THE Water Research FOUNDATION

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

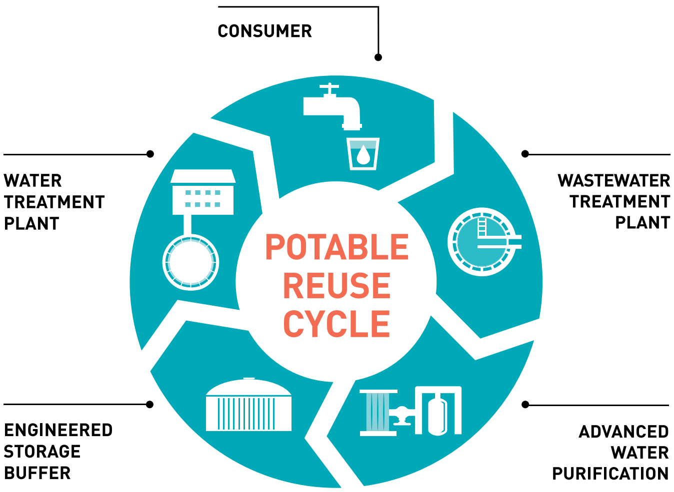
Since the mid-1990s, WRF has led the industry in water reuse research. WRF joined forces with the National Research Council (NRC) on a first-of-its-kind study on the long-term viability of potable reuse. *Issues in Potable Reuse* (371), published in 1998, answered questions on toxicity, contaminants, 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.



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

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 for Evaluating and Demonstrating Safety of Water from Direct Potable Reuse Treatment 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.

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, for selecting appropriate water quality and treatment monitoring tools, and for 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.