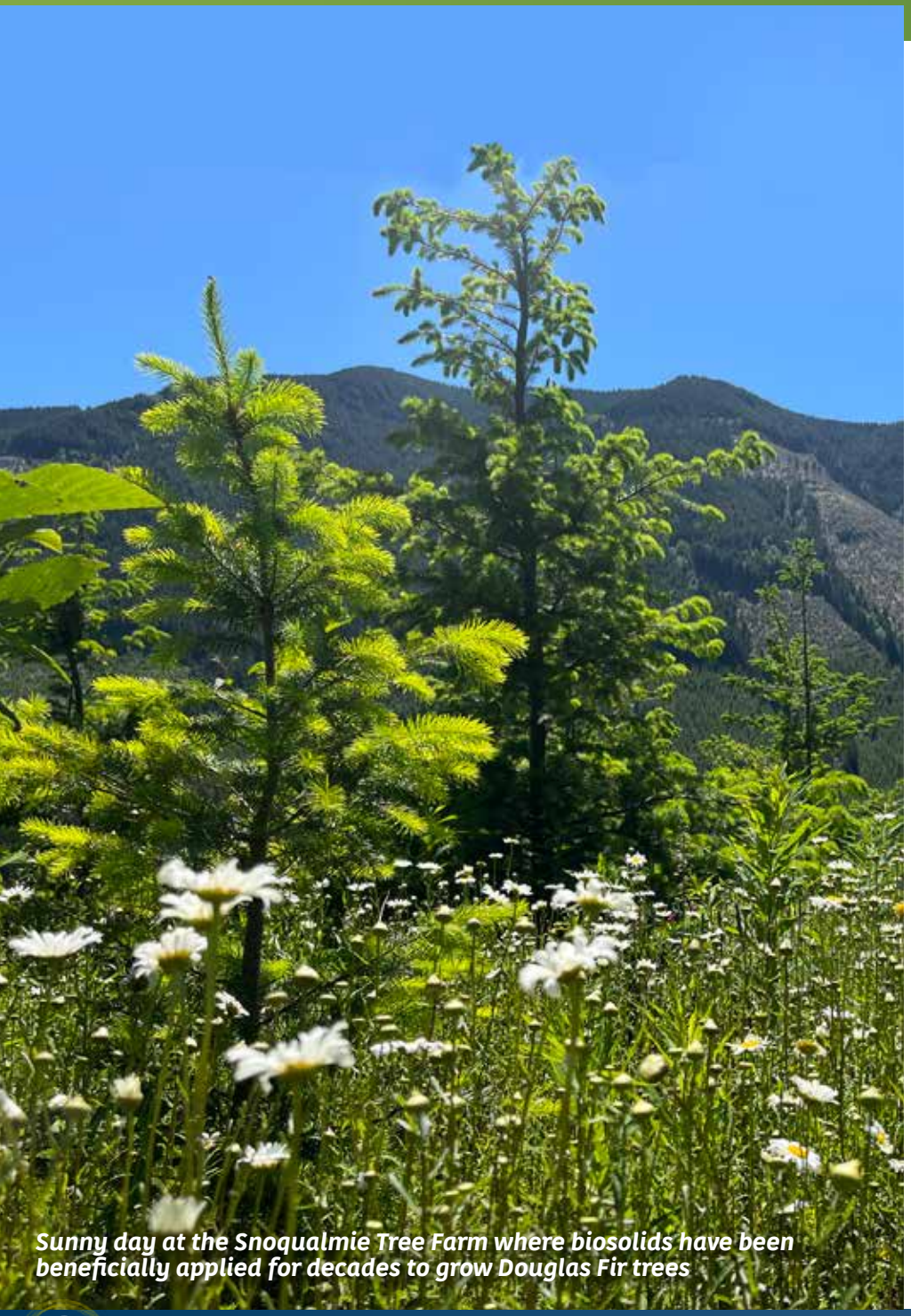
King County

Department of Natural Resources and Parks
Wastewater Treatment Division

2023

Resource Recovery Research Report



Sunny day at the Snoqualmie Tree Farm where biosolids have been beneficially applied for decades to grow Douglas Fir trees

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2023 Resource Recovery Research Report

Working with External Researchers to Understand Human and Environmental Health

Every day, Wastewater Treatment Division (WTD) employees are collaborating with researchers across the country to expand our collective understanding of everything from cutting edge wastewater treatment technologies to the intricacies of building healthy soil. This annual report summarizes the work of WTD's Resource Recovery section with external researchers over the past year.

What is Resource Recovery?

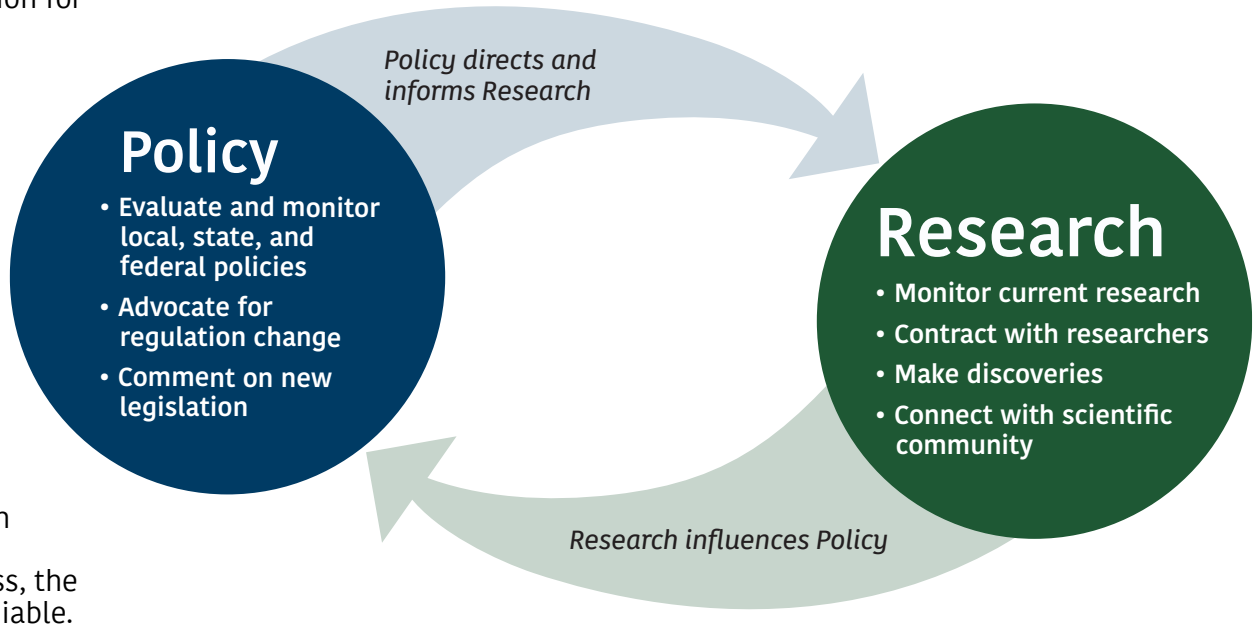
Resource Recovery is a team dedicated to bringing valuable resources, technology, and sound business practices together to deliver products and programs that inspire our communities to be part of an environmentally sustainable future—today. We develop and manage programs that deliver products and services in support of the Wastewater Treatment Division's vision for the utility of the future.

Together with our colleagues and community partners, Resource Recovery provides leadership around sustainability, education, technology, and the reuse of valuable resources such as renewable energy, recycled water, and "good plant nutrients" (Loop®biosolids).

Why Work with External Researchers?

In order to support our programs, ensure the highest level of operational efficiency and innovation, and advocate for smart policy, WTD leads with science. One would have to work hard to find a project at WTD that does not have a mountain of research behind it. Although it sometimes means slowing down enough to follow the scientific process, the confidence it should bring to our decisions is undeniable.

Our quest for information not only benefits our utility; it benefits the global wastewater treatment community. As one of the larger utilities in the United States, King County's infrastructure, technologies, and programs can be a model for others, and an incubator for innovation in the field of wastewater treatment. By collaborating with the larger research community to participate in research studies, provide samples or information, we participate in an information exchange that helps the entire field advance. By funding graduate student research, we help grow the next generation of wastewater professionals who will continue to steward our wastewater treatment systems, and human and environmental health, into the future.



Soil sampling team at the Boulder Park Project

Why an Annual Report?

We are proud of the research projects and collaborations spearheaded by Resource Recovery. We hope that by sharing our projects and outcomes, we can further leverage the considerable time and effort put into this research, so that others can benefit from the knowledge we have gained, or spark connections to other projects. If this report inspires some potential research questions or partnerships, please contact Cat Gowan, Resource Recovery Research Coordinator (cgowan@kingcounty.gov).

Our 2023 External Research Partners

University of Washington

- School of Environmental and Forest Sciences
- Civil and Environmental Engineering

Washington State University

- Center for Sustaining Agriculture and Natural Resources
- Department of Crop and Soil Sciences
- Puyallup Research and Extension Center

The Keystone Concept

The King County Solid Waste Division

Seattle Public Utilities

The Freshwater Trust

Batker Consulting

Consor Engineering

The King County Water and Land Resources Division

Washington Water Trust

Jacobs Engineering

2023 Projects

This year, our research collaborations were all about health, human and environmental. On the human side, we've been delving into the contaminants that come into the wastewater treatment plants from our homes and communities, and exploring novel treatment options. To ensure good environmental stewardship, we've been digging into soil health, nutrient removal, and ecosystem services. Read on for a summary of the whats, whys, hows, takeaways, and next steps for each research project.

Focusing on Human Health

Per- and polyfluoroalkyl substances (PFAS) and other chemicals of emerging concern (CECs) and contaminants have been high on the priority list for WTD this year. Internally, we embarked on a yearlong PFAS sampling effort in our facilities, provided funding in support of three research projects, and other support for six additional projects.

Novel and Existing Media Used for Separation of PFAS

Research partners:

University of Washington, Civil and Environmental Engineering

What:

Examining novel and existing options for removing PFAS from wastewater

Why:

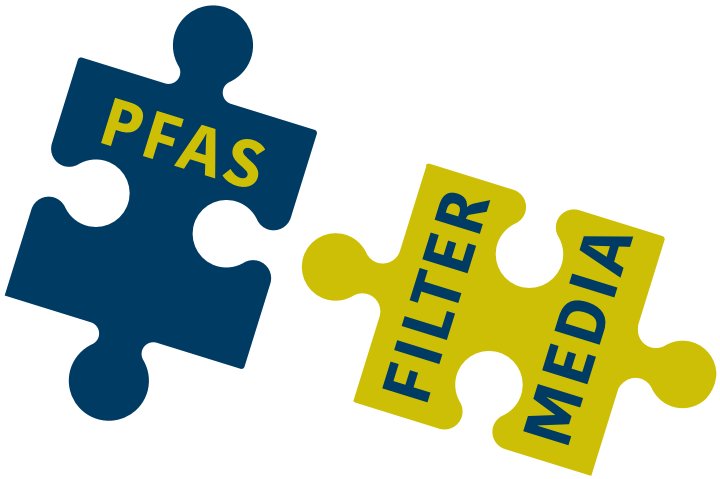
Wastewater treatment facilities are a reflection of our communities, because wastewater contains everything we wash away from our homes and businesses. Due to the extensive use of PFAS in residential households and industries, PFAS is present in our wastewater. Current wastewater treatment processes, however, are not capable of removing or destroying PFAS. While efforts to remove PFAS at their sources are underway, WTD is supporting research into how to remove PFAS from wastewater.

How:

One issue with removing PFAS from wastewater is that it is present in *really* small amounts compared to other constituents in wastewater. So, if you use a filter media of some kind, like activated carbon, that media is going to fill up with other things very quickly before it even has a chance to capture PFAS. This project uses a polymer (a stable, chemical molecule) to modify a media so that the media acts like a puzzle piece that fits a PFAS compound specifically. This makes the media more selective for removal of the PFAS compound. The researchers are comparing how much PFAS these specialized filter medias remove versus standard filter medias.

Takeaways and Next Steps:

Right now, the researchers are doing lab studies with artificially high levels of PFAS to test how effective the filter medias are. Next, they'll improve the puzzle-piece polymer, compare other products, and start testing it on King County wastewater, rather than water with known amounts of PFAS.



Aerial view of South Treatment Plant in Renton, WA

Organohalogen Degradation

Research Partners:

University of Washington,
Civil and Environmental Engineering

What:

The earliest stages of examining a potential destruction technique for PFAS and certain other CECs, known as organohalogens.

Why:

Part of the reason PFAS is so difficult to handle is because it does not break down naturally in the environment; the chemical bond between carbon and fluorine is too strong to break under natural conditions. Right now, there are no practical or economical ways to destroy the PFAS directly in untreated wastewater or treated wastewater effluent. There are some options (still expensive and difficult) to concentrate and remove PFAS, but removal alone doesn't fully solve the problem.

How:

Wastewater, and all surface waters, contain something known as dissolved organic matter, which is a mix of carbon-containing broken down bacteria and plant materials. Some of the compounds within dissolved organic matter can generate something called hydrated electrons when exposed to UV light. Hydrated electrons are strong enough to break down (or degrade) the carbon-fluorine bond in chemicals like PFAS. This project is examining whether it is possible to create an environment where there are enough hydrated electrons to destroy PFAS in treated wastewater effluent.

Takeaways and Next Steps:

This project is highly theoretical right now. The next step will be determining if there is the right concentration of dissolved organic material in wastewater to create the hydrated electrons.

Recycled Water Demonstration Garden

Research Partners:

Washington Water Trust, The University of Washington Civil and Environmental Engineering, Washington State University Center for Sustaining Agriculture and Natural Resources

What:

A two-year evaluation of Chemicals of Emerging Concern (CECs), crop production, and soil fertility comparing recycled water to water from the Sammamish River.

Why:

Currently, many edible food crops in the Sammamish valley are irrigated using surface or ground water from the Sammamish River basin which reduces critical stream flow during dry summer months. Using recycled water, rather than river water, for irrigation could have many benefits, such as helping maintain salmon habitat, reducing the use of chemical fertilizers, and reducing the amount of nutrients going into Puget Sound.

How:

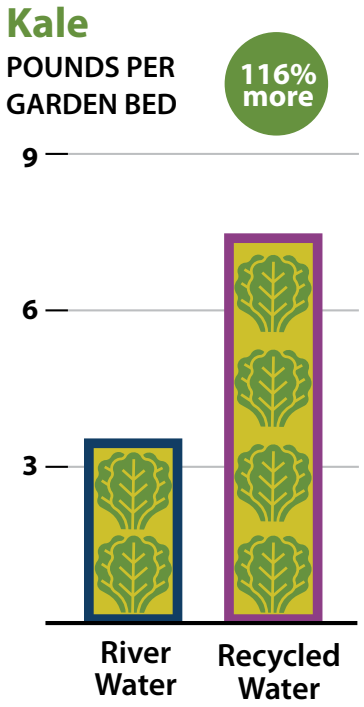
The project team constructed sixteen raised garden beds to grow a crop of kale and carrots. The beds were irrigated with either recycled water or Sammamish River water. Over the course of the project, researchers analyzed the water, soil, and crop tissue for over 200 different CECs. In addition, researchers also analyzed a number of different factors to gauge soil health and crop production.

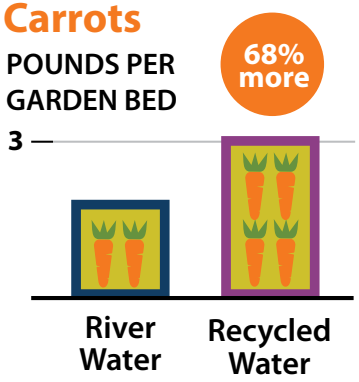
Takeaways and Next Steps:

The study determined that both recycled water and Sammamish River water contained CECs, but only at very low concentrations. Although kale is more likely to absorb CECs, concentrations in kale and carrots were both low. Recycled water resulted in higher crop yields, increasing the amount of kale grown by an average of 116%, but it did result in some excess phosphorus in the soil.

The study report has been evaluated by toxicologists and will be available soon.

NUTRIENTS IN RECYCLED WATER MEANS MORE CROP YIELD





Lab technician at West Point Treatment Plant in Seattle, WA

Other Research Contributions

In addition to the research projects directly funded by WTD, we also provided wastewater samples or letters of support for a variety of projects. Letters of support can include varying levels of participation if the project is funded from acting on advisory boards, providing data, or running pilots. We supported the following projects primarily concerned with human health:

- A Letter of Support for Hazen and Sawyer for a proposal to the Water Research Foundation's (WRF) Request for Proposals (RFP): Cost-Effective Approaches for Control of Multiple Constituents of Emerging Concern (CECs)
- Letters of Support for Michigan State University, Tulane University, and the University of Washington for the Environmental Protection Agency RFP: Ecology of Antimicrobial Resistance Exchange and Elimination during Wastewater Disinfection, Anaerobic Digestion, and Biosolids Stabilization
- A Letter of Support for the University of Washington for a proposal to the Water Environment Federation Pilot Program for Rapid Onsite Testing of Influenza, Respiratory Syncytial Virus, and SARAS-COV-2 in Wastewater
- Samples of West Point influent for the University of Washington and UC Berkeley to assist a study exploring the best method to survey for antibiotic resistance genes in wastewater
- Participation in interviews and workshops for WRF project run by Ohio State University: Unlocking the Nationwide Potential of Water Reuse
- Samples of West Point effluent for the University of Washington to assist an undergraduate capstone project studying common pollutants in Puget Sound
- Samples of influent from Brightwater, South Plant, and West Point for the University of Notre Dame to assist a nationwide survey of pathogens in sewage
- Samples from the long-term biosolids application site GP-17 for the University of Arizona to assist a nationwide survey of PFAS in lands applied with biosolids

Focusing on Environmental Health

This year was all about soil health and nitrogen management. We continued research on long-term biosolids application sites, with an eye towards maximizing soil benefits and understanding potential contaminants. Our other direct support focused on understanding the costs of nitrogen management, a potential option for improving nitrogen removal at the treatment plants and estimating the economic value of recovered resources.

Tracking Forest Nitrogen

Research Partners:

University of Washington, School of Environmental and Forest Sciences

What:

An effort to connect decades of biosolids application history in commercial forest land with soil and water quality data over the same period.

Why:

All WTD biosolids are applied at an agronomic rate, meaning we only apply as much nitrogen as the crop requires. In an agricultural setting with annual harvests of food crops, this is straightforward to calculate. In a forestry setting, where the crop of trees grows for 40 years before harvest, it's a little more complicated. It is possible that we have been applying biosolids very conservatively in the forest and could realize more yield and soil improvements if we applied more biosolids, but first we must test this theory.

How:

The main impact we are trying to avoid by using an agronomic rate is having excess nutrients run off into water bodies, so we have monitored streams in the forest areas for years for nutrients, to test whether extra nutrients show up in water bodies downstream of application sites. This project is collecting application data, soil data, and water quality monitoring data to determine if there have been any water quality impacts in the application area.

Takeaways and Next Steps:

Thus far, there are no signs that biosolids application has impacted water quality, meaning that the nitrogen being applied is being used by the trees and understory effectively. It is possible that the particular nitrogen in biosolids can be identified very specifically. The next step is trying to identify that specific biosolids nitrogen that can be traced throughout the ecosystem, allowing us to see exactly where the nitrogen from biosolids is going.

Snoqualmie Tree Farm biosolids application site

Planting a tree with biosolids-based compost

Ecosystem Services Valuation of Biosolids

Research Partners:

King County Solid Waste Division, Seattle Public Utilities, The Keystone Concept, Batker Consulting, and Consor Engineering

What:

A study to determine the economic value of the environmental benefits of applying biosolids and compost

Why:

We know, from decades of research, that biosolids do a lot more for the environment than provide nutrients to crops. Biosolids and compost also help with soil formation and health, carbon sequestration, and water supply. We wanted to know the economic benefit of ecosystem services like these, to show just how much value biosolids are bringing to the table.

How:

Putting a number on traditionally intangible benefits requires an extensive literature review and a lot of data. For instance, valuing soil erosion protection provided by adding compost requires: 1) the economic benefits of soil conservation, 2) avoided costs from flooding and sediment removal, 3) increased soil productivity in agricultural or forestry settings, and lastly, 4) an understanding of compost impact on soil loss.

Takeaways and Next Steps:

A final report will be available soon, followed by digestible fact sheets to share this information with a variety of audiences!

Using Biosolids for Agriculture

Research Partners:

Washington State University,
Department of Crop and Soil Sciences

What:

Two long-term biosolids demonstration sites at the Boulder Park Project in Eastern Washington: GP-17 site (started in 1994) and JS-14 site (started in 2020)

Why:

The GP-17 demonstration site was originally designed to determine biosolids application rates that both maximized crop yield and followed good nutrient management practices. Because of its longevity as a demonstration site and the long span of data collected over the years, now, the GP-17 plot is critical to understanding impacts of biosolids on a variety of soil health factors and carbon sequestration.

JS-14 is a relatively new demonstration site designed to investigate the potential intertwined benefits of biosolids applications, cover-cropping, and livestock grazing to soil health.

How:

The GP-17 project is set up to compare five plots: three getting different biosolids application rates (low, medium, high), one getting synthetic fertilizer, and one getting no amendments (a control). The biosolids plots are applied every four years and the commercial fertilizer plot is applied every year a crop is planted. Generally, they are planted with winter wheat and researchers measure yield every harvest. In addition to measuring yield, researchers are also testing soil health properties like bulk density, organic matter, and soil carbon.

JS-14 is testing a more complicated mixture of plots: biosolids versus synthetic fertilizer, versus no fertilizer, with the addition of cover crop versus no cover crop AND livestock grazing versus no livestock grazing. Biosolids are only applied once every four years, while the synthetic fertilizer is applied every time a crop is planted. Researchers are measuring livestock weight, crop yield, and soil health indicators.

Takeaways and Next Steps:

The GP-17 plots have consistently shown biosolids applications to either match or out-perform synthetic fertilizers. Long-term studies like this are invaluable resources and the researchers and farmer plan to keep this study going. In 2024, the research team will continue analyzing hundreds of samples from the GP-17 plots for carbon data. The researchers have been writing a manuscript on soil health data to add to the six other peer-reviewed papers published based on this project to date.

The JS-14 project crops had a rough start in 2023 with historically low rainfall, but the site produced fat and happy cows! Not to be deterred by this year's lack of rain, the research team will continue monitoring the impacts of biosolids application, cover-cropping, and grazing in out years.

Harvesting the Boulder Park Project research plots

Many of the microplastics found in wastewater come from fabrics

Microplastics

Research Partners:

Washington State University, Puyallup Research and Extension Center

What:

A project to quantify the amount of microplastics present in biosolids-amended soils and determine if microplastics are taken up by plant roots.

Why:

Although wastewater treatment plants are effective at removing large pieces of plastic from wastewater, microplastics, sized at 5 millimeters or less, are very hard to screen out. Microplastics come into wastewater treatment plants from sources like our clothing or personal care products and are too small to be filtered out of the wastewater, often ending up in our biosolids. Very little is known about the amounts or effects of these microplastics in biosolids-amended soils.

How:

The researchers have taken soil samples from the Boulder Park GP-17 study site to determine the number of plastic particles. To identify the kinds of plastic particles, researchers use a technique called a Laser-directed Fourier-Transform Infrared Spectroscopy, which uses the absorption of different frequencies of light to identify different kinds of materials. There is only one instrument in the US that can perform this work and it is located at the University of Massachusetts. Our Boulder Park soil went on a journey this year!

Biosolids are not the only source of microplastics in soils. Researchers are also testing for plastics coming down from the atmosphere through rainfall collectors and air samplers. They are also conducting lab studies on plastic uptake by plants in different soils and a hydroponic system.

Takeaways and Next Steps:

Now, that we're getting a better idea of plastic concentrations, the researchers will be focusing more on plant and soil health: is the accumulation of microplastics outweighed by the soil health improvements from biosolids? Are the plants being used in the root uptake experiments stressed by microplastics? Hopefully we'll have some idea by the end of 2024.

Nutrient Removal Optimization

Research Partners:

University of Washington, Civil and Environmental Engineering

What:

Exploration of a nitrogen removal intensification technology: Nuvoda's Mobile Organic Biofilm (MOB)

Why:

As part of complying with the Department of Ecology's Puget Sound Nutrient General Permit, WTD needs to explore ways to optimize our existing treatment plant infrastructure to remove nitrogen from wastewater. Many technologies for nitrogen removal are expensive or difficult to implement. This project is exploring a technology for removing more nitrogen without making major changes to an existing treatment process.

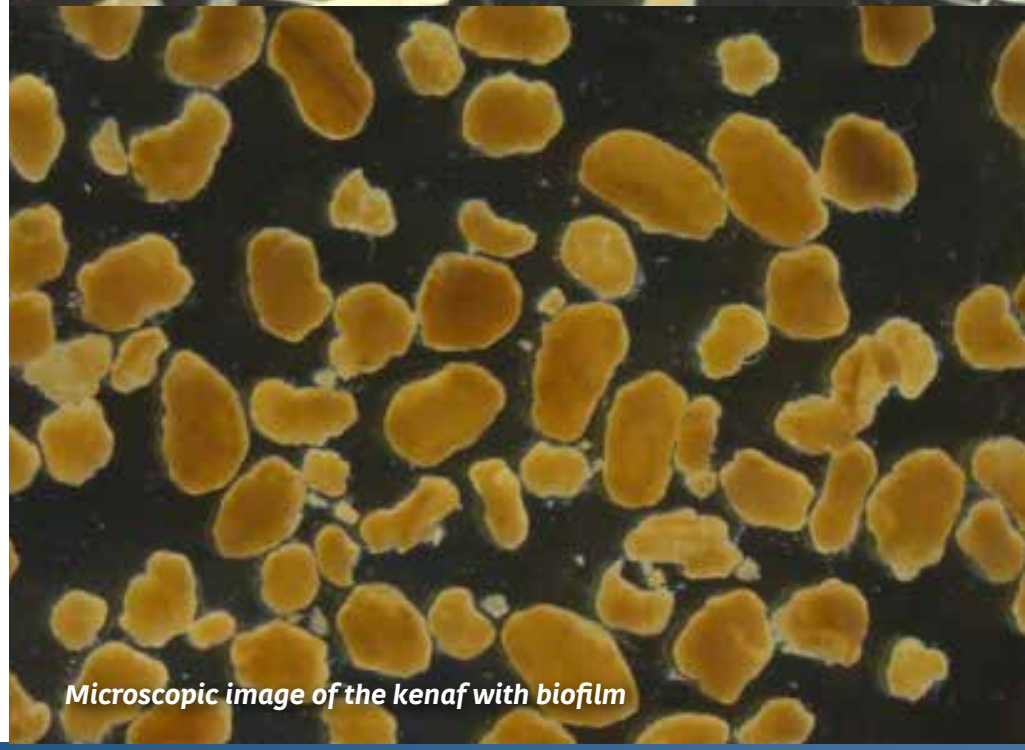
How:

Biological nitrogen removal is the cultivation of two general groups of microorganisms, nitrifiers and de-nitrifiers, that transform nitrogen in water into nitrogen gas which can safely go into the atmosphere (approximately 78% of our atmosphere is nitrogen gas already). These microorganisms take longer to grow and do their jobs than other beneficial microorganisms in wastewater. The MOB technology uses particles of kenaf, a plant that does not break down quickly during wastewater treatment, to grow multi-layered biofilms of nitrifiers and de-nitrifiers. The biofilms have time to establish because the kenaf particles are screened, retained and recycled through the treatment process. This gives the nitrogen-transforming microorganisms time to grow and do their job.

Takeaways and Next Steps:

Researchers are currently testing this technology in a lab, rather than in an actual treatment plant. The data is showing promise, and the next step is pilot testing at West Point Treatment Plant.

Fresh kenaf, a plant that does not breakdown quickly during wastewater treatment



Microscopic image of the kenaf with biofilm

Recycled water being used to grow food for food banks at City Soil Farm at South Plant in Renton, WA

Nitrogen Interventions

Research Partners:

The Freshwater Trust, Jacobs Engineering

What:

A report to review the most regionally applicable nitrogen control interventions, both within and beyond the treatment plants, and determine their cost-effectiveness.

Why:

Focusing entirely on upgrades at the treatment plants to reduce nitrogen into Puget Sound may not be as environmentally beneficial as a more holistic approach. By examining opportunities for treating stormwater, agricultural inputs, and septic, we can have a better idea of how to best protect Puget Sound.

How:

Researchers evaluated wastewater treatment, stormwater, agricultural, and septic nitrogen reduction strategies and pulled together their cost-effectiveness based on cost per pound of nitrogen.

Takeaways and Next Steps:

Based on the report, wastewater treatment upgrades and agricultural interventions (manure storage/composting/treatment, fencing-off stream and river areas, and buffers) are the most cost-effective options for nitrogen management. WTD will be spending the next two years working on the Nitrogen Reduction Evaluation required by the Department of Ecology and determining how nitrogen management fits into our long-term priorities.

Other Research Contributions

In addition to the research projects directly funded by WTD, we also provided wastewater samples and/or letters of support for the following projects primarily concerned with environmental health:

- A Letter of Support for Jacobs for a proposal to the WRF RFP: Advancing the Understanding of Nitrous Oxide Emissions Through Enhanced Whole-Plant Monitoring and Quantification
- A Letter of Support for University of Washington for a proposal to the National Science Foundation and the Natural Sciences and Engineering Research Council of Canada: Iron-biochar composites as regenerable, reactive amendments for hydrophilic stormwater contaminant degradation
- A Letter of Support for the Pima County Regional Wastewater Reclamation Department for a proposal to the WRF RFP: Evaluation of Adsorptive Medias for Optimizing Siloxane Removal from Biogas
- A Letter of Support for WSSC Water, University of Maryland, Johns Hopkins University, Argonne National Laboratory, and Brown and Caldwell for a proposal to the Department of Energy: Developing Carbon-Negative Biosolids Treatment Process via CO_2 Upcycling to Enhance Sustainable WRRFs
- Samples of anaerobic digester sludge and feed sludge from West Point for the University of Oklahoma and the University of Washington in order to understand the diversity, distribution, succession, and stability of the anaerobic digester microbiome
- Samples of dewatered biosolids from Brightwater, South Plant, and West Point for the University of Washington to determine if King County biosolids have a specific nitrogen signature
- Samples of dewatered biosolids from Brightwater, South Plant, and West Point for Sapphire Americas to determine if biosolids would be an effective alternative fuel for Ash Grove Cement

Soil sampling at the Snoqualmie Tree Farm

Dormant Dahlia beds at the Christie True Environmental Education Center at the Brightwater Treatment Plant in Woodinville, WA

Ongoing Resource Recovery Research Programs and Activities

King County has Three Long-Running Research Programs:

Biosolids research with the University of Washington

WTD has been working with UW soil scientists to study the best practices and impacts of biosolids applications since we first started applying biosolids in the early 1970s. We have supported countless graduate students and continue to work with professors from the School of Environmental and Forest Sciences on multiple projects a year, primarily focusing on urban and forestland use of biosolids.

Biosolids research with Washington State University

WTD's long-standing relationship with WSU began in 1994, with the creation of the GP-17 biosolids demonstration site. Similar to our program with the UW, WTD has supported many graduate students interested in the agricultural application of biosolids and works with professors from the Department of Soil and Crop Sciences to continue studying the impact of long-term biosolids applications in Eastern Washington.

University of Washington Research Award Program

Since 1992, the Resource Recovery Technology Assessment Program, together with the University of Washington Department of Civil and Environmental Engineering, has been supporting the next generation of engineering leaders by providing them an opportunity to conduct applied research that not only supports their advanced educational goals but allows them to influence potential innovation at WTD.

Sitting at the Table

Resource Recovery employees also support research by contributing to external research committees:

Cat Gowan and Erika Kinno: Northwest Biosolids Research Committee

Drew Thompson and Carl Grodnik: Water Environment Federation Energy Management Task Force

Eric Schey: Pacific Northwest Clean Water Association Sustainability and Biosolids Committee

Bob Bucher: Water Research Foundation Research Planning

More Information

King County Resource Recovery Website

Contact: Cat Gowan, WTD Resource Recovery Research Coordinator at cgowan@kingcounty.gov or 206-263-0746

More About the Team

The Policy and Research Unit of Resource Recovery is responsible for coordinating much of the external research covered in this report.

We hold the following values:

We are trusted subject matter experts. We bring science and research to policy development, and we generate technical information for decision-makers. We promote best practices for our internal and external customers.

We are innovators. We are connected to scientists and industry peers and seek new ideas, research outcomes, and technologies. We support wastewater treatment innovations in our utility and beyond.

We are proactive. We closely watch emerging environmental issues, policy developments, and public concerns. We stay on top of trends in wastewater treatment and its products, in service to our utility and community.

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