Potable Reuse

THE CHALLENGE

All communities need a resilient supply of clean, safe water. Some utilities can tap into additional water sources when their primary supplies face quality or quantity issues. However, because traditional water sources are dependent on location, many utilities don't have access to contingency supplies. As pressures from extreme weather and shifting populations make backup supplies more critical, many utilities are looking to diversify their water supplies.

These circumstances make potable reuse an attractive option—purifying water from wastewater treatment plants to meet drinking water standards. Potable reuse can help meet current and projected water demands and provide reliable locally based water supplies. While the need for potable reuse is apparent, a lack of guidance on how to implement these solutions and negative public perception can make it difficult for utilities to integrate this option into their water portfolio.

THE RESEARCH

Since the mid-1990s, WRF has led the industry in water reuse research. WRF joined forces with the National Research Council (NRC) on a first-of-its-kind study on the long-term viability of potable reuse. *Issues in Potable Reuse* (371), published in 1998, answered questions on toxicity, contaminants, and treatment options—and found that it could be a viable option. Since then, WRF has built a body of research exploring both indirect potable reuse (IPR), where treated wastewater passes through an environmental buffer before rejoining the drinking water supply, as well as the shift toward direct potable reuse (DPR), where purified wastewater is introduced into a drinking water treatment facility or directly into the water distribution system. WRF has also undertaken research on non-potable reuse, onsite and distributed reuse systems, decentralized systems, stormwater capture, and the contribution of reuse practices to improve nutrient-impaired waters.

Through partnerships with state, federal, and international agencies, WRF has leveraged more than $100M to advance water reuse, with over half directly funding potable studies. This research covers a full range of community, utility, and regulatory topics to help develop more cost-effective, secure potable reuse systems. One key effort was a nearly two-decade long collaboration with the U.S. Bureau of Reclamation on 124 reuse projects valued at $53M.

In 2009, WRF partnered with WateReuse California to release one of the first comprehensive reports on DPR, *Direct Potable Reuse: A Path Forward*. As a result of this partnership, in 2012 the DPR Initiative was launched—a four-year joint effort resulting in 34 cutting-edge projects to advance DPR as a water supply alternative, including a key demonstration project in San Diego. Results from this effort are synthesized in the 2016 report, *Potable Reuse Research Compilation* (Reuse-15-01/1717).

Criteria and Guidelines

When it comes to potable reuse, safety and reliability are of increased importance, but without national regulations for potable reuse, the development of water quality criteria for this purpose is in the hands of each state. WRF has tools and guidance to help states determine the best path forward for safe, effective potable reuse and to ensure that current and future guidelines are backed by the best science. WRF research has helped several states begin the process of establishing guidance for potable reuse, including California, Arizona, New Mexico, Florida, Texas, Oregon, and Virginia.

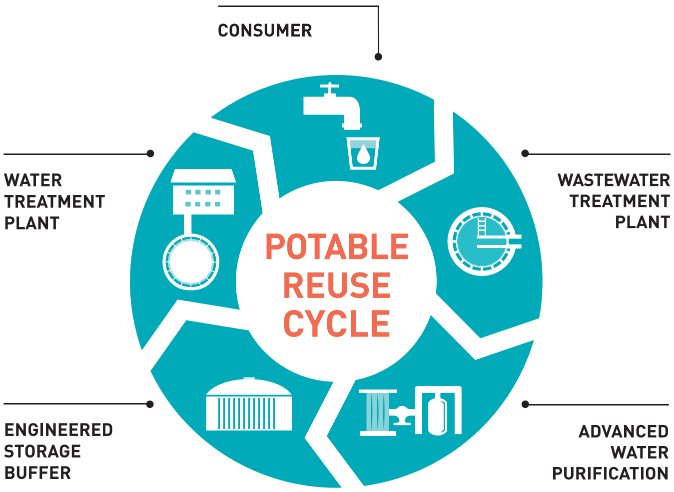
In 2011, many utilities that had been exclusively using IPR options began exploring DPR. Implementing DPR offers potential operational advantages and benefits to a utility's bottom line; but many utilities had questions about the most effective treatment options. WRF launched a multi-phased research project. *Examining the Criteria for Direct Potable Reuse* (Reuse-11-02/1689), released in 2016, contains criteria for assessing the effectiveness of different advanced treatment trains. The research funded the first U.S.-based pilot of an advanced treatment train for DPR under realistic operating conditions. This project informed several states that have either developed or are looking to develop water quality criteria for potable reuse.

More recently, WRF has provided research to utilities, municipalities, and agencies to assist them in the development of DPR guidance or regulations. In conjunction with the Water Environment Federation and the American Water Works Association, WRF released the 2015 document *Framework for Direct Potable Reuse* (Reuse-14-20), which included regulatory and technical considerations, to assist decision makers in understanding the role DPR can play in an overall water portfolio. *Assessment of Techniques to Evaluate Water from Direct and Indirect Potable Reuse Facilities* (Reuse-13-15 /4508), published in 2019, provides guidance for utilities and regulators to evaluate the safety of DPR systems, laying the groundwork for a proactive DPR-monitoring process that protects public health, including the selection of monitoring and control tools.

Treatment and Best Practices

Because the bar for potable reuse treatment practices is often higher than that of other water sources, WRF helps utilities keep up with a stricter set of demands. WRF research drives advances in treatment and technology, including membrane- and non-membrane-based treatment options, helping to improve fit-for-purpose treatment and ensure contaminants are properly managed.

In 2016, WRF established best practices for DPR by demonstrating the reliability of multiple treatment processes to meet the highest water quality standards. *Critical Control Point Assessment to Quantify Robustness and Reliability of Multiple Treatment Barriers of DPR Scheme* (Reuse-13-03/1700) pinpoints the elements in a treatment train that are most important to ensuring water safety. Findings suggest that both membrane- and non-membrane-based potable reuse systems can effectively manage microbial and chemical contaminants with proper monitoring and operational practices.



Potable reuse is the process of taking treated effluent from a typical wastewater treatment plant and purifying it further with advanced technologies.

Organics are added into municipal wastewater collection systems as water moves through the domestic water cycle. The removal of these organics by wastewater plants and advanced water treatment at potable reuse plants is critical to protecting public health for direct potable reuse (DPR) projects. However, no universal approach has been adopted for controlling organics in potable reuse projects. Published in 2020, *Characterizing and Controlling Organics in Direct Potable Reuse Projects* (Reuse-15-04/4771), developed a framework for controlling organics in DPR projects based on extensive analytical testing at six potable reuse facilities. The proposed framework is especially relevant for potable reuse facilities that do not use reverse osmosis in the treatment process.

Beyond practices for initially purifying DPR water, WRF research also explores best practices for incorporating these sources into our drinking water supply—including guidance on how to blend purified water with traditional water sources. The 2018 report, *Blending Requirements for Water from Direct Potable Reuse Treatment Facilities* (4536), examines variables such as the proportion of recycled water to raw water, quality of recycled water (based on treatment processes), and different introduction points.

Short-term studies offer promising results, indicating that DPR blends of up to 50 percent do not present added risk in terms of enhanced regrowth of pathogens or antibiotic-resistant bacteria compared to conventional drinking water sources.

Published in 2020, *Evaluating Post-Treatment Challenges for Potable Reuse Applications* (Reuse-16-01/4780) examines three post-treatment challenges found in potable reuse: corrosion, mobilization of native metals during aquifer recharge for potable reuse, and the formation of disinfection byproducts (DBPs) including N-nitrosodimethylamine (NDMA). The project applied corrosion control pipe loop testing; metals mobilization soil column testing; and various tests investigating DBPs and NDMA rebound in finished water, including nitrosamine precursor evaluation, influence of reverse osmosis membrane age, and evaluation of alternative advanced oxidation processes for DBP precursor removal. The results demonstrated that strategies can be applied effectively on a case-by-case basis for mitigating corrosion control issues; for mitigating metal mobilization by targeting pH; and for reducing NDMA formation in the finished water.

Fostering Integration

Even with effective guidelines and practices, the successful integration of potable reuse into a utility's water portfolio relies heavily on an organization's ability to support these changes. WRF research helps ease the integration, providing tools and resources to address gaps in operations planning, training, and certification, as well as methods to secure funding to get DPR programs off the ground.

Because potable reuse systems use technologies not widespread in traditional treatment systems, these operations face greater scrutiny—requiring different operations strategies, as well as training and certification not fully covered under current wastewater and drinking water programs. WRF research helps fill this void. The 2017 project *Development of an Operation and Maintenance Plan and Training and Certification for Direct Potable Reuse Systems* (Reuse-13-13/1707) illustrates a standard process for DPR operations and upkeep, highlighting risk management procedures. The research also takes the first steps in identifying the employee skills and training needed to sustain these activities.

Building on this research, the 2018 project *Curriculum and Content for Potable Reuse Operator Training* (Reuse-15-05/4772) features some of the first tools designed to help utility personnel understand specific treatment processes and other unique issues that are fundamental to the safe operation of potable reuse facilities. Based on a facility's treatment processes and other specific needs, utilities can tap into a series of eight modules designed to educate operators on technologies and topic areas not typically found in water treatment systems. This information is helping to form the basis for standard training programs, including an operator certification program for advanced water treatment developed by the California-Nevada section of AWWA and the California Water Environment Association that can be applied to potable reuse systems.

Because funding is often an organizational hurdle in implementing DPR, WRF helps utilities better

SOLUTIONS IN THE FIELD:
Potable Reuse in California

Driven by a California state mandate to study the feasibility of developing uniform criteria for direct potable reuse (DPR), WRF launched the DPR Initiative in 2011. Raising $6M from utilities, consulting firms, and manufacturers—which grew to $24M with in-kind contributions—the four-year effort produced 34 research projects. The research explores everything from regulatory concerns to economic feasibility to public perception.

In 2021, WRF will publish results of DPR research funded by a $1.4 million grant from the California State Water Resources Control Board (SWB), along with additional funding from Metropolitan Water District of Southern California. SWB is relying on this research to aid in the development of uniform water recycling criteria for DPR that are protective of public health. Because safety is a top concern, research focused on better methods and guidance for pathogen risk assessment and monitoring.

understand the costs—as well as potential benefits—of adopting these projects. In 2014, WRF released *The Opportunities and Economics of Direct Potable Reuse* (Reuse-14-08/1712), which measures the cost of DPR versus other alternative sources, considering factors such as carbon footprint and the amount of new water a utility stands to gain. This research helps utilities make informed, cost-effective decisions and build better business cases for project upstarts.

Communication and Outreach

While community interest in potable reuse projects has grown substantially in the last decade, particularly in water-scarce regions, public acceptance remains an obstacle. Understanding community concerns—and involving the public in the process—is a critical piece of successful potable reuse projects. WRF has helped the water sector make strides in this area, increasing the understanding of long-held perceptions of recycled water use, identifying primary concerns, and developing educational and communication tools to provide greater assurance.

The 2015 report, *Model Communication Plans for Increasing Awareness and Fostering Acceptance of Direct Potable Reuse* (Reuse-13-02/4540), features a catalog of community-tested methods and messages for those involved with or planning potable reuse projects. This how-to guide contains strategies and public outreach tools designed to be adapted for specific community needs. Whether pursuing IPR or DPR options, the research helps utilities understand common concerns and how to summarize the critical need to expand water supply sources. Communication plans walk users through the information they can provide to help communities understand how the process works and the steps to build support and awareness of existing and planned potable reuse programs.

INNOVATION

The WRF Innovation Program embraces innovation to support healthy, sustainable communities, with efforts focused on moving water technology to the field quickly and efficiently. Because innovative technologies and processes will play a critical role in making potable reuse a sustainable water source, WRF chose reuse as a priority innovation topic for potential pilot and technology validation projects. These projects will evaluate promising reuse technologies and processes beyond the bench scale.

WHAT'S NEXT?

As the need for alternative water supplies continues to grow, WRF is moving forward with new research to further carve out a lane for potable reuse as a sustainable option. In 2019, WRF initiated a new reuse-related research area, Water Reuse and Beyond: Water Quality Monitoring, Methods, Data, and Interpretation, to help water reuse practitioners better understand the usefulness of and realize benefits from the newest water quality monitoring tools. The first project funded in this area, *Assessing Water Quality Monitoring Needs, Tools, Gaps, and Opportunities for Potable Water Reuse* (5079) will provide guidance for conducting technology scans, selecting appropriate water quality and treatment monitoring tools, and optimizing the information the tools provide, to ensure the quality of potable reuse.

In addition, WRF received another $3.1M grant from the SWB to advance potable and nonpotable reuse. The 20 projects under this grant are ongoing through 2023, and will help California, other states, and the international community address technical and operational reuse challenges. One of these projects is *Integrating Real-Time Collection System Monitoring Approaches into Enhanced Source Control Programs for Potable Reuse* (5048). This project will determine what level of real-time collection system monitoring is feasible, appropriate, and necessary for protection of downstream potable reuse, including technology such as artificial intelligence and machine learning, and develop a framework for integrating real-time monitoring into existing pre-treatment program requirements (e.g., permits, local limits) to further advance potable reuse practices at a national scale.

Use of DNA Nanostructure as Viral Surrogates in Potable Reuse Applications (5104) will develop and validate novel surrogates for awarding virus log reduction values (LRVs) in membrane-based potable reuse systems. This will be achieved through development and characterization of DNA nanostructures that mimic virus morphology and a novel technology known as "DNA origami." This approach has the potential to augment the toolbox of surrogate parameters.

Geochemical Considerations for Managed Aquifer Recharge (MAR) Implementation in Potable Reuse (5051) will advance the understanding and practice of MAR in potable reuse applications by developing a robust decision support framework and other supporting tool to guide utilities in assessing physical and geochemical issues during the planning, design, and construction phases of an MAR project, and ultimately during its operation.

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THE Water Research FOUNDATION

Non-Potable Reuse

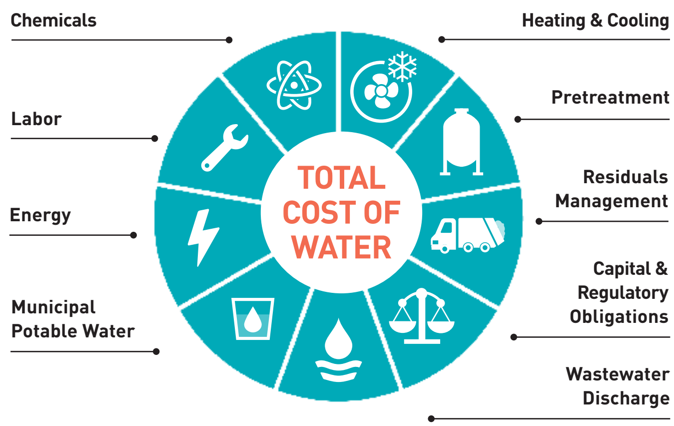
THE CHALLENGE

One of the biggest challenges today's communities face is the ability to provide safe, sustainable sources of water—not only for drinking, but for an assortment of other everyday uses that don't require water treated to drinking water standards. With a growing number of pressures straining our water sources, many utilities are relying on non-potable water reuse to keep up with demand—recycling municipal wastewater and water from impaired sources for activities that don't involve human consumption, such as landscape and crop irrigation, industrial processes, and other uses. Depending on the purpose and the risk of human exposure, different types of wastewater can be treated to meet specific quality standards. By treating water to match its intended use, utilities can avoid the high costs associated with over treatment—producing a product that relieves the demand on drinking water resources and offers a host of environmental benefits, including lower energy consumption, decreased diversion of water from sensitive ecosystems, and decreased discharges of nutrients and other pollutants.

While non-potable reuse systems have the potential to extend drinking water supplies and may require less treatment than potable reuse operations, these systems can be difficult to develop and maintain due to regulatory uncertainty. Challenges like the cost of maintaining separate "purple-pipe" distribution systems and long-held public perceptions on water reuse also increase this challenge.

THE RESEARCH

Starting in the mid-1990s, WRF was among the first organizations to explore the long-term viability of water reuse, charting its path as a sustainable resource. As the need for alternative water sources continued to grow, WRF stepped up these efforts, making this area a critical focus in the early 2000s. Since that time, WRF has launched more than 150 projects, leveraging over $100M in applied research to advance the science of water reuse, including roughly $1M each year in non-potable reuse. This research works to



As industries weigh the cost of using reclaimed water against traditional water sources, they must factor in all of the expenses that go into treating and transporting water.

help develop the most cost-effective processes and technologies to support water quality standards, protect public health, and preserve the environment—as well to more effectively integrate these systems into current operations.

Through strategic partnerships with state, federal, and international agencies, WRF has explored a range of community, utility, and regulatory issues to help develop sustainable water reuse systems. Key collaborations include efforts with the California State Water Resources Control Board, the Pentair Foundation, and the Metropolitan Water District of Southern California, as well as a nearly two-decades long collaboration with the Bureau of Reclamation to advance water reuse and accelerate the adoption of transformative technologies. This joint effort resulted in 124 research projects valued at $53M.

In 2018, the California State Water Board expanded their work with WRF, providing a $4.5M grant to identify and execute key research needed to bolster the production and use of recycled water in California. A substantial amount of this funding will go directly toward non-potable studies, which will drill into issues such as agricultural reuse, industrial reuse, and the energy-water nexus.

Agricultural Reuse

Because agriculture accounts for 80% of total water use in the United States, increasing water reuse practices in this area has the potential to have a big impact—making it a top priority for WRF. Agricultural reuse for food crops is currently practiced in many states, including California, Florida, and Colorado. To help supplement these efforts, in 2012, WRF began to strategically partner with agricultural organizations to better understand cross-sector issues, such as sources and impacts of nutrients, as well as to aid in moving agricultural reuse forward.

The 2019 WRF project *Agricultural Use of Recycled Water: Impediments and Incentives* (Reuse-15-08/4775) takes stock of some of the top challenges involved with switching from traditional water sources to recycled water for agricultural irrigation—looking at causes of setbacks and potential challenges and offering strategic solutions. Through interviews with both utilities and growers, a spatial assessment of irrigated farmlands, case studies of successful projects around the world, and a collaborative workshop, the findings highlight the largely untapped potential for agricultural reuse and serve as a springboard for other research efforts—including a follow-up study that is weighing the environmental, economic, and social costs and benefits of this agricultural water source.

This research also helped launch several WRF workshops and cross-sector events focused on finding collective solutions for overcoming challenges associated with agricultural reuse. The 2018 Agricultural Water Reuse Workshop took an important collaborative step, bringing together the agricultural community, water utilities, regulatory agencies, and consultants to work toward the common goal of making water reuse more feasible for growers and utilities. The workshop, which attracted over 100 attendees, included presentations by WRF agricultural reuse researchers and an expert panel session to identify potential collaboration areas across sectors and future research gaps.

Another 2019 study also made strides in agricultural reuse, this time with a focus on groundwater recharge—which has the potential to restore more than 300,000 acre-feet of sustainable groundwater each year in California alone. *Groundwater Replenishment with Recycled Water on Agricultural Land* (Reuse-16-03/4782) documents how agricultural areas with a need for reliable water supplies, due to a lack of access to surface water or reduced availability of groundwater, could benefit from combining agricultural reuse with groundwater recharge, resulting in substantial cost savings. The research also covers top concerns, including pathogens, nutrients, salinity, crop risks, and regulations, and offers approaches to address these issues.

Industrial Reuse

Because industrial facilities rely on water for a variety of uses beyond drinking, there is a significant opportunity to use recycled water. And because these facilities can also generate large amounts of wastewater, they have the option of capturing, treating, and reusing their own wastewater for industrial processes or other uses such as landscape irrigation. This means less reliance on outside water sources, which can translate into cost savings and improve community relations. But, because reuse in industrial settings is different than in municipal settings, there are often questions about how to design, construct, and operate these systems. WRF research is targeting these issues, offering guidance and resources to effectively implement industrial reuse projects—with a focus on the unique organizational, regulatory, and motivational issues involved with industrial reuse to help ensure projects align with business strategies.

The 2016 study, *Drivers, Successes, Challenges, and Opportunities for Onsite Industrial Reuse* (Reuse-13-04/1701), highlights industrial water reuse practices, homing in on the best opportunities based on various industrial sectors, including the food and beverage, oil and gas, and manufacturing sectors, and explains how water reuse can help improve their bottom line. This work was expanded on in the WRF research project *Framework for the Successful Implementation of Onsite Industrial Water Reuse* (Reuse-14-04/1709). Released in 2017, the research identifies elements necessary for developing successful onsite industrial reuse programs and how to achieve a favorable return on investment—an key piece in the project approval process.

More recently, WRF research has also explored how industrial reuse can prove mutually beneficial to both the power industry and wastewater treatment facilities. Particularly in the United States, where up to 80% of power plants are within 10 miles of a wastewater treatment facility, there is a large opportunity to collaborate. Findings from WRF's 2019 report, *Multipurpose Reuse of Reclaimed Water at an Electric Utility and for Wetlands Rehydration in Florida* (Reuse-15-12/4778), provides an overview of tangible benefits to both wastewater and power utilities, barriers that limit joint efforts, and potential risks to both operations. The report evaluates the ability of current treatment technologies to meet water quality requirements for applications, such as cooling towers and boilers, and includes cost estimates for individual treatment process trains.

Onsite Non-Potable Systems

Although there is an increased interest in onsite non-potable reuse, the lack of water-quality or monitoring standards for these systems can make implementing these projects difficult. To help expand the use of onsite non-potable systems, WRF joined forces with the U.S. Water Alliance to establish the National Blue Ribbon Commission for Onsite Non-Potable Water Systems. The commission, which works to advance best practices for non-potable reuse within individual buildings or on local scales, has already released more than a dozen resources.

To further help fill the void, in 2017 WRF released the guidebook *Risk-Based Framework for the Development of Public Health Guidance for Decentralized Non-Potable Water Systems* (SIWM10C15/4632), which lays out a flexible process for developing systems that are reliable, efficient, affordable, and protective of public health. The framework, the result of collaborative efforts between public health and utility leaders, offers a fit-for-purpose approach, looking at site-specific conditions and targeting human health-based goals, which could help inform regulatory conversations.

Potential potable water offset by using non-potable water for toilet and urinal flushing:

25%	75%
Residential Buildings	Commercial Buildings

WRF and the U.S. Water Alliance are also moving forward on another newly launched collaborative project, *Onsite Non-Potable Water System: Guidance Manual and Training Modules* (4909). This project is in the process of developing a manual and training program for engineers and operators for design, operations, and monitoring of onsite non-potable water systems. The manual will also be of use to regulators permitting these systems and utilities working with communities to implement them.

Water Reuse Diversification

As water demands shift, many communities are turning to water reuse as an alternate source to keep pace with growing and moving populations. Although water reuse has already found a place in many industries—including agriculture, landscaping, energy production, and industrial and manufacturing processing—WRF research is helping to open up new opportunities. Research is laying the foundation for water reuse to become a bigger piece in a balanced water portfolio through non-traditional applications.

Recycled Water Use in Zoo and Wildlife Facility Settings (Reuse-07-06/1641), released in 2013, chronicles water reuse practices at two-dozen zoos and wildlife facilities in the United States and abroad. The research offers the water sector its first glimpse at the current state of recycled water use in these settings, which typically operate using large amounts of water. It looks at water quality, treatment technology, current regulations and guidelines, and possible animal health effects. The study outlines potential water quality criteria to support long-term animal health, and helps assess the suitability of recycled water for potential uses at zoos—a first step toward the development of a standard sustainability program that encourages the use of recycled water at these facilities.

Assessing and Communicating Risk

As the use of the recycled water continues to gain momentum, receiving more recognition as a viable and beneficial practice, risk to public health remains a top priority. WRF research has been leading the way in accurately measuring potential risks, as well as helping to communicate results to the public—which is key to expanding these efforts.

To investigate the presence of residual chemicals in recycled water, in 2012 WRF undertook an effort to understand the health effects of these substances, considering factors like exposure pathways and concentrations. *Risk Assessment Study of PPCPs in Non-Potable Recycled Water to Support Public Review* (Reuse-09-07/1665), measures the risk of common pharmaceuticals and personal care products (PPCPs)—starting with a small group of substances like ibuprofen, caffeine, and DEET, as well as some of the top exposure scenarios, such as a golfer playing on a course that uses recycled water. Results showed that risks from PPCPs in water reuse are comparable to risks from the same substances in drinking water, and much less than the levels of these chemicals most people experience through daily exposure. These findings were broken down in a series of easy-to-understand communications pieces, including a video, talking points, and answers to frequently asked questions, which could aid in overcoming negative public perceptions and generating reuse project support.

Along the same lines of research, *Attenuation of PPCPs through Golf Courses Using Recycled Water* (Reuse-08-02/1802) explores the fate and transport of PPCPs in the environment, looking at how these substances behave when applied to turf grass. The multi-year, collaborative project assessed the presence of 15 PPCPs, demonstrating the ability of turf grass to remove up to 98% of PPCPs under most conditions and underscoring the viability of recycled water for irrigation purposes. It also called out key factors that impact how much reclaimed water should be applied, including soil type, turf type, and evapotranspiration rate, providing guidance for turf managers going forward.

LIFT

The Leaders Innovation Forum for Technology (LIFT) is an initiative that helps move water technology to the field quickly and efficiently. Because innovative technologies and processes will play a critical role in making water reuse a sustainable practice, WRF launched the LIFT Water Reuse Focus Group. The group is currently investigating more efficient membranes and other novel treatment processes to decrease energy use and treatment costs, real-time monitoring of contaminants using advanced sensors, and technologies aimed at making water reuse more widespread.

WHAT'S NEXT?

As shifting environmental conditions and other changes raise our reliance on alternate water sources, WRF will continue to provide sound science to support the role non-potable reuse will play in a balanced water portfolio. Although growers have been increasingly turning toward water reuse to meet their irrigation needs, there is still much to learn about agricultural reuse. WRF is helping to fill knowledge gaps with newly launched research like *SAR-Soil Structure Interactions to Provide Management Options for Recycled Water Use in Agriculture* (4963), which hopes to shed light on specific plant-soil interactions after irrigation with recycled water. Another new project, *Assessing the State of Knowledge and Impacts of Recycled Water Irrigation on Agricultural Crops* (4964) is working to develop guidance on growing crops for farmers using recycled water.

As it becomes more important for industries to improve their water management practices, the use of municipal reclaimed water and onsite reuse of industrial wastewater will likely play a larger part. WRF research will remain focused on this critical area, as well as explore the viability—and ensure the safety—of new industrial uses. One ongoing project is studying the emerging area of reusing oil-field produced wastewater for applications such as irrigation. WRF will also look to extend work on onsite reuse in buildings and other applications, continuing to invest in other ways this valuable resource can be used.

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