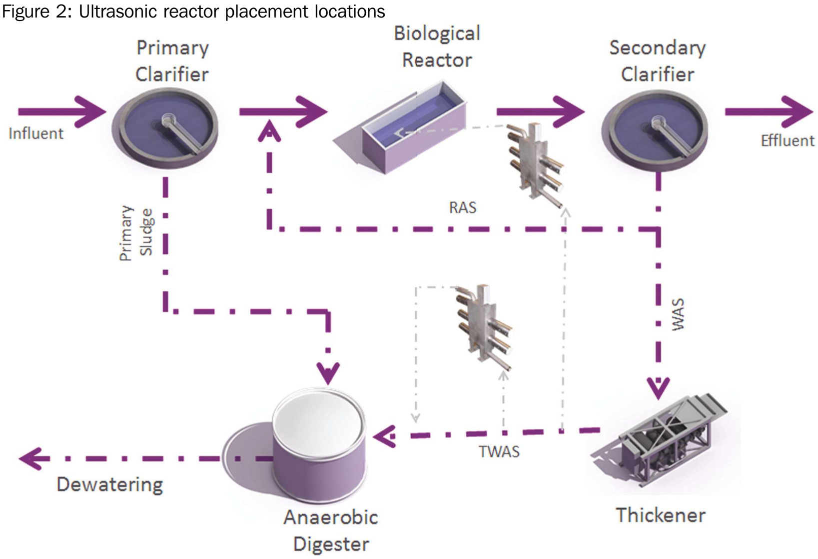


Figure 2: Ultrasonic reactor placement locations



waste is highly degradable, it is recommended that only the thickened waste active sludge (TWAS) be treated. The TWAS being treated should be in the range of 30,000 to 60,000 mg/L solids concentration. A thicker solids content optimizes the effectiveness of the reactor because water in sludge acts as a barrier from the ultrasound, minimizing the effectiveness of the acoustic cavitation. Sludge with minimal water content will cause rupturing of the microorganisms more effectively. Figure 2 shows the optimal locations (as described above) for placing the ultrasonic reactor in a wastewater treatment process. The ultrasonic reactor can be placed in either of the two locations; however, they can also be used in both.

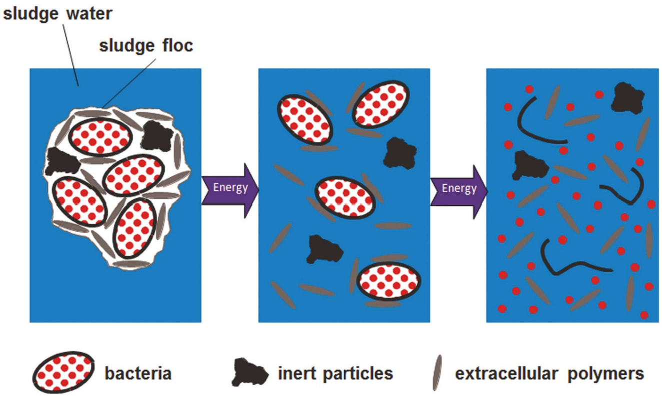
Ultrasonic Disintegration In Anaerobic Digestion Applications

Providing pretreatment with the ultrasonic reactor prior to the anaerobic digestion process provides several benefits, including 15 to 30 percent improved methane gas production, increased volatile solids destruction (resulting in reduced sludge disposal costs and/or reduced tank sizes and retention times), viscosity reduction, foaming control, and even improved dewatering.

There are four stages of the anaerobic digestion process, and it is well-known that the first stage, hydrolysis (complex organic matter to soluble organic molecules), is the rate-limiting step and, therefore, should this stage be altered or "boosted," the anaerobic digestion process is able to be improved. Ultrasonic disintegration not only breaks the sludge floc apart, but with the appropriate dose, the microorganism cell walls are ruptured, providing easy access to the intercellular material (see Figure 3 on the next page).

The cell lysis created by the ultrasonic reactor has been shown to change the reaction kinetics of the anaerobic digested sludge. The process allows for improved volatile solids (VS) reduction, which in turn correlates to an increased gas production. Because of the change in the reaction kinetics, the hydraulic retention time (HRT) is also altered, allowing for more capacity in the digester tank. One study comparing treated and nontreated sludge found that the VS destruction with a four-day HRT on a treated sample had the same VS destruction on a nontreated sample with a 16-day HRT.

Figure 3: Ultrasonic sludge disintegration



Ultrasonic sludge disintegration is an excellent application for anaerobic digesters that have a short HRT (overloaded), low VS destruction, or even low gas production. Utilizing the ultrasonic reactor is an excellent way to help "supercharge" an anaerobic digester.

Anaerobic Digestion Application Case Study: Bamberg WWTP, Germany

The Bamberg WWTP is a traditional activated sludge plant having a 12-MGD design capacity, but was actually being loaded around 15 MGD, equating to an 18-day digestion time in the anaerobic digesters. The plant selected to use ultrasonic sludge disintegration to pretreat the sludge prior to entering the digester. The ultrasonic reactor was tested to determine if the technology could be used in lieu of building a new digester.

Results: The ultrasonic reactor was tested for a four-month period where 30 percent of the TWAS flow was treated (as shown as one of the placement locations in Figure 2, going from the TWAS to the digester). After the testing period, the data showed the following:

- Improved VS destruction from 42 to 54 percent
- Digested sludge VS reduced from 60 percent (as percent of total solids) to 54 percent
- Biogas production increase by 30 percent

Due to the successful testing, the plant elected to keep the ultrasonic reactor and avoided the construction of a new digester.

Ultrasonic Sludge Disintegration In BNR Applications

In order to achieve complete nitrogen removal, the denitrification process must occur. Denitrification is the biological reduction of nitrate (NO3) into nitrogen gas by facultative heterotrophic microorganisms. There are three items required to achieve denitrification: 1) heterotrophic bacteria; 2) nitrate, which is used as an energy source by the microorganisms to metabolize and oxidize organic matter; and 3) organic matter, which serves as a food source for the heterotrophic bacteria to survive.

Carbon requirements are a very important aspect of the denitrification process. As a rule of thumb, a 6:1 carbon-to-nitrogen ratio is required to achieve complete nitrogen removal. Many wastewater treatment facilities find maintaining this ratio can be problematic, especially ones with solids handling processes that recycle excessive nitrogen back to the liquid treatment processes, which causes depletion of the carbon-to-nitrogen ratio. There are up to 200 wastewater treatment facilities in the U.S. that add methanol to achieve denitrification. Although the addition of methanol is common and relatively inexpensive, there are disadvantages such as increases in sludge loads and disposal costs, fluctuating prices (typically $1.50 to $3.50 per gallon), since most of it is imported, and dangerous handling, since methanol is flammable.

Ultrasonic sludge disintegration is an excellent application for any wastewater treatment facilities that have BNR processes that are adding external carbon sources such as methanol or MicroC™ to achieve the denitrification process for complete nitrogen removal. Ultrasonic pretreatment technology causes the cell walls of microorganisms to rupture, which allows their cellular material to be available as an additional source of organic matter. Ultrasonic pretreatment technology provides an internal carbon source and prevents the addition of external carbon sources. There is substantial operating cost savings by preventing the addition of an external carbon source. It requires approximately 3.5 pounds of methanol to remove 1 pound of nitrogen. For example, a 5-MGD wastewater treatment facility will spend approximately $80,000 annually on methanol addition for every 10 mg/L of nitrogen (420 pounds/day of nitrogen) that needs to be removed, and this assumes a methanol cost of $1 per gallon.

BNR Application Case Study: Datansha WWTP, Guangzhou, China

The Datansha WWTP in Guangzhou, China, operates a conventional activated sludge process where they added methanol to achieve denitrification. In order to eliminate methanol addition, Datansha WWTP added an ultrasonic reactor downstream from the sludge thickener (as shown as one of the placement locations in Figure 2, going from the TWAS to the biological reactor).

After the sludge passes through the ultrasonic reactor, it is fed into the bio-tanks of the activated sludge process and used as a carbon source to achieve denitrification. In comparison to methanol addition, by using the ultrasonic reactor at Datansha WWTP, there was a 20 to 30 percent increase in nitrogen removal, 80 percent cost savings, and sludge minimization of 15 percent. ■

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James Goldhardt has been working for Ovivo for over five years and is the anaerobic digestion group manager. He attended the University of Utah and graduated in mechanical engineering.

Filamentous Bacteria Controlled: A Quick And Easy Solution

The City of Kalispell used ingenuity, and just a few inexpensive parts, to solve a problem common to biological nutrient removal facilities.

By Rebecca Bodnar

Filamentous foaming bacteria: the nuisance of many biological nutrient removal (BNR) wastewater treatment plants. Although filamentous microorganisms are a natural part of the biomass in plants and are the backbone of floc formation and settling, the overproliferation of filamentous microorganisms causes the sludge to float (foaming) and causes problems with nitrification and phosphorus removal, aesthetics, poor settling, and the formation of high-sludge blankets. Left unresolved, filamentous bacteria can reduce clarifier capacity, cause digester foaming, and carry over to effluent. The City of Kalispell (MT) Advanced Wastewater Treatment Plant (WWTP) upgraded in 2007 to a Modified Johannesburg configuration for phosphorus and nitrogen removal. Seasonally in spring, filamentous bacteria growth consistently rises sharply and becomes a problem in the aeration basins. A huge amount of floating sludge accumulates in the tanks, and removal of the floating layer is a serious problem.

Left unresolved, filamentous bacteria can reduce clarifier capacity, cause digester foaming, and carry over to effluent.

Tried, Not True

Three filamentous organisms can cause activated sludge foaming: *Nocardia sp.* (most common), *Microthrix parvicella* (less common), and *Type 1863* (rare).[1,2] The more common foam-causing filaments, *Nocardia* and *M. parvicella*, both favor BNR plant characteristics: long solids retention times (SRTs), alternating aerated/nonaerated zones, foam-trapping environments, and fatty acids as a food source. Many control measures exist, including eliminating food sources, lower SRT, and surface wasting. These measures all have drawbacks. Eliminating the food source, fatty acids, is difficult to accomplish while maintaining phosphorus removal; lowering the SRT reduces sludge-handling capability and interferes with both phosphorus and nitrogen removal; and surface wasting can be labor-intensive. During the overproliferation of the filaments, the Kalispell WWTP operators employed these methods, but the foam continued to accumulate.

Simple methods resolved sludge foaming at the Kalispell WWTP, pictured here.

Ingenuity To The Rescue

Chlorine and hydrogen peroxide have been used successfully to selectively kill filamentous bacteria.[3] Chlorine is the most widely used toxicant, as it is relatively inexpensive and readily available. A highly concentrated chlorine solution (0.5 to 1.0 percent) has been shown to be successful.[4] A Kalispell WWTP operator, Aaron Losing, brainstormed an idea to utilize an existing spray system to efficiently and cost-effectively spray the foam with chlorine. During the plant's original construction in 1992, the engineering staff foresaw the potential for foaming and equipped each individual biocell in the plant bioreactor with a spray bar across the width of the cell. The plant utilizes nonpotable effluent to physically move or push the foam out the biocells and into a collection channel at the end of the bioreactor for surface wasting. This system worked well until the plant was upgraded in 2007 to the current configuration. After 2007, the system did not remove enough of the filamentous microorganisms, and the removal process became increasingly labor-intensive. However, the existing spray bar system created an excellent starting point for the addition of chlorine spray for foam control.

Three-inch chlorinating dosing tablets (found at pool maintenance stores) are

At the end of the aerated zone of the biological reactor, foam can be seen accumulating throughout the tank, especially at the outlet.

inserted into a perforated 3-inch PVC pipe fitted with a perforated plastic shower drain at the bottom to form a basket. The basket is inserted into the top of a 4-inch PVC pipe and is plumbed into the spray-bar system to mix in-line with nonpotable water.

Within three days, without change in weather, SRT, etc., there was a noticeable difference.

The amount of chlorine tablets used (dosage rate) is dependent on weather and plant conditions. Dosing begins immediately upon any visual indication of foaming. Dosage is easily regulated by controlling the outlet valve of the mechanism. The initial cost of the device was $225. The monthly expense of this system has averaged $95.

In conclusion, filamentous foaming is an operating problem associated with BNR facilities. Through operator ingenuity, and using an established system, the Kalispell WWTP was able to control its foaming problem efficiently and inexpensively. ■

1. Jenkins, D.; Richard, M.; Daigger, G.T. (1993) *Manual on the Causes and Control of Activated Sludge Bulking and Foaming*, 2nd ed.; Lewis Publishes: Chelsea, Michigan.
2. Richard, M. (1989) *Activated Sludge Microbiology*. Water Pollution Control Federation: Alexandria, Virginia.
3. Wanner, J. (1994) *Activated Sludge Bulking and Foaming Control*. Technomic Publishing: Pennsylvania.
4. Water Environment Federation and the American Society of Civil Engineers/ Environmental and Water Resources Institute (2006) *Biological Nutrient Removal (BNR) Operation in Wastewater Treatment Plants*; Alexandria, Virginia.

Rebecca J. Bodnar's background is in environmental science and geochemistry. She is the City of Kalispell's chemist and industrial pretreatment coordinator. Bodnar works at Kalispell's Advanced Wastewater Treatment Plant and for five years has assisted in plant operation and protecting Montana's water resources.

Coming Clean With The Environment

With population and energy costs rising, Long Island wastewater treatment plants figured out a cost-effective way to control pollution and conserve resources.

By Jon Richens

Long Island is a long, slender island, located directly east of Manhattan in the southern tip of New York State. In the 20th century, the north shore of Long Island earned the nickname of "Gold Coast" and attracted large private estates of the likes of the Vanderbilts, Roosevelts, Whitneys, Charles Pratt, J.P. Morgan, F.W. Woolworth, and others. The western end of the island includes Brooklyn and Queens, while the eastern tip includes the famous Hamptons.

Long Island has always been the getaway place for the rich and famous of New York. The beautiful vistas of the north shore, white sandy beaches of the outer barrier islands, and world-class fishing attract people from all over the state. As more and more people take on a longer commute in exchange for a home outside the congested cities, the population continues to increase. Long Island has moved up to be the most-populated island in the U.S., and the 17th most-populous island in the world.

With the explosion of the population, public utilities have needed to be upgraded and/or replaced. Many of the more obvious utilities were improved to support the growth. However, with any increases in population, the waste load that a given environment can absorb may be tested and, in many cases, overloaded. In an effort to protect the public, beaches, local aquatic life, and the groundwater of Long Island, the local environmental agencies and Suffolk County worked together to develop new discharge standards for local wastewater treatment plants.

Due to the growing population in the region, resources were being consumed at an ever-increasing rate. The price of electricity, in particular, climbed significantly — its demand growing faster than its supply. In an effort to find new technologies to help in the conservation of resources and energy, the state of New York implemented the New York State Energy Research and Development Authority (NYSERDA). The role of NYSERDA was to provide support to groups, through grant funding, for the purpose of testing, as well as the full-scale implementation of new energy-saving technologies. NYSERDA joined forces with the New York State Environmental Facilities Corporation (EFC) to help upgrade local wastewater treatment plants with energy-efficient technologies that could meet the more-stringent effluent limits.

Today, the plant is achieving high-quality effluent with total nitrogen averaging around 3 mg/L.

Pilot Program

In early 2002, a local Long Island newspaper company was in need of a wastewater treatment technology that could efficiently and cost-effectively treat their waste stream to the levels required for subsurface discharge. Their existing activated sludge system, followed by a denitrification filter, was struggling to meet the required effluent. The waste stream was made up of a combination of sewage, biodegradable inks, solvents, and cleaners from the printing process. In 2003, the company, in conjunction with NYSERDA, entered into the testing phase of a combined fixed-film and activated sludge process from WesTech Engineering. This technology — the STM-Aerotor — could be easily retrofitted into the existing aeration basins with minimal modifications to the structures. Following a six-month pilot program, the technology was deemed feasible for saving energy and providing complete nitrification and denitrification for this difficult waste stream. Today, the completed plant includes an anoxic zone, STM-Aerotors, and membranes.

A close view of the combined fixed-film and activated sludge process in action.

Municipal Application

Even before the above treatment plant was beginning its testing phase, the Village of Greenport, on the northeast tip of Long Island,

Due to the growing population in the region, resources were being consumed at an ever-increasing rate.

The technology can be retrofitted into existing aeration basins, as seen here.

was evaluating technologies to prepare for the upcoming total nitrogen limit of 5 mg/L that it would be required to meet. Greenport is a tourist town with high seasonal fluctuations in population. For many years, Greenport utilized aerated lagoons followed by secondary clarification. Knowing that new technology would be needed to meet the new limits, and with money being an issue, the Village of Greenport was able to secure NYSERDA funding for the pilot testing of the STM-Aerotor. Following a successful pilot, a full-scale plant was installed in 2010. Today, the plant is achieving high-quality effluent with total nitrogen averaging around 3 mg/L. Moreover, the new system is using 30 percent less energy than a comparable conventional activated sludge or sequencing batch reactor (SBR) system.

While the above plants were in the midst of the testing and design work for their facilities, the Village of Patchogue was in a similar predicament regarding upcoming effluent limits and the need to find a cost-effective solution. The mayor of the Village of Patchogue was a big driver in pushing for improvements to the effluent quality of the sewage treatment plant in an effort to protect the Patchogue River and Great South Bay. Knowing that the Village of Patchogue's rotating biological contactor (RBC) treatment system would not achieve the required effluent, the village worked to find a suitable treatment process that would be simple to operate, would achieve the required level of quality, and would not have a high operating expense over the life of the system. Following their evaluation of various technologies, the STM-Aerotor was selected based on its simplicity, treatment capabilities, and cost-effectiveness. Moreover, the existing site was fairly tight, and the compactness of the process allowed for the construction of the system into a tight footprint, which allowed the reuse of other unit processes of the existing facility. The STM-Aerotors were put into service in May of 2011. Through the care and effort of the operations staff, the Patchogue wastewater treatment plant achieves biochemical oxygen demand (BOD) and total suspended solids (TSS) levels of less than 10 mg/L and effluent total nitrogen around 3 mg/L. ■

Jon Richens is a senior process engineer at WesTech Engineering, where he has worked for the past 16 years. He has a Bachelor of Engineering degree from the University of Utah and is a registered professional engineer. Richens specializes in the design, application, and optimization of biological treatment systems.

Seeing Through The FOG (Fats, Oils, And Grease)

A review of different methods and devices for FOG removal, with emphasis on cost control, lowered power profiles, and efficacy

By Douglas D. Sunday and Dr. J.H.Wakefield

FOG deposits are the bane of the wastewater industry, affecting both the collection and treatment functions. Over the years, there have been many attempts to "get a handle" on this problem, and there have been many different ways proposed in these efforts. Let us examine one of the latest that is proving to be successful.

To begin with, we should understand both the chemical and physical identity of what actually comprises FOG deposits. They are an unholy "gemisch" of various lipids of widely different chemical and physical behaviors. They vary from oils (which are in liquid form) to greases (which may be solid or semisolid, depending on their chemical identities), to fats (which are usually solids, though they too may exhibit liquid or semisolid form), as well as waxes (which are almost always solids). They also can contain compounds that are lipid-soluble, such as steroids, various pharmaceutical agents, and even organic solvents.


A look into FOG: fats, oils, and grease accumulation

Currently, the most successful removal method involves the breaking down of these FOG deposits into microparticulates. These engendered microparticulates may be emulsoids (usually oils in a liquid suspension), or they may be solids, which exhibit very small sizes. As a consequence of these small sizes, the surface area is increased dramatically, and chemical reactions, which are slow to nonexistent with larger particles, can be of great importance in the degradation of these really small particles. This is particularly evident in the microbiological degradation of these FOG compounds.

We all know that increased surface area, per se, virtually always results in increased reactivity. What we tend to dismiss is that the actual physical configuration of these compounds and the particulate characteristics also attribute mightily to the chemical activity. For example, it is well-known that saturated fats are much harder to degrade microbially than unsaturated or polyunsaturated fats. Why this is the case resides in both the chemical sites of attack by different microbial enzymes involved, as well as how these enzymes are able to operate on these differing sites.

It is analogous to comparing the surface of a lamellar structure (such as graphite or a composite material) to a piece of steel wool. The graphite surface presents few active sites for an enzyme to attach to, whereas a tortuous surface, such as steel wool, provides many such attachment sites for an enzyme to take advantage of. In a similar (or analogous) manner, saturated fats present a very limited opportunity for enzymatic degradation, as opposed to that found in both unsaturated and polyunsaturated fats.

An Alternative Solution

A new class of digesters has been designed to modify the substrates (e.g. FOG deposits) by converting them into microparticulate surfaces in which the microbial enzymes find ready access to these hard-to-breakdown compounds or molecules. At the same time, these digester devices are providing extreme turbulence (to facilitate collisions and subsequent attachment) for the benefit of these degrading microorganisms to "work their magic" and feeding them a most digestible diet of nutrient-rich particulates delivered in an oxygen-rich environment. Although it is well to remain mindful of general principles, in the real world of waste treatment, success or failure depends on how well the system is engineered to deliver these considerations in a practical manner.

These particulates are so small and fissured that they provide a ready carbon source to the many microorganisms within the waste stream and sludge.

In this case, criteria were carefully taken into account to ensure that the final design was practical in every sense to address the everyday problems encountered in the removal of FOG deposits. The actual sites of deployment of these devices were to be grease traps and lift stations, but other sites might be used from time to time — especially wastewater treatment facilities. To these ends, designers determined that the most important criteria to address were sizing with respect to air/wastewater movement and aeration; operational costs with respect to maintenance, parts replacement, and accessibility; and operator safety with respect to change-out, cleaning, and electrical issues.

This particular technology, developed by DO2E, is unique from several perspectives: There are no moving parts (they are all essentially modified air-lift devices); they are constructed of high-grade, noncorrosive material; and the electrical systems employed, as well as the blower systems, are removed from the "business end" of the devices for improved safety.

Internal configuration of 2-HP digester control cabinet

They operate from a remote blower that provides high-volume, low-pressure air through a central manifold containing a multitude of air outlet orifices of specific sizing that enables a maximum air-lift effect and an air-exchange aeration (oxygenation) effect as well. The Venturi effect formed draws wastewater and its fluid column through inlet orifices, which are quite large. As the fluid is accelerated up this pathway, entrained solids are impacted at high velocity against fixed concentric edges and blades at the top of the device and thereby broken down into much smaller fragments. This mixture is repeatedly recirculated as the fragmentation results in ever smaller particles being realized.

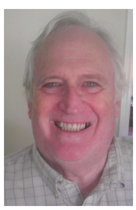
These particulates are so small and fissured that they provide a ready carbon source to the many microorganisms within the waste stream and sludge. This is why these devices are so efficacious in destroying FOG deposits and preventing their reformation.

Data have been collected showing that these FOG deposits do not re-form, even in force mains that are miles long. Simple experiments can readily affirm this, but municipalities must rely on actual results from the field for their decision makers in this regard. A primary design objective has been to make these devices as efficient as possible, and to that end the designers have provided a three-phase power capability with the larger units, as well as providing specific units for differing voltages (115V, 240V, 480V, 600V) and differing frequencies (50 Hz or 60 Hz), so that these units may be used in different electrical systems worldwide. Other specialized requirements may also be fabricated as necessary for a particular application.

The actual impact on most wastewater collection and treatment systems is that the use of these digesters expands the functions of the collection system as a pretreatment component of the entire wastewater treatment system. This occurs as a result of lowering the BOD (biochemical oxygen demand)/COD (chemical oxygen demand) challenge to the waste treatment facility, as well as by changing the operational influent flow to assist in the elimination of blankets and rafts of paper products that are a major problem of FOG buildups. This, in fact, reduces the loading on influent screening requirements and subsequent buildups on any of the aeration diffusers employed in the waste treatment plant.

The technology provided by these digesters enables both the operational personnel as well as the design engineers to practically eliminate the impact of FOG deposits on operations. And all of this is "on the cheap." ■

Douglas D. Sunday is an experienced water and wastewater Class A operator in Florida for the past 40 years.



Dr. J.H. Wakefield has been a consulting analytic chemist and environmental/materials engineer for more than 30 years.

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