THE Water Research FOUNDATION

Resource Recovery

THE CHALLENGE

In recent decades, the wastewater sector has moved toward a vision of wastewater treatment plants as water resource recovery facilities (WRRFs). WRRFs can produce clean water, recover nutrients like phosphorus and nitrogen, and reduce fossil fuel consumption through the production and use of renewable energy.

In the early 2000s, the wastewater industry began to focus 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 waste-water and solids as a top research need. Additionally, in 2021 WRF chose Efficient Resource Use and Recovery as one of five high-priority research themes, which will help advance the water sector toward a circular economy.

THE RESEARCH

Since the early 2000s, WRF has conducted a variety of research on resource recovery. Projects have focused on recovering resources from wastewater, including nutrients (phosphorus and nitrogen), high-value carbon products, rare earth elements (metals), and high- or exceptional-quality biosolids. WRF has also investigated 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.

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. This research center demonstrated 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

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.

completed under this grant, focusing on topics such as biological nutrient removal (BNR); co-digestion with fats, oils, and grease; integrated management of animal manure wastes; and more.

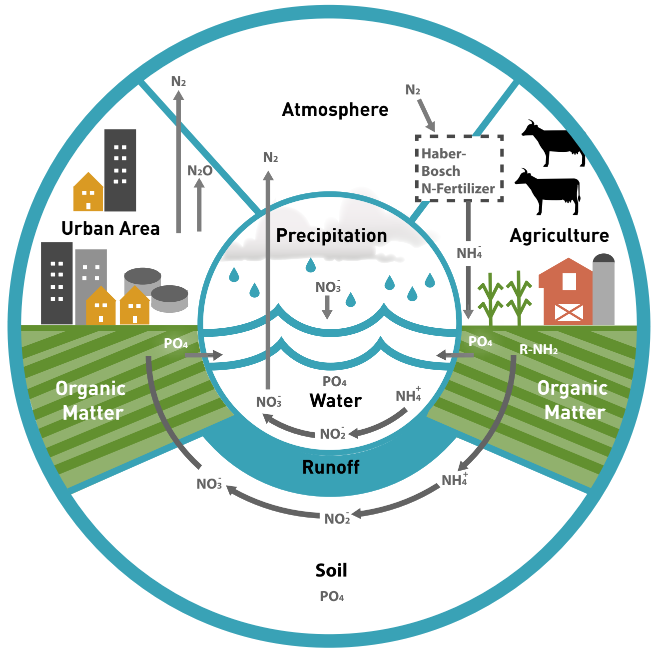
WRF's Nutrient Removal Challenge, which ran from 2007 through 2019, produced 44 reports and involved over 500 contributors. One notable project funded through this effort investigated adsorption, which offers an efficient, stable, low-cost technology for phosphorus and nitrogen removal. *State of Knowledge of the Use of Sorption Technologies for Nutrient Recovery from Municipal Wastewaters* (NUTR1R06x/1525) investigated various sorption technologies, and found that optimized ion exchange resins and metal oxide sorbents had the greatest potential for use in nutrient recovery.

Reliable nutrient removal must be achieved with fewer inputs (e.g., cost, energy, chemicals) and reduced environmental impacts (e.g., life-cycle emissions) to prevent nutrient-induced eutrophication. Achieving resource-efficient nutrient removal requires comprehensive review and synthesis of diverse information on nutrient removal and recovery technologies. *Characterizing, Categorizing, and Communicating Next-Generation Nutrient Removal Processes for Resource Efficiency* (4976) synthesized information on recently developed nutrient management technologies (both removal and recovery) and benchmarked these technologies against established processes.

Low-energy, low-carbon BNR technologies can improve energy efficiency and increase energy recovery potential, but impacts on phosphorus removal or recovery are poorly understood. *Understanding the Impacts of Low-Energy and Low-Carbon Nitrogen Removal Technologies on Bio-P and Nutrient Recovery Processes* (4819) used a multi-pronged approach to evaluate process configurations and underlying mechanisms that facilitate low-energy nitrogen and phosphorus removal and recovery. This approach allowed for the development of complementary strategies that utilities can consider using with a variety of process configurations.

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, many facilities have turned



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

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.

Many utilities have experienced poor dewaterability performance, such as lower cake total solids and higher polymer demand, with enhanced biological phosphorus removal (EBPR) and anaerobic digestion. Understanding the mechanisms that cause these issues and identifying solutions were the complementary themes of two dewaterability projects that finished in 2019. *Testing a Biofloc Model to Understand Dewatering and Solve Dewaterability Issues Related to Resource Recovery* (NTRY12R16/4818) focused on the characteristics of digested solids that impact dewaterability and evaluated approaches to improve dewaterability. *Impact of EBPR on Dewaterability* (NUTR5R14d/4827d) focused on chemical conditioning of digested solids, both EBPR solids and non-EBPR solids, to improve dewaterability.

Energy Recovery Through Food Waste Co-Digestion

Although the treatment and transport of water require a large amount of power, they also present a huge opportunity for energy generation. WRF is finding ways to capture that energy and use it as a viable power source to ultimately create enough power to offset or exceed a utility's energy needs. WRF has focused much of its research in this area on food waste co-digestion.

Co-digestion with organic feedstocks can improve digester performance, increase methane production for energy generation, and decrease operating costs. Source separated organic (SSO) 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. Since 2016, WRF has also funded a Research Priority Area on food waste SSO feedstock co-digestion: Source Separated Organic Feedstock Pre-Treatment and Management Practices.

In 2022, WRF will be closing out the SSO research area with two final projects: *Characterization and Contamination Testing of Source Separated Organic Feedstocks and Slurries for Co-Digestion at Resource Recovery Facilities* (4915) and *Evaluation of Existing Source Separated Organic Feedstock Pre-Treatment and Management Practices* (5037). Project 4892 will also be completed: *Quality of Biogas Derived from Wastewater Solids and Co-Digested Organic Wastes: A Characterization Study*. These three WRF projects touch on different but interconnected aspects and stages of co-digestion: pre-treatment technologies and strategies, contamination and characterization testing, and biogas quality.

Food Waste Co-Digestion at Water Resource Recovery Facilities: Business Case Analysis (ENER19C17/4792) highlights successful business strategies that create value and manage the risks of adopting co-digestion of food waste—including fats, oils, and grease (FOG); food manufacturing residuals; and food scraps—with wastewater solids to enhance recovery of biogas, soil amendments, and nutrient products. The report presents a framework that WRRFs can use to analyze the opportunities that co-digestion could provide in their own organizational, market, and policy contexts to help them develop long-term business strategies and implementation plans that advance their missions and long-term goals. Seven WRRFs also contributed case studies capturing details of their food waste co-digestion business cases.

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. Novel approaches are needed to intensify treatment within existing tank volumes to

SOLUTIONS IN THE FIELD: Louisville Metropolitan Sewer District

The LIFT Scholarship Exchange Experience for Innovation & Technology Program (SEE IT), a collaboration between WRF and the Water Environment Federation (WEF), 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, the sludge undergoes thermal hydrolysis, a process in which it 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 destroy pathogens in the sludge and sterilize 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.

accommodate sustained growth, or to reduce operational costs for existing treatment processes. 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* (TIRR1R15/1764). This report found new ways to recoup valuable resources and get relevant technologies 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. The results include a ranking of each technology's readiness level to assist facilities in finding the right solution for their site.

In 2021, WRF and the U.S. Department of Energy (DOE) highlighted a group of advanced water resource recovery system projects, recently awarded by DOE totaling $27.5 million, in a webcast series, *Research and Development for Advanced Water Resource Recovery Systems*. These projects will help provide sustainable water sources and affordable treatment options to industry, municipalities, agriculture, utilities, and the oil and gas sector. WRF is leading one of these projects (5141), which is described in the What's Next? section below.

INNOVATION

Maintaining an appropriate balance of phosphorus in biosolids is a concern for utilities. One option is to precipitate and remove phosphorus before dewatering, using a process like the CalPrex® technology. WEF and WRF's joint initiative, the Leaders Innovation Forum for Technology (LIFT), supported a project, *Demonstrating the CalPrex System for High-Efficiency Phosphorus Recovery* (5004) to independently validate the CalPrex® system. During the CalPrex® process, brushite, a calcium phosphate mineral, is precipitated by reacting soluble phosphorus at pH 6.5 with calcium hydroxide. The brushite is then extracted to produce a valuable fertilizer. This research will help WRRFs evaluate alternatives for removing phosphorus from sludge going to digesters, address O&M issues related to struvite scaling in pipes and poor sludge dewaterability, better meet phosphorus regulations, and recover valuable fertilizer.

For more on WRF's research on resource recovery, see WRF's research syntheses on the following topics:
- **Biosolids**
- **Energy Optimization**
- **Nutrients**

WHAT'S NEXT?

In September 2021, WRF was awarded a $2.2 million grant from the DOE to lead a project, *Data-Driven Process Control for Maximizing Resource Efficiency* (5141). This project will develop and demonstrate data-driven process controls in full-scale facilities for five promising process technologies that offer substantial energy and resource recovery benefits. The five applications that will be investigated are:

- Carbon diversion: High-rate contact stabilization
- Biological nutrient removal: ammonia-based aeration control/ammonia vs. NOx control + main-stream partial denitrification with anammox (PdNA)
- Disinfection: peracetic acid
- Phosphorus recovery: MagPrex™
- Holistic biosolids optimization

Other ongoing projects include *Acid+ Digestion* (5108), which will optimize acid gas digestion of biosolids and ultimately develop a novel advanced digestion process called Acid+ Digestion. Acid+ Digestion would offer WRRFs an option to increase digester capacity; enhance nutrient resource recovery as struvite; protect digestion, dewatering, and centrate handling from struvite fouling; and reduce biosolids phosphorus. *Biorecovery of Nutrients from Municipal Wastewaters with Co-Production of Biofuels and other Bioproducts* (5146) is investigating the use of filamentous algae in suspension for phosphorus removal from wastewater.