THE Water Research FOUNDATION

Resource Recovery

THE CHALLENGE

In recent decades, the wastewater sector has moved away from the idea of wastewater treatment plants as waste disposal facilities, instead envisioning these plants as water resource recovery facilities (WRRFs). WRRFs can produce clean water, recover nutrients (such as phosphorus and nitrogen), and potentially reduce fossil fuel consumption through the production and use of renewable energy.

In the early 2000s, the wastewater treatment industry was experiencing a paradigm shift to one focused on "re-N-E-W-able" resources (N – nutrients, E – energy, W – water) with the vision that most, if not all, materials in wastewater can be commoditized. In 2009, WRF subscribers identified the recovery of useful products from wastewater and solids as one of the top research needs.

A true One Water challenge, resource recovery intersects with complementary issues such as nutrient recovery, biosolids, energy optimization, and process intensification.

THE RESEARCH

In 2010, WRF launched its Resource Recovery Issue Area to focus research on this emerging issue. The Resource Recovery Issue Area has focused on recovering resources from wastewater (other than energy and water), with the primary objective of recovering nutrients—both phosphorus and nitrogen. The Issue Area has also undertaken research on recovering high-value carbon products, rare earth elements (metals), and high-quality biosolids (or exceptional-quality biosolids). WRF has also conducted research on the unintended consequences of resource recovery, and how resource recovery practices affect other plant operations (e.g., whether the use of a low-energy nutrient removal technology impacts the recovery of phosphorus).

Nutrient Recovery

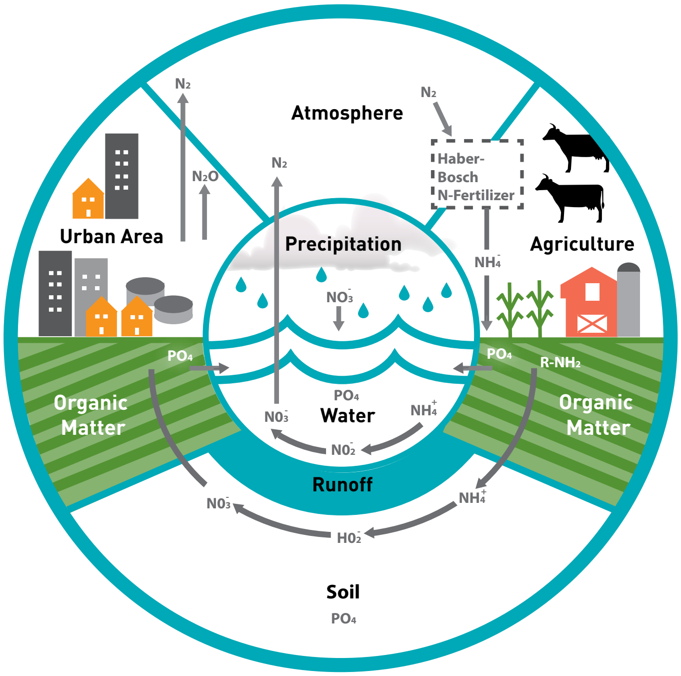
Because a growing number of facilities are taking nutrient treatment a step further and extracting these valuable resources, WRF is exploring the best practices to make the most of everything from nutrient-rich biosolids to the phosphorus and ammonia in liquid waste.

Re-N–E–W-able Resources

NUTRIENTS | **ENERGY** | **WATER**

Used water, which was previously thought of as waste, is now seen as a valuable source for highly commoditized resources—including nutrients, energy, and clean water.

In 2014, WRF was awarded a $2.2M Science to Achieve Results (STAR) grant from the U.S. Environmental Protection Agency (EPA) to create a National Research Center for Resource Recovery and Nutrient Management. Working with some of the top universities and non-profit organizations in the United States, WRF is helping to create a shift in the water sector where nutrients are not regarded as waste but rather as valuable products. The research center is a hub for groundbreaking science, demonstrating breakthroughs such as the application of urine separation to collect nutrients for agricultural use and commercial-scale generation of energy and bio-fertilizers. Research has also helped utilities meet regulatory goals for nitrogen reduction at much lower costs, using less energy, and with a smaller chemical footprint. Seven research projects were completed under this grant, focusing on topics such as biological nutrient removal; co-digestion with fats, oils, and grease; integrated management of animal manure wastes; and more.



WRF's National Research Center for Resource Recovery and Nutrient Management takes a holistic approach, looking at the entire water cycle.

Biosolids

Once wastewater is treated, WRRFs must determine what to do with the resulting solids—a unique blend of organic and inorganic materials, trace elements, chemicals, and even pathogens. There is no uniform solution for handling and processing the constituents that may be present.

Weighing in at more than seven million dry tons per year, the sheer volume of solids is something many facilities struggle to manage. Because they are often rich in nutrients, like nitrogen and phosphorus—which also happen to be the perfect ingredients for promoting plant growth—many facilities have turned to land application. But before these solids can fertilize farmland, they must be safe—undergoing rigorous treatment to meet regulations, at which point they become known as biosolids.

In the 1980s, WRF emerged as an early leader in biosolids research. WRF has completed more than 100 projects in this area. Research focuses include disposal, thickening and dewatering, treatment optimization, biosolids quality, beneficial use, risk assessment, and communication.

Because hauling and disposal costs are tied directly to the amount of solids generated and their water content, WRF has identified processes that reduce volumes and produce drier products. In 2000, WRF published a study on polymers, the additives used by facilities to boost thickening and dewatering. *Analysis and Fate of Polymers in Wastewater Treatment* (94REM2) breaks down impacts of excessive chemical dosing and helps identify appropriate levels, significantly reducing polymer use in the dewatering process, which saves treatment facilities more than $20M each year.

The presence of trace organics in biosolids destined for land application has been well documented by several WRF studies. In 2010, WRF made significant progress in measuring the actual impact in *Trace Organic Chemicals in Biosolids-Amended Soils: State-of-the-Art Review* (SRSK5T09). The research pinpoints the highest-priority trace organics based on occurrence, bioaccumulation, and toxicity and details how each is affected by specific processes. Building on these findings, it creates a path to evaluate and model risks from human and ecological exposure.

Energy Recovery

Although the treatment and transport of water require a large amount of power, they also present a huge opportunity for energy generation. From energy embedded in biosolids and wastewater to pressure in piping systems, WRF is finding ways to capture that energy and use it as a viable power source to ultimately create enough power to offset (or possibly exceed) a utility's energy needs.

At WRRFs, biosolids currently offer the most developed opportunity to recover energy and WRF has significantly advanced this science, particularly around anaerobic digestion. When coupled with combined heat and power (CHP) facilities, anaerobic digestion is regarded as one of the more successful approaches for increasing onsite electricity generation, a key step in self-sufficiency.

Ongoing research is finding methods to boost energy recovery from biogas, including emerging technologies that improve solids digestibility, advanced biogas cleaning, and co-digestion. *Co-Digestion of Organic Waste Products with Wastewater Solids* (OWSO5R07) demonstrates important discoveries about organic loading rates and digester stability, zeroing in on the types and amounts of feedstock that have a synergistic effect on biogas production—improving the economic viability of co-digestion, as well as industry confidence in the process.

In 2016, WRF began focusing research on source separated organic feedstocks. Co-digestion with organic feedstocks can improve digester performance, increase methane production for energy generation, and decrease operating costs. EPA has identified food waste as one of the least recovered materials in the municipal solid waste industry, making up 20% of national municipal solid waste. Because of this and other independent drivers, states such as California and Massachusetts have adopted initiatives to reduce the amount of organic waste accepted at municipal landfills. A shifting regulatory landscape is leading WRRFs to evaluate co-digestion with residential and commercial food waste from post-consumer sources. Source separated organic feedstock is defined as originating from commercial generators such as restaurants (excluding grease), commercial kitchens and cafeterias, grocery stores, and residential generators separated from other wastes at the source.

Excess pressure in piping at water facilities is another source for harvesting clean, renewable power. WRF partnered with Halifax Water to design and install a recovery turbine, making Halifax the first Canadian utility to use an inline microturbine in a closed distribution system. The resulting report, *Energy Recovery from Pressure-Reducing Valve Stations Using In-Line Hydrokinetic Turbines* (4447),

SOLUTIONS IN THE FIELD: Louisville Metropolitan Sewer District

The LIFT Scholarship Exchange Experience for Innovation & Technology Program (SEE IT) provides scholarships for utility personnel to visit other utilities with innovations of interest. In 2017, Louisville Metropolitan Sewer District (MSD) used their scholarship funds to investigate newer biosolids technologies that weren't as established in the United States as they were in other parts of the world. MSD sent staff to the United Kingdom to learn about thermal hydrolysis, advanced acid-phase anaerobic sludge digestion, and combined heat and power.

Based on what MSD learned during their trip, they decided that implementing some form of thermal hydrolysis technology would be a good fit for MSD. After wastewater treatment, thermal hydrolysis is a process in which sludge is "pressure cooked" followed by a rapid decompression. These steps sterilize the sludge and make it more biodegradable, which improves digester performance. The high temperature and pressure destroys pathogens in the sludge and sterilizes it, which results in a Class A product that can be used for land application. Thermal hydrolysis also allows for higher loading rates to anaerobic digesters and improves dewaterability.

details key planning and design considerations, economics, and risk mitigation, which can be used as a guide by other utilities considering energy recovery from a turbine generator.

Intensification of Resource Recovery

Municipal WRRFs function at the energy-water-food nexus of a world that is increasing in population and undergoing rapid urbanization. The urban land area consumed by existing WRRFs is often landlocked and cannot support the growing urban population without process intensification. New approaches are critically needed to intensify treatment within existing tank volumes to accommodate sustained growth, or to reduce operational costs for existing capacities.

Process intensification is a standard term used in engineering, and it can be applied broadly. For instance, treatment intensification could be defined as any system that significantly outperforms conventional designs, and performance could be defined using effluent quality, energy consumption, or capital expenditures.

In 2016, WRF published *State of Knowledge and Workshop Report: Intensification of Resource Recovery (IR2) Forum* (TIRR1R15). This report helped find new ways to recoup valuable resources and get the technologies that can make it happen into the field quickly. As part of this effort, WRF evaluated more than 30 emerging technologies, including many that are helping to revolutionize anaerobic digestion and heighten the final products. The results include a ranking of each technology's readiness level, which can assist facilities in finding the right solution for their site.

LIFT

The Leaders Innovation Forum for Technology (LIFT) is an initiative that helps move water technology to the field quickly and efficiently. Through its Technology Survey, LIFT identifies priority topics, called Focus Areas. For these Focus Areas, LIFT facilitates innovative technology testing and demonstration. Several LIFT Focus Areas are relevant to resource recovery, including Biological Nutrient Removal, Phosphorus Recovery, Energy from Wastewater, and Biosolids to Energy. These Focus Area groups are actively exploring new and evolving technologies. For example, the Biosolids to Energy Focus Area has helped advance the application of hydrothermal processing to wastewater sludge. The thermochemical process uses water, heat, and pressure to turn solids into renewable energy. The group is also investigating pyrolysis, supercritical water oxidation, hydrothermal liquefaction, and gasification.

For more on WRF's research on resource recovery, see WRF's factsheets on the following topics:

- **Biosolids**
- **Energy Optimization**
- **Nutrients**

WHAT'S NEXT?

This is complex research and a high value to WRF subscribers aiming to become utilities of the future. There is a need to move toward resource recovery that goes beyond energy and nutrients. Many municipalities still dispose of biosolids in landfills, which is a lost opportunity. In a conservative industry, it is unlikely that individual organizations are likely to come up with solutions themselves. Future WRF research will explore the business case of recovering commodities from wastewater. Topics will include business case development, including optimization and environmental impact, on recovery of other commodities (e.g., volatile fatty acids (VFAs), polyhydroxyalkanoates (PHAs), bioplastics, and others) from wastewater.