using a suitable heat exchanger.

One range of heat exchangers that is proving popular with wastewater AD operators around the world is the DTI series from HRS Heat Exchangers, which is a double tube heat exchanger. The inner tube is corrugated to ensure improved heat transfer performance and superior resistance against tube wall fouling, resulting in reduced maintenance periods. Additionally, the tube-in-tube design permits the processing of fluids with particles without any tube blockage, making it particularly suited to sewage AD plants.

For example, using heat exchangers to pasteurize digestate – the biofertilizer left over at the end of the AD process – is more efficient than using tanks with heating jackets since heat exchangers have a much lower heat requirement, as much as half of that of some other systems. This result is due to the fact that tank systems have lower heat transfer efficiency and usually dump the hot water after use, rather than reclaiming it. Using heat exchangers means that effective digestate pasteurization is possible using surplus heat, rather than needing to install an additional heat source such as a biomass boiler, which could add hundreds of thousands of pounds to a project. The right system can also provide a continuous pasteurization process (see sidebar), using less energy than alternative systems while allowing additional thermal regeneration, or recovery, levels of up to 60 percent. This saved heat can then be used elsewhere, such as at an evaporation plant.

Improved digestate

Heat can also be used to separate water from digestate by concentration. This technique can reduce the overall quantity of digestate by as much as 80 percent, greatly lowering the transport costs associated with the removal of digestate. A well-designed system, such as HRS Heat Exchangers' Digestate Concentration System (DCS), will include measures to retain the valuable nutrients in the digestate while the evaporated water can be condensed and reused. For example, the captured water can be added back to the feedstock as it enters the digester, making the entire process almost self-sufficient in terms of water use and eliminating liquid discharges from the plant. After concentration, the treated digestate dry solid content can be as much as 20 percent (often a fourfold improvement), making it much easier to transport and handle.

A well-designed system could recover and use 40 percent of the heat produced by a wastewater AD plant. This surplus heat source could significantly improve the cost efficiency of water resource recovery facilities – and surely municipalities could benefit from reduced costs or even additional revenues.

Author's Note

Matt Hale is international sales and marketing director at HRS Heat Exchangers, located in Phoenix, Arizona, and Atlanta, Georgia, United States (US). HRS specializes in thermal technology and offers heat transfer solutions in a variety of industries. The company operates through a global network of offices: Australia, India, Malaysia, Spain, and US; with manufacturing facilities in the United Kingdom, India, and Spain.

Malt producer's treatment process recovers power, fertilizer

Malt producer Muntons uses technology from HRS Heat Exchangers at their production plant at Stowmarket, England, to help treat 88,000 tons of liquid a year, generating a quarter of the electricity used by the plant and producing a high-quality biofertilizer, which can be used to grow barley for the production of malt.

Following both aerobic and anaerobic treatment, the effluent is treated in a 3-tank HRS Digestate Pasteurization System. By pasteurizing one tank, while one is being emptied and the third filled, continuous operation is achieved. Waste cooling water from the CHP engine is used to heat the sludge in corrugated tube-in-tube heat exchangers, which is more efficient than heating an entire tank of digestate. HRS has also incorporated an energy recovery section into the process to make it even more efficient: energy is transferred from the hotter (pasteurized) sludge to the colder (unpasteurized) sludge, reducing energy consumption by up to 70 percent compared to conventional systems andusing heat which would otherwise be wasted.

This pasteurization process means that the digestate from the treatment plant is free from plant pathogens, so local farmers can use it as fertilizer.

DNA analysis shows healthier methanogen populations, more biogas

Energy recovery from wastewater treatment biological process is gaining momentum as facility operators realize the operational and financial benefits. A partnership formed by US companies ThinkR3 LLC and Energenecs offers diagnostic and technical assistance in increasing biogas yields and additional revenue. *World Water* Editor-In-Chief Pamela Wolfe reports.

More water resource recovery facilities are using DNA sequencing to analyze and optimize wastewater treatment biological processes, including those in anaerobic digesters and biological nutrient removal systems. Consequently, there is a growing demand for technical advice and solutions to convert DNA-based insights into action – particularly given the expanding renewable energy market, according to CEO John Tillotson of ThinkR3 LLC.

For this reason, Tillotson says the company is partnering with Energenecs, which provides onsite support for Microbe Detectives' DNA diagnostic services. ThinkR3 LLC was formerly known as Microbe Detectives LLC, which pioneered the application of next-generation DNA sequencing in the wastewater industry. ThinkR3 uses the Microbe Detectives brand for its DNA diagnostic services. The company is based in Downers Grove, Illinois, United States (US).

Renewable energy

Tillotson says the emerging market for biogas – referred to as Renewable Natural Gas (RNG) – repre-

sents a strategic opportunity to advance energy independence. He cites that in 2011 the American Gas Foundation (AGF) found that RNG could meet the natural gas needs of half of all American homes. The American Biogas Council estimates that untapped biogas opportunities in the US have the potential to power 7.5 million homes while removing approximately 15.4 million passenger vehicles from roads. Currently, nearly 2,200 water resource recovery facilities with anaerobic digesters produce biogas in 50 US states. Approximately 13,200 more facilities in the US are ripe for development. Worldwide, biogas anaerobic digesters are used in wastewater and landfill systems to create renewable energy.

Fortunately, a growing awareness of resource recovery in the wastewater sector, including facility operators, is helping to advance these opportunities. Tillotson says this shift reflects the gradual transition in the past decade regarding wastewater treatment from being a "cost of operation" model to a "revenue-producing asset" model. Clearly, the latter view recognizes the significant financial opportunities for improved public services and investment returns, he adds.

Microbiome analysis

DNA diagnostics are still an early phase of digester optimization. Microbe Detectives' DNA methods are used to identify and quantify nearly 100 percent of all bacteria and archaea in a digester sample in a single test. In contrast, Tillotson says, "Very few facilities operators do any sort of biological analysis of their anaerobic digesters because of the severe limitations of other currently available test methods. Field microscopes are the most common biological analysis method at wastewater facilities. Although they are valuable tools, they cannot see 99 percent or more of the bio population."

Targeting the relevant microbiome data, however, is essential to avoid producing overwhelming and useless information to municipal operations staff. Tillotson explains that data should be specialized on what is important to know about the digesters' ecology. "For example, methanogens are the category of microbes that produce methane (CH_4)," he says. "Microbe Detectives' DNA methods identify and quantify all known methanogens in a single test. Why is this important? The more healthy and thriving the methanogens, the more biogas. So measuring methanogen populations can serve as a Key Performance Indicator (KPI) of biogas production."

Tillotson adds, "We also measure and quantify biological diversity, which is used as a KPI of how susceptible a digester is to an upset condition such as foaming or odor. The greater the biodiversity, the greater the resistance to an upset condition."

Study reveals digester insights

The January 2017 report "Performance Comparison of Biogas Anaerobic Digesters using DNA Sequencing," by Microbe Detectives in partnership with Dr. Alison Ling of Barr Engineering, revealed new insights on microbial community data, digester operation, and outcome data, which are useful in understanding what is happening inside the digester. This knowledge is necessary for exploring ways to optimize the anaerobic digestion process and increase biogas recovery yields.

Some of the report's insights include:

- Higher relative abundances of total archaea, pseudomonads, and commomonads correlated to higher percent of methane (CH_4) in produced gas
- Thermophilic conditions and blanket-type reactors correlated to higher archaea relative abundances and higher percent of CH_4 in produced gas
- Chemical oxygen demand (COD) removal correlated directly to CH_4 production
- Higher volatile fatty acid (VFA) to alkalinity ratios and lower pH in the ranges observed (pH 6.7–7.8 and VFA to alkalinity ratio of 0.04–0.24) correlated to higher archaea relative abundances
- Digesters treating municipal wastes harbored more diverse and evenly distributed communities than digesters treating only industrial wastes, possibly due to the regular addition of waste activated sludge.

Tillotson believes the opportunities to use this type of data combined with design, operational, and treatment data to optimize the anaerobic digestion process and increase biogas recovery yields are expansive for both the municipal and industry sectors. Energenecs' role is to use this data to help facility operators identify problems as well as the process equipment and control systems to achieve their goals. "It's quite an exciting journey where everyone can win, including our planet," he says.

Milwaukee applies DNA analysis to wastewater reclamation

The Milwaukee Metropolitan Sewerage District (MMSD) is using Microbe Detectives' DNA analysis services to detect nearly all microorganisms present within mixed liquor samples from the South Shore Wastewater Reclamation Facility (SSWRF) and provide the MMSD with a comprehensive monthly report of the findings. Starting in June 2018, the contract calls for Microbe Detectives to provide a comprehensive analysis report after completing 12 months of weekly sampling and analysis.

"These powerful analytics will help MMSD better understand its conventional activated sludge process at SSWRF and give insight on nitrification, phosphorus removal, biological nutrient removal potential (including presence of phosphorus-accumulating organisms and glycogen-accumulating organisms), foaming, filaments, bulking, poor settling, and positive coliform identification in its process," says Matt Magruder, environmental research manager at MMSD.

Plans are underway to expand DNA analysis into anaerobic digestion and other MMSD operational systems.

Microbe Detectives reveals DNA insights

Dr. Trevor Ghylin founded Microbe Detectives in 2013, based on his PhD work at the University of Wisconsin at Madison that aimed to expose new insights on troubleshooting and optimizing wastewater biological processes. Dr. Ghylin discovered that this capability was also effective at validating the impact of changes in design, operations, and treatments on biological performance in wastewater facilities.

Microbe Detectives first commercialized its DNA services in 2014 by focusing on the wastewater industry. In 2016, the company began specializing in analyzing the DNA of anaerobic digesters, given the enormous potential in the recovery of renewable resources such as biogas. The company was renamed ThinkR3 LLC in December 2018.

Microbe Detectives is a 2014 graduate of the Water Council's BREW accelerator in 2014, winner of the 2015 Wisconsin Innovation Awards and the 2017 WEF Gascoigne Award, and was selected by BlueTech Research to participate in the 2018 BlueTech Forum/WEFTEC Innovation Showcase.

> The emerging market for biogas – referred to as Renewable Natural Gas (RNG) – represents a strategic opportunity to advance energy independence.
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> **John Tillotson, CEO of ThinkR3 LLC**