A Survey of Regulatory, Technical, and Public Outreach Challenges and Opportunities for Direct Potable Reuse with an Emphasis on Tucson and Pima County, Arizona

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Challenges and Opportunities for Direct Potable Reuse:
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> "…it is not the history of the water or how it is delivered that is most important. The quality of the water delivered to customers is what matters most. We have the technology to treat most any kind of source water to meet any possible needs that include irrigation, industrial, and drinking. That makes direct potable reuse a viable option in any community" (Nagel, 2015).

Introduction

Water Stress

Billions of people lack access to clean water. While water may be physically available, political, social, and economic inequalities, mismanagement, poor sanitation, deteriorating infrastructure, climate change, and demands that exceed supplies, result in public health crises, economic disasters, mass migrations, and conflicts (Felter & Robinson, 2021; Macpherson & Snyder, 2013).

In the United States, as in other parts of the world, disease and racism have emphasized the need for clean, reliable water sources. The COVID-19 pandemic demonstrated that limited access to running water was one of the main factors in high transmission rates on Native American reservations (Tanana, et al., 2021). In 2014, Flint, Michigan's poorest residents became the victims of a tragic policy that introduced corrosive water into lead pipes (Denchak, 2018).

The U.S. Census Bureau estimated that by 2030, the U.S. population will reach 360 million people, with more than 8.5 million residents projected to live in Arizona (Hummer & Eden, 2016). Between 2010 and 2020, the largest western population gain was Maricopa County, which increased by 397,031 residents (Thompson, 2020).

Several states, including Arizona, California, and Nevada have been experiencing drought conditions since 2000. As of 2021, more than 52% of the Western U.S. was classified as experiencing severe drought, including Arizona, California, and Nevada (U.S. Department of Agriculture, 2022).

In August of 2021, the Bureau of Reclamation declared a Tier 1 shortage for the Colorado River for 2022. Mandatory, Tier 1 cuts are part of the drought contingency plan approved in 2019 by seven western states that share water under the Colorado River Compact of 1922. The lower basin states are Arizona, California, Nevada, and the upper basin states are Colorado, New Mexico, Utah, and Wyoming. Native American Tribes and Mexico have also been part of the drought planning process (Bureau of Reclamation, 2022).

Water managers, municipal planners, and government officials need to begin considering other water sources. Direct potable reuse (DPR) is one that will be critical in environments where water is scarce (Macpherson & Snyder, 2013).

Methodology

The research for this paper included reading and evaluating more than 100 studies, reports, online newspaper articles, and PowerPoint presentations; submitting written questions to Scottsdale Water staff, along with conducting five hours of Zoom and Teams interviews with Tucson Water and Pima County Regional Wastewater Reclamation Department (RWRD) staff, and a water reuse consultant. Documents were located through the University of Arizona library system, and from Environmental Protection Agency (EPA) websites, Regulations.gov, Water Resources Research Center, and the WateReuse Foundation. Additional research was located using bibliographic entries in some of the research articles.

Recycled water and direct potable reuse

Challenges and benefits of recycled water as potable reuse

Earth's water supply is limited. Water used today has cycled through the planet's hydrologic system as surface and groundwater, through rivers, lakes, and streams, and as precipitation around the globe. In 2012, the National Research Council's Water Science and Technology Board's *Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater,* stated "Recycled water should no longer be considered a water of 'last resort.' In the U.S., up to one-third of the water used nationally each day can be recycled back into water supplies" (National Research Council, 2012b).

Recycling wastewater addresses both wastewater disposal and water supply issues. Wastewater disposal can be expensive, but wastewater processed for non-potable or potable reuse provides revenue, offsetting treatment costs. As potable reuse costs decline, the costs of traditional potable water service have increased, making potable reuse an attractive augmentation option for dwindling water supplies (Hummer & Eden, 2016).

Water recycling has become an integral part of some water systems, where recycled water is now used to meet the needs of agriculture, green non-potable infrastructure, and other uses where water need not meet drinking water standards. Effluent from wastewater treatment facilities can be treated to acceptable standards for both non-potable and potable uses (Middel, 2013).

Recycled water creates safe, sustainable, drought-resistant supplies that enable communities to leave water in existing natural environments (Nagel, 2015). This idea is not new. The country's oldest dual distribution system is in Grand Canyon Village, Arizona, which has been using reclaimed water for nonpotable uses since 1926 (National Research Council, 2012a).

Phoenix built its first wastewater treatment plant in 1931 at 23rd Avenue. The treated wastewater was used for farm irrigation.

In 1962, the Sanitation District of Los Angeles County began adding highly treated reclaimed water to Southern California's potable water system (National Research Council, 2012a). In 1978, in Fairfax County, Virginia, the Upper Occoquan Service Authority was the first in the U.S. to use effluent from an advanced treatment plant to directly augment a surface water reservoir. Other potable reuse projects proposed in the 1990s and 2000s, however, have been rejected for political, social, and economic reasons, often because of misinformation (Smith, et al., 2018).

In 1973, the Arizona Municipal Water Users Association negotiated an agreement among five member cities and Arizona Public Service to provide treated wastewater to the Palo Verde Nuclear Generating Station. It is the only nuclear power facility in the U.S. cooled by recycled water. Arizona Municipal Water Users Asssociation (AMWUA) cities now recycle more than 95% of their treated wastewater to sustain fishing lakes, create wetlands, irrigate fields and parks, and store underground for future use (Tenney, 2017).

In 1976, California's Orange County Water District began injecting 15 million gallons per day of highly treated municipal wastewater into the groundwater aquifer. In 2008 the system was expanded to 70 million gallons per day. The advanced treatment groundwater replenishment system uses municipal effluent from a nearby wastewater treatment plant, microfiltration, reverse osmosis, and an advanced oxidation process to further treat the water, which is pumped into recharge basins and injected into wells, mixing with groundwater. The system helps provide drinking water for more than 2 million people, serving as a model for other potable use projects (Harris-Lovett, et al., 2015).

But potable reuse also has its challenges. Wastewater can contain natural contaminants from viruses and bacteria, and synthetic contaminants from pharmaceuticals, hygiene products, industrial chemicals, or agricultural fertilizers requiring management and mitigation (Rock, 2016). Advanced water treatment plants, however, incorporate redundant monitoring systems and up-to-date purification methods to meet Environmental Protection Agency (EPA) drinking water standards (Nagel, 2015).

The aging U.S. water infrastructure was designed to protect public health, dispose of wastewater, and provide safe drinking water (WateReuse Association, 2022a). The system includes more than 2.2 million miles of pipes, but every two minutes a breakage contributes to the daily loss of 6 billion gallons of treated water (American Society of Civil Engineers, 2021). In the next seven years, the volume of recycled water is projected to increase from 4.8 billion gallons per day to 6.6 billion gallons per day (WateReuse Association, 2022a).

Preliminary implementation of direct potable reuse

Sending anything into space costs about $10,000 per pound, so shipping water to the crew of the International Space Station (ISS) is both impractical and expensive. Because each crew member is allocated about two liters of water per day, the ISS relies on a 2008 NASA DPR water recovery system (WRS) that collects humidity and distills about 85% of water in urine. The WRS uses physical and chemical processes to remove contaminants from wastewater to store in a tank for reuse. Water quality is continuously monitored by ISS sensors and cycled back through the system (Environmental Protection Agency, 2012; Hummer & Eden, 2016).

In the past, DPR on Earth was viewed with skepticism by water professionals and academics (Scruggs et al., 2019), but events in California and Texas, the states leading U.S. DPR efforts, and a National Research Council Report (2012b), initiated its acceptance. In 2009, the board of trustees of WateReuse California established an ad hoc committee to explore DPR. Favorable reception by California environmental groups, costly, large-scale purple pipe recycling systems, indirect potable reuse compliance issues resulting from geological conditions, drought, and water treatment technology improvements were some of the factors that made DPR an attractive water source (Miller, 2015).

Advanced treated wastewater

There are two applications of DPR. In the first, advanced treated water (ATW), produced in an advanced water treatment facility (AWTF), is introduced into the raw water source immediately upstream of a drinking water treatment facility (DWTF) as raw water augmentation. This option is used in Texas' Colorado River Municipal Water District's Big Spring Raw Water Production facility and the City of Wichita Falls DPR Project (Mosher & Vartanian, 2018).

In the second, water produced in an AWTF permitted as DWTF is introduced directly into a drinking water distribution system. This process is referred to as treated drinking water augmentation. This method is currently used in Windhoek, Namibia (Tchobanoglous et al., 2015). El Paso, Texas, recently completed pilot testing for this type of DPR project (Walker, 2022).

DPR versus IPR

Distinguished from *de facto* reuse (see Appendix A), both indirect potable reuse (IPR) and DPR are planned uses for treated wastewater. The technical, regulatory, and public perception challenges encountered by, and lessons learned from, the implementation of IPR are not identical to those encountered by DPR (Texas Water Development Board, 2022). They do, however, provide guidance for the implementation of DPR, especially in the areas of public education and engagement (Scruggs, et al., 2019). Both IPR and DPR require public acceptance.

Successful IPR and DPR projects must provide high quality drinking water, and be managed by utilities trusted by regulatory authorities, stakeholders and the public (Texas Water Development Board, 2022).

IPR is wastewater treated to near-potable or potable standards, released into an environmental buffer, mixed with water from other sources, removed from the buffer, and purified to drinking water standards (Hummer & Eden, 2016). In the past, IPR has been the accepted standard, because the public believes that an environmental buffer is necessary to remove contaminants (Nappier et al., 2018). IPR environmental buffers, if available, enable excess water to be stored during low demand times for use during high demand periods, but stored water is always subject to degradation from natural or chemical contaminants (Gerrity, et al., 2013), undetected polluted groundwater (Tchobanoglous, et al., 2011), and agricultural and urban runoff (Leverenz, et al., 2011), requiring additional treatment.

The relocation of IPR to an environmental buffer may involve significant transportation and removal costs. In Las Vegas, for example, treated wastewater effluent flows by gravity to Lake Mead. Before treatment it must be pumped, and then returned to the water supply. In San Diego's proposed IPR system, water will be pumped more than 20 miles, discharged into the San Vicente Reservoir, and then allowed to flow back into to the city for human consumption (Gerrity, et al., 2013). The removal of IPR from a riparian area can also result in long-term habitat loss and destruction of native species, which are then replaced by invasive, non-native species that resist eradication.

As Van Rensberg (2015) noted, the use of IPR is "Ironic in the context of the intense public scrutiny of DPR is the fact that unplanned indirect potable reuse, whereby treated municipal wastewater, and sometimes untreated or poorly treated agricultural or industrial wastes, are returned to a water body upstream of an off-take for a conventional drinking water treatment plant, is being practised to this very day in many places in the world. Yet this practice is considered acceptable despite the ever-deteriorating quality of source water bodies from which potable water is abstracted."

DPR has several advantages over IPR, even though the use of DPR remains controversial (Gerrity, et al., 2013) because of the "yuck factor," defined as the public's perception of that they drinking recycled sewage (Sanchez-Flores, et al, 2016). Treated in an advanced water treatment facility to meet EPA standards (Rock, 2016), there are no restrictions on DPR. Its quality is superior to IPR, and nearly all contaminants can be removed (Graf, 2022).

Because no environmental buffer is required (Hummer & Eden, 2016), DPR can be placed directly into a drinking water system without additional cleaning, pumping, transmission, or water loss, unlike IPR water after buffer removal (Belanger, et al., 2019). So in some circumstances, DPR may be more cost-effective to produce than IPR (Lahnsteiner, et al., 2018).

The absence of an environmental buffer, however, reduces the time operators have in order to identify contaminants and offload water that does not meet drinking water standards; DPR monitoring systems must be responsive and redundant (Rock, et al., 2016). But unlike environmental buffers, engineered storage buffers are contained, controlled, and secure environments that prevent contamination and evaporation, which allows for constant sampling and monitoring from many sources along the purification process (Tchobanoglous, et al., 2011).

Components of a DPR program

Challenges of a DPR program involve technology, regulatory requirements, and public outreach. The technology component establishes treatment technologies capable of protecting public health; treatment performance, reliability, maintenance, and management programs;

multiple technical, operational, and management barriers; and policies for blending DPR with other water sources. The regulatory component addresses potential public health risk and mitigation processes, permitting, and operator training and certification requirements. The public outreach component communicates with and engages stakeholders and the public; establishes outreach challenges, goals, and measures of success; and creates materials and support for effective DPR programs (Tchobanoglous, et al., 2015).

Technological Challenges

Of these three, the technology component is the easiest to resolve, given that high-quality water purification processes have been in use for more than 50 years and are well understood. The challengies lie in implementation, limited by funding, geography, staffing, and the availability of other water resources, rather than technical knowledge.

Advanced wastewater treatment

Advanced wastewater treatment (AWT) is any process that reduces the level of impurities in a wastewater below that attainable through conventional secondary or tertiary treatment (Tchobanoglous, et al., 2015; Institute for Sustainability, n. d.). The application of AWT technology to clean effluent to DPR direct standards has been used for more than 40 years, as the result of incremental changes to existing treatment processes (Leverenz, et al., 2011; Hummer & Eden, 2016).

Future DPR planning and implementation must include a multiple barrier approach to water purification, methods for adding DPR to the existing or new water systems, real-time water monitoring and impurity detection, a containment system for the removal of water that does not meet purity standards, and an engineered storage buffer (American Water Works Association, 2018). AWT plants will be designed, built, and operated with the goals of increasing efficiency and improving demineralization processes with less energy (Leverenz, et al., 2011).

The treatment train

Current DPR treatment trains consist of purification processes, determined by sustainability, costs, site accessibility, and state and local regulations (Hummer & Eden, 2016). The primary objective of the treatment train is to significantly reduce chemical and biological pathogens through a combination of UV disinfection, membrane filtration, ozone oxidation, and chemical disinfection (Khan, 2013).

Biological processes remove excess nutrients, including nitrogen and phosporus. For nitrogen, the two-step process requires nitrification of ammonia nitrogen to nitrate-nitrogen by nitrifying bacteria, then denitrification of the nitrate nitrogen into nitrogen gas. Physicochemical processes including deep-bed filtration, floating media filtration, and membrane filtration. other technologies include ozone treatment, UV exposure, membrane bioreactor, advanced oxidation processes, and nanotechnology (Tuser, 2021).

Treatment must achieve at least 12-log reduction for intestinal viruses, 10-log reduction for Giardia cysts, and 10-log reduction for Cryptosporidium oocysts. Log reductions reduce pollutants by factors of billions or more (Hummer & Eden, 2016).

Monitoring processes, contaminants, pathogens, and risk

Because AWT does not use an environmental buffer, reliable and redundant monitoring are critical (Nagel, 2015) in identifying thousands of unregulated, undocumented contaminants found in municipal wastewater (Rock, et al., 2016). Identifying these contaminants requires using indicator compounds and organisms, and surrogate parameters to estimate concentrations (Rock, et al., 2016; Graf, 2022). An indicator compound is a measurable chemical or microorganism that represents physiochemical and biodegradable characteristics of other chemicals or microorganisms. A surrogate parameter is a measurable change of a bulk parameter that indicates treatment barrier performance (Rock, et al., 2016).

De minimis risk refers to negligible risk levels based on health and safety criteria and toxic exposure. The EPA Office of Drinking Water approaches *de minimis* risk using a regulatory range from 10^{-4} to 10^{-6}, where 10^{-4} defines the level all regulations must meet, and 10^{-6} defines negligible risk is present (Trussell et al. 2013). The EPA has utilized and accepted this level of computed risk as a target for treated drinking water for many years (Rock, et al., 2016).

Blending with other sources

A 2018 Water Research Foundation study concluded that mixing DPR and traditional drinking water sources produced a blend with undetectable organic compounds, similar corrosion levels, and less pathogen growth (Salveson, et al., 2018). Because of its high purity, mixing it with other water sources will increase the purity of the blend (Tchobanoglous, 2011).

Current treatment processes include multiple barriers, microfiltration, RO, advanced oxidation (Leverenz, et al., 2011; Tchobanoglous, 2011). Future processes are expected to increase efficiency, improve demineralization with less energy and provide better monitoring (Leverenz, et al., 2011).

Costs

DPR costs depend on several factors and the choice to use DPR must be done on a case-by-case basis. Studies have compared the costs of AWT, brackish and seawater desalination, and conservation, however, the cost ranges for individual treatment processes, conveyance, engineered and environmental buffers, and blending facilities are not always well-defined (Thobanoglous, et al., 2015). These factors are affected by existing water supply and treatment system technology, local geography, and energy costs, as well as competing environmental, social, and political demands (Kostiuk, et al., 2015). Costs can range from several hundred to thousands of dollars per acre-foot (Raucher & Tchobanoglous, 2014).

Regulatory Challenges

Regulatory challenges require leadership, stakeholder cooperation, and are more difficult to resolve than technical challenges. Laws, regulations, rules, and guidelines can take years to draft and approve, as the technology upon which they were based becomes obsolete.

Federal regulations

The 1948 Federal Water Pollution Control Act was expanded in 1972 as the Clean Water Act (CWA), establishing the regulatory structure for pollutants discharged into U.S. waters (Environmental Protection Agency, 2021b). The 1996 Safe Drinking Water Act (SDWA) amendments required the EPA to consider risk and cost assessments and peer-reviewed science when developing water-related standards (Salveson, et al., 2018). The U.S., however, has no federal regulations addressing reclaimed water use or potable reuse (Rock, 2016), so states and local agencies are responsible for establishing potable reuse standards (Gerling, 2016), provided that those state standards are at least as rigorous as those in the SDWA and the CWA (Environmental Protection Agency, 2022a). California, Arizona, Texas and Nevada have already developed some regulations (Omerod & Singletary, 2020).

The EPA's *2009 National Primary Drinking Water Regulations* document lists more than 90 possible microorganisms, disinfectants, disinfection byproducts, inorganic chemicals, organic chemicals, and radionuclides, maximum allowable concentrations, public health hazards, contaminant sources, and public health goals (Environmental Protection Agency, 2021a). Each contaminant has a maximum contaminant level, specifying its highest allowable level in drinking water (Rock et al, 2016).

State regulations

Federal DPR regulations do not exist. Drought-stricken California and Texas have been especially proactive in drafting DPR-related regulations. The California DPR initiative began in 2012 as a partnership between the WateReuse Research Foundation and WateReuse California (Thomure, n. d.). The state established a water recycling goal of 2.5 million acre-feet by 2030, more than four times its current water recycling effort, which is mathematically impossible with only nonpotable reuse and IPR (Miller, 2015).

California Water Code, Division 7, Chapter 7.3 required adoption of DPR criteria through water augmentation by December 31, 2023 (California Water Boards, 2022). In 2017, the California State Water Board's Division of Drinking Water drafted a single criterion for DPR to streamline system development. The criteria recognized multiple DPR scenarios applied uniform health and safety regulations, defined the relationship between drinking water treatment plants and advanced water treatment trains, and addressed risk management scenarios (California State Water Resources Control Board, 2019). The current criteria also include collection, detection, measurement of chemical and microbial constituents; wastewater source and corrosion control; operator certification; and public health surveillance (Mosher, 2021).

Chapter 28 of California Assembly Bill 574 defines DPR as "the planned introduction of recycled water either directly into a public water system, as defined in Section 116275 of the Health and Safety Code, or into a raw water supply immediately upstream of a water treatment plant…," "raw water augmentation means the planned placement of recycled water into a system of pipelines or aqueducts that deliver raw water to a drinking water treatment plant that provides water to a public water system," and "treated drinking water augmentation means the planned placement of recycled water into the water distribution system of a public water system" (California State Water Resources Control Board, 2019).

The Texas Water Development Board published the 178-page *Final Report: Direct Potable Reuse Resource Document* (2022), establishing source control, monitoring framework, water quality goals, treatment and testing strategies, risk assessment strategies, regulatory and legal considerations, and public outreach plans for DPR implementation. The Texas Commission on Environmental Quality (TCEQ) approves DPR projects on a case-by-case basis in accordance with the innovative and alternative treatment clause in the Texas Administrative Code 30 TAC §290.42(g) that allows "any treatment process that does not have specific design requirements" listed in that chapter to be considered for permitting. A licensed professional engineer must provide pilot test data or data collected at similar full-scale project to demonstrate that the system will produce water that meets all requirements (Mosher, J. & Vartanian, D., 2018).

Colorado and Florida are in the process of considering DPR guidelines (WateReuse Association, 2022b). There are currently no regularly used DPR systems in Colorado. A few utilities have created DPR pilot projects to demonstrate its future usefulness in meeting the state's water needs, requesting the Colorado Department of Public Health & Environment (CDPHE) develop DPR regulations, enabling the utilities to begin communicating with stakeholders and the public about DPR. CDPHE is expected to complete the DPR rule in early 2023 as part of Regulation 11 of the Colorado Primary Drinking Water Regulations (Colorado Department of Public Health & Environment, 2022).

The Florida Department of Environmental Protection is drafting several rules addressing DPR, including Chapter 62-550 F.A.C. Coded Draft Rule May 2021, which establishes DPR water quality standards, defines advanced treated water, and requires DPR pilot programs to demonstrate that an advanced water treatment facility produces water purer than other sources in the area (Florida Department of Environmental Protection, 2022).

Arizona regulations

In 2010, the Governor's Blue Ribbon Panel on Water Sustainability issued its final report, recommending conservation and recycling strategies. In 2012, the Steering Committee for Arizona Potable Reuse (SCAPR) was formed "To guide Arizona water interests in identifying and mitigating impediments to potable reuse (real or imagined) within industry standards of practice" (Thomure, n. d.). SCAPR organized advisory panels to explore flexible advanced treatment technologies for contaminant removal, and public acceptance of potable reuse. Expert input on communication strategies, best practices, timelines, and public relations campaigns were collected and published (Thomure, n. d.).

Arizona's Next Century: A Strategic Vision for Water Supply Sustainability, published by the Arizona Department of Water Resources (2014), noted that exploration of DPR was necessary due to increasing water demand. The report established a 10-year plan, including a review of legal and institutional barriers to DPR. The report stated that reclaimed water could offset projected state water imbalances by about 50%.

Arizona has a good start. ADEQ set stringent treatment standards for new and expanding wastewater treatment plants that require nitrogen reduction to below drinking water limits and removal of fecal coliform bacteria, an indicator of pathogens to non-detectable levels. Water quality standards are designated in rule for five reclaimed water quality classes, based on human health protection, and an effective permit system expanded safe reclaimed water use (Graf, 2016).

On January 1, 2018, the Arizona Administrative Code preventing water providers from using recycled water for DPR was repealed (Graf, 2022), and replaced by *Part E. Purified Water for Potable Use R1809-E701 Recycled Water Individual Permit for an Advanced Reclaimed Water Treatment Facility* (State of Arizona, 2019a). The new regulation specified that an AWTF could submit an application for a recycled water permit to ADEQ that included information on how the facility would meet the SDWA.

Other application requirements include the facility's design to be certified by a professional engineer; water source flow data; chemical and microbial maximum contaminant levels; water constituents used for treatment monitoring and efficiency; laboratory analysis methods; results of pilot water treatment; operation and maintenance plans, including corrective actions for out-of-range results and contingencies for the relocation of non-compliant water; operator training plans; and technical, financial, and management capability (State of Arizona, 2019).

Public Outreach Challenges

Public relations challenges

The public often, and incorrectly, believes IPR obtained from ground filtration to be purer than DPR water from an AWTF, failing to understand that unless their water is derived from deep aquifers or pristine rivers, they are likely drinking water that has already been processed at an upstream wastewater treatment facility, or that has come in contact with agricultural, industrial, or municipal runoff (Salveson, 2016; Campbell & Scott, 2011; Leverenz, et al., 2011). IPR is not a new idea. Creating major distinctions between it and DPR for the consumer is confusing and rife with misinformation (Salveson, 2016).

The best technology and well-drafted regulations will not overcome the absence of public acceptance and the presence of misinformation for either IPR or DPR projects (Walker, 2022). A 2010 California study identified key components of a successful public DPR campaign: develop appropriate technology, survey stakeholders, create messages based on the outcomes of similar projects, and formulate a communications strategy (Cain, 2011).

In order for DPR to be accepted, water managers and utilities need to clearly communicate the differences in concise language that can be understood by non-scientists (Salveson, et al., 2016). Public IPR and DPR outreach must include a rationale for its use, water safety and security, identification of public perception, a communication plan, project materials, and opportunities for the public to visit proposed DPR facilities, if possible (Tchobanoglous, et al., 2015). The media can play a role in disseminating information and preempting public misinformation and objection (Tortajada & Nambiar, 2019).

One of the best ways to understand these challenges is to examine both failures and successes of international (see Appendices B and C) and domestic IPR and DPR projects (see Appendices D, E, and F) where social, political and economic challenges played significant roles in public rejection and acceptance.

The Denver DPR Pilot Program

In 1970, Denver built an AWTF pilot plant, funded by an EPA grant to the University of Colorado. For five years, the plant used secondary effluent from the Metropolitan Denver Sewage Disposal plant to demonstrate the safety and reliability of the plant. After the grant expired, Denver continued to maintain and upgrade it (Cain, 2011; Work, 1980).

Research and design data were collected with economic, legal, and marketing feasibility studies including U.S. EPA participation, analytical quality testing, and health effects research.

Before the study, a University of Colorado survey showed that only 38% of participants favored DPR, but after public education efforts, another public opinion survey showed that 84% of Denver customers would accept DPR if water quality met or exceeded their current drinking water parameters and if safety was certain. The attitudes of Denver's citizens were clearly affected by public education and outreach efforts (Cain, 2011; Work, et al., 1980).

Between 1985 and 1992, Denver conducted a DPR demonstration project to examine the feasibility of converting secondary effluent from a water treatment facility (WTF) to potable water quality that could be piped directly into the drinking water system (Tchobanoglous, et al., 2011). One of the program's goals was to generate public awareness of DPR as a possible future drinking water source. It was the first municipal DPR program to survey the public about reused water as a potable source (Macpherson & Snyder, 2013).

The influent to the DPR plant was unchlorinated secondary effluent treated at the Denver Metropolitan Wastewater Reclamation District's regional WTF. The treatment process at that facility included removal of sediment and sludge. The water fed into the DPR treatment system, which included UV, RO, ozonation, chlorination, and ultrafiltration, was not used, but stored and shown as part of the project's public outreach program (Tchobanoglous, et al., 2011).

DPR in Big Spring, Texas

Formed in 1949, the Colorado River Municipal Water District (CRMWD) supplies water for arid west Texas communities, including Big Spring. Between 1950 and 1990, CRMWD built three dams to create surface water reservoirs storing water from Texas' Colorado River and developed four large groundwater well fields. Although CRMWD's surface water reservoirs have a combined storage capacity of over 1.2 million acre-feet, drought resulted in water levels below intake levels and dry reservoirs (California State Water Resources Control Board, 2016).

Sixty inches of annual evaporation, several decades of drought, and an increasing population related to the oil and gas industry, lack of space for an additional reservoir, and no suitable aquifers, caused CRMWD to reject both IPR and more expensive desalination (Sanchez-Flores, et al., 2016; Scruggs, et al., 2016).

Construction of the Big Spring reclamation facility began in 2010. By 2013, 2.5 million gallons per day of treated Big Spring effluent was being diverted to an advanced water treatment facility where it was purified using microfiltration, RO, and advanced oxidation processes. That water was then blended with treated water from the system's three reservoirs, piped into the Big Spring water treatment plant, and treated to SDWA standards (Sanchez-Flores, et al., 2016).

As the only option available, the Big Spring DPR project was successful because the CRMWD and the TCEQ conducted an extensive operation, monitoring, and reporting evaluation process (Tchobanoglous, et al., 2011).

Between 2005 and 2007, CRMWD presented and explained the DPR concept in public town-hall meetings. Media assistance from the *Big Spring Herald*, which accurately portrayed the project, and Texans' appreciation of the importance of water, nearly eliminated public opposition. As the first DPR facility in the U.S., Big Spring also made national headlines (Scruggs, et al., 2020).

Scottsdale's Water Campus: DPR comes to Arizona

The AWTF at the Scottsdale Water Campus, one of the most sophisticated water treatment systems in the world and has been recharging ultrapure water into the drinking water aquifer for more than 20 years (Grendahl, 2022). The plant's underground storage has an annual permit limit of 16,800 acre-feet for recharge of CAP, and the reclaimed wastewater is used primarily on golf courses. During the winter, when the golf courses require less water, the stored water is recharged into the aquifer through dry wells (Eden, et al., 2007).

In 2013, the plant became the first in the country to use large-diameter RO technology to remove hundreds of contaminants of emerging concern (CECs) identified by University of Arizona and Arizona State University experts. Based on their recommendations ultraviolet and ozone treatments were added to the treatment train. The Campus has a state-of-the art water quality testing laboratory and an online, real-time monitoring system (Hummer & Eden, 2016).

In September 2019, at the end of a pioneering 18-month permitting process, the Arizona Department of Environmental Quality (ADEQ) issued Arizona's first permanent DPR permit to Scottsdale Water (City of Scottsdale, 2022). To obtain the permit, Scottsdale Water relied on its 23 years of IPR experience (Grendahl, 2022). This ultrapure water will not, however, be part of Scottsdale's drinking water system, and will continue to be used to water golf courses and recharge the aquifer. Scottsdale has more than adequate water supplies to serve its customers, but under prolonged drought conditions, DPR may be an option in the future (Baumgardner, 2022). DPR costs are currently higher than CAP surface water costs, however, as drought pricing continues to increase the cost of CAP surface water, DPR and CAP costs may be similar (Kirklin, 2022).

Scottsdale Water "capitalized on this vast experience to educate our customers about recycled water. This public outreach has been extremely successful and has made extensive strides toward acceptance of the one water concept" (Grendahl, 2022). The Water Campus DPR permit only allows the utility to provide water for making a water-based beverage for an event, or direct tasting of the water by 1,500 people in a year. Since receiving the permit, Scottsdale

Water has been providing taste testing at its Water Citizen Academy and during facility tours (Grendahl, 2022).

ADEQ does not currently have a DPR operator certification program, so the Water Campus requires that the operator in charge have both Grade 4 Wastewater Treatment and Grade 4 Drinking Water Treatment certifications. Lower-level operators must maintain wastewater treatment certification, and work toward gaining drinking water certification. The ADEQ Water Quality group provides annual drinking water training to operators and responds to questions and concerns (Grendahl, 2022).

The permitting process established by ADEQ with Scottsdale Water will serve as an example for the agency working with other Arizona water utilities attempting to obtain a DPR permit (City of Scottsdale, 2022), especially those that may not have large water departments (Mosher & Vartanian, 2018; Graf, 2022).

In 2019, ten Scottsdale breweries were serving specialty beers made from the AWTF wastewater for the One Water Brewing Showcase, an event sponsored by Scottsdale Water and Scottsdale Arts to celebrate the utility's DPR permit, the third issued in the U.S., and to educate the public about DPR (Sherbert, 2019).

Arizona Pure Water Brew Challenge

In 2008, Pima County and Tucson were about to begin a regional water study that included a water inventory, wastewater infrastructure, future water demand, and ways to cooperate. Reclaimed water was being used only for watering grass and on golf courses, and voters were urged to accept Proposition 200, a ban on "toilet-to-tap" water by some Tucson activists, even though its use wasn't legal in Arizona. The proposition was defeated by 72% of voters, despite reports that pharmaceuticals had appeared in drinking water supplies (Meltzer, 2008).

At the time, some water lawyers speculated that if effluent were treated to drinking water standards, it could be delivered without changing state law, but state officials said otherwise. Scientists at San Diego's Scripps Institution of Oceanography said there was a 50% chance that Lake Mead would be dry by 2021, endangering the supply of CAP water (Meltzer, 2008).

County Administrator Chuck Huckleberry said the technology for treating wastewater was improving, and by the time local policymakers need to make decisions about Tucson’s water future, treated effluent might be cleaner than the water that was in Tucson’s drinking water supply (Meltzer, 2016).

Eight years later, in 2016, the Arizona Community Foundation announced the $250,000 Water Innovation Challenge at the March WaterNow Alliance Sustainable Water Summit in Tempe. The challenge’s purpose was to “advance the sustainability of Arizona’s water future and engage all Arizonans in safeguarding water as a precious resource” (WaterNow Alliance, 2017). Twenty-three proposals were evaluated by 20 judges, who selected the Arizona Pure Water Brew Challenge (AZ PWBC) as the winner. Its goals were to engage the public in discussions about water reuse and build acceptance of DPR as a drinking water source (WaterNow Alliance, 2017).

AZ PWBC was comprised of personnel from of Pima County RWRD, Marana Water, Tucson Water, University of Arizona, CH2M, Carollo Engineers, HDR, WateReuse, AZ Water, and Clean Water Service (Arizona Community Foundation, 2018). AZ PWBC built a mobile advanced wastewater treatment facility in an old shipping container (Sheehy, 2018), traveling around Arizona and providing breweries with purified wastewater, labeled as *AZ PURE*. Like other DPR efforts, the treatment train included an ultrafiltration membrane, RO membranes, UV disinfection, advanced oxidation, granulated carbon columns, and a chlorine contact chamber (Arizona Community Foundation, 2018).

The team attended state-wide events, local fairs, gave tours of the mobile facility and provided visitors with a bottle of purified water. Twenty-six breweries in Arizona chose to use the truck's purified water in beers they produced for a September 2017 beer competition. Each brewery received between 300 and 1,000 gallons of *AZ PURE* (WaterNow Alliance, 2017; Arizona Community Foundation, 2018). The challenge was won by Tucson's Dragon Brewery (Sheehy, 2018).

In 2017, the beer truck traveled more than 5,000 miles, attending 16 events in seven Arizona cities, and others in Long Beach and Denver treating more than 82,000 gallons of municipally treated wastewater. It was tested more than 3,000 times by University of Arizona's Water & Energy Sustainable Technologies Center, Pima County RWRD Compliance and Regulatory Affairs (CRAO) Laboratory, University of Arizona's WEST Center Chemical Engineering Lab, Eaton Eurofins Analytical, and Radiation and Safety labs, into high purity bottled water suitable for beer (Arizona Community Foundation, 2018; WaterNow Alliance, 2017).

To determine the public's attitude about DPR, the team, WaterNow, and Arizona State University's Decision Center for Desert Cities surveyed and collected more than 2000 responses. One format assessed changing public attitude, and the second was administered to visitors of the mobile truck. WaterNow and AZ PWBC created a messaging strategy, reminding the public that "all water is recycled" and "judge water by its quality, not its history," while avoiding terms including "effluent" and "recycled wastewater." They used Facebook, Twitter and Instagram, and drafted family, friends, colleagues, and water experts to volunteer (WaterNow Alliance, 2017).

Media outlets in San Francisco and Ft. Collins publicized the beer challenge. Fifty-eight stories about the beer challenge reaching 1.6 million Arizonans and 1.3 million Twitter users. As a result, the AZ PWBC received $1.5 million in in-kind equipment and consultation service donations (WaterNow Alliance, 2017).

Feasibility and the future

Future technology, regulatory, public outreach requirements, and Tucson

Before a community or water utility can implement DPR, there are many technological, regulatory, and public relations questions that need to be addressed. WateReuse, National Water Research Institute, the American Water Works Association and Water Environment Federation convened an independent panel to identify issues that could lead to federal regulations and guidelines (Tchobanoglous, et al., 2015).

Future technology-related needs include improved real-time monitoring, implementation of new water purification methods and engineered storage buffers, and exchange of AWTF performance data (Tchobanoglous, et al., 2015).

Future regulatory needs include DPR rules and guidelines that integrate CWA and SDWA permitting, technology specifications to minimize public health risk, treatment process standards, and operator training and certification requirements. Part of the guidance in the permitting process is to ensure that critical control points between treatment processes are effective, ensuring that water that is not meeting the highest quality anticipated at the end of the process is not accidentally released to the customer. Critical control point monitoring will be at a key factor in the permitting process, and in the engineering design or any treatment process (Kmiec, 2022).

Federal regulations, however, must address existing state regulations and guidelines, including those in California, Texas, and Arizona, because each has been successful and proactive in DPR. Their experiences inform the future. Provided that states adhere to the minimum requirements established by the CWA and SDWA could also provide useful assistance to states and local utilities with less technical capacity that are considering DPR (Smith, 2018).

Future public outreach requires recognition of political, social, and economic conditions that affect public DPR perception, stakeholder and community participation, activities that build trust between the community and water utilities, and clear messages about DPR that limit misinformation (Tchobanoglous, et al., 2015; Smith, 2018). Tucson Water continues to create well-developed public campaigns to ensure that Tucson Water's messaging is clear. The introduction of DPR would be prepared well in advance and with a lot of thought, public courtesy, DPR facts, and opportunities for public dialog (De Roock, 2022).

The Arizona Water Reuse Association is developing DPR rules with ADEQ. Together they have initiated discussions to delineate DPR regulations and guidelines (Walker, 2022). They suggest that the state allow Class A+ or Class B+ reclaimed water as the input into AWTF for DPR production. By utilizing "+" grade water the need for nitrogen treatment is minimized (Arizona Department of Environmental Quality, 2018).

The DPR proposed rules document states that Arizona DPR projects conduct a six-month, site-specific, scalable pilot study to verify treatment technologies. Although the technologies are well understood and have been successful in ensuring public health, each location has different water sources and operates in a unique community. Public support and acceptance have proven critical, and can be facilitated by allowing the public to sample water produced by the pilot AWTF plant (Arizona Department of Environmental Quality, 2018).

No DPR for Tucson, at least for now

On January 1, 2023, the Rio Verde Foothills community will no longer receive water delivered from Scottsdale. Arizona's western town of Cibola has acres of farmland that Greenstone, a Phoenix investment firm, is trying to purchase for its Colorado River water rights which it plans to sell to Queen Creek. These situations are just the beginning. Kyl Center for Water Policy in Arizona senior research fellow Kathleen Ferris claimed that these water battles, between the "haves" and "have nots" are reminiscent of those of the Wild West (Marsh, 2022).

Unlike Rio Verde Foothills and Cibola, Tucson is not dealing with a water shortage, and the city and Pima County need not be worried about developers usurping CAP water. Future DPR discussions, if they occurred, would be held at the policy level between Tucson Water, the city manager's office, and the mayor and council at that time, who would have to approve the capital improvement budget for Tucson Water (Kmiec, 2022).

Tucsonans are proven conservationists. Between 1989 and 2015, Tucsonans reduced their water use from 188 gallons per day to 130 gallons per day, a 30% decrease. Despite an increase of more than 200,000 residents, Tucson's 2015 water use was about the same as it was in 1985, declining by about 23.3% between 2005 and 2015 (Mayer, 2017). In 2018, Tucson was named one of five national winners in the 7th Annual Wyland National Mayor's Challenge for Water Conservation (City of Tucson, 2018).

Tucson has a municipal and industrial subcontract for CAP water and that type of contract is higher level priority user contract, higher than agricultural contracts. Even under Tier 2 and Tier 3, Tucson Water's CAP contract will not change. Tucson Water will still be able to order CAP water, store and use it, and have an annual water excess. Under the Tier 2 or Tier 3 cuts, the annual order may be reduced by as much as 20%, but Tucson Water's annual total demand by Tucson Water customers is currently just over 100,000 acre feet per year. Under current scenarios, Tucson Water banks about a third of its CAP allotment for future use, so there will be sufficient water to meet the needs of Tucson Water customers in the future (Kmiec, 2022).

Tucson Water's (2015) 2020 Strategic Plan includes two water source and quality issues, *Key Policy Issue No. 3: Meet All Current and Future Water Quality Issues and Requirements* and *Key Policy Issue No. 5: Strengthen Both the Water Supply Sustainability and the Financial Stability of Tucson Water* (Tucson Water, 2015). Neither addresses DPR, nor does ADEQ's 2021 *Charter Onsite Wastewater Treatment Technical Work Group document* (Arizona Department of Environmental Quality, 2021)

Tucson Water, Pima County Regional Wastewater Reclamation Department, and DPR

Tucson Water will continue to provide technical assistance to ADEQ, because there may be a time in the future when Tucson may want to utilize DPR. Tucson Water wants to make sure that state rules and those who are already engaged in DPR, are doing it safely, effectively and efficiently. "Tucson Water is doing the legwork to ensure that the rules and guidance are there to ensure safety, quality, effectiveness, and efficiency are all part of the process" (Kmiec, 2022).

The utility is working with ADEQ to address CECs. The EPA has a list of nearly 100 regulated compounds and is performing measurements on unregulated contaminants, including pharmaceuticals, to ensure that removal occurs before the final product is added to the water system (Kmiec, 2022).

Pima County RWRD, like most Arizona wastewater reclamation facilities, produces Class A+ water. “If you subscribe to the one-water concept of reusing water over and over, it's not that big of a leap to purify the water to the highest extent possible and it keeps water locally. It’s always going to be the least expensive alternative source of water” (Prevatt, 2022).

If DPR becomes part of the city or county’s water portfolio, the utilities will need to address potential environmental impact on riparian areas currently benefitting from recharge efforts, requiring making compromises (Prevatt, 2022).

DPR may become a viable alternative in small- and medium-sized cities that cannot rely on CAP or Salt River Project water, or who lack varied and stable water resources (Mosher & Vartanian, 2018). Both utilities’ efforts will likely help those communities with lower water utility budgets: “…we learned early on in our marketing campaign was that it probably won't be Phoenix, Tucson or any of the larger cities. It will likely be communities like Williams, Arizona, or remote places that simply don't have the resiliency of alternative water sources...it is incumbent on the larger communities like the Phoenix cities, Pima County and the City of Tucson to partner together and do the heavy lifting, research and demonstrations. Otherwise, the smaller communities will continue to be challenged” (Prevatt, 2022).

Appendices

Appendix A: Water reuse terms

Advanced oxidation: use of ozone , ultraviolet (UV) light, and hydrogen peroxide to for pathogen disinfection and organic contaminant removal (Gerling, 2016)

Advanced wastewater treatment (AWT): the processes and procedures involved in wastewater treatment, beyond secondary treatment, for direct potable reuse applications (American Water Works Association, 2018)

Biological treatment: using bacteria and other microorganisms to remove organic materials, including nitrate and nitrite (Gerling, 2016)

Class A+ water: reclaimed water is wastewater that has undergone secondary treatment, filtration, nitrogen removal treatment, and disinfection, and there are fewer than 23 coliform organisms in 100 milliliters (State of Arizona, 2019b)

Class B+ water: reclaimed water is wastewater that has undergone secondary treatment, nitrogen removal treatment, and disinfection, and there are fewer than 800 coliform organisms in 100 milliliters (State of Arizona, 2019b)

De facto reuse: treated wastewater is reused but not officially recognized or planned, for example, drinking water is used downstream from a wastewater treatment plant (WWTP) (Environmental Protection Agency, 2012)

De minimis levels: the minimum threshold for which a conformity determination must be performed, for various criteria pollutants in various areas (Environmental Protection Agency, 2021c)

Direct potable reuse (DPR): introduction of reclaimed water, with or without retention in an engineered storage buffer, directly into a drinking water treatment plant, either located with or remotely from the advanced wastewater treatment system for the purpose of augmenting the potable water supply (Environmental Protection Agency, 2012; Miller, 2015)

Effluent: treated wastewater to a quality level that meets regulations allowing it to be discharged to a water body or used for purposes that will not result in human contact (Middel, 2013)

Engineered storage buffer: storage facility used to provide retention time before advanced treated water is introduced into the drinking water system (American Water Works Association, 2018)

Environmental buffer: a groundwater aquifer, surface water reservoir, lake, or river, in which advanced treated water is introduced before being used for potable reuse (American Water Works Association, 2018)

Indirect potable reuse (IPR): a surface or groundwater drinking source is augmented with reclaimed water followed by time in an environmental buffer before drinking water treatment (Environmental Protection Agency, 2012; Water Research Foundation, 2015)

Membrane filtration: use of microfiltration and ultrafiltration membranes to remove suspended particles and pathogenic microorganisms (Gerling, 2016)

Membrane desalination: use of reverse osmosis (RO) and nanofiltration barriers to remove salts, pharmaceuticals, and other dissolved contaminants (Gerling, 2016)

Non-potable reuse: planned water reuse applications, including irrigation, landscaping, recreational lakes, toilets, fire hydrants, decorative fountains, and other uses that do not require drinking water quality (Environmental Protection Agency, 2012; National Research Council, 2012a)

Ozone: used to disinfect and break down organic contaminants (Gerling, 2016)

Planned water reuse: refers to water systems designed to beneficially reuse wastewater; includes agricultural and landscape irrigation, industrial process water, potable water supplies, and groundwater supply management (Environmental Protection Agency, 2022a)

Potable reuse: planned augmentation of a drinking water supply with reclaimed water (Environmental Protection Agency, 2012)

Preliminary treatment: removal of suspended and floating particles (Gerling, 2016)

Primary treatment: removal of some suspended solids and organic matter (Gerling, 2016)

Reclaimed water: synonymous with recycled water; a subcategory of effluent treated to a standard allowing for reuse in environments with limited human contact, for example, as a golf course water source municipal wastewater treated to meet specific water quality criteria for reuse (Middel, 2013; Environmental Protection Agency, 2012)

Secondary treatment: removal of remaining suspended solids and organic matter (Gerling, 2016)

Tertiary treatment: removal of targeted dissolved solids and finer suspended materials (Gerling, 2016)

Unplanned water reuse: refers to situations in which a source of water is mostly previously used, treated, reclaimed municipal wastewater; occurs, for example, when a community gets its water supply from a river that receives water from upstream treated wastewater discharges (Environmental Protection Agency, 2022a)

Wastewater: used water discharged from homes, business, industry, and agricultural facilities (Environmental Protection Agency, 2012)

Water reuse: also known as water recycling or water reclamation, reclaims water from a variety of sources then treats and reuses it for agriculture and irrigation, potable water supplies, groundwater replenishment, industrial processes, and environmental restoration (Environmental Protection Agency, 2022a)

Appendix B: Windhoek, Namibia: DPR comes to sub-Saharan Africa

Windhoek, Namibia's water supply consists of dams fed by ephemeral rivers and borehole water (Lahnsteiner, et al., 2013). As the most arid country in sub-Saharan Africa, its water sources rely on infrequent and inconsistent rainfall. The city exhausted all conventional water supplies within 500 kilometers, considered transporting water from the Okavango River, more than 800 kilometers from the city, or using desalinated seawater pumped up 1700 meters, but those scenarios were too expensive (Van Rensberg, 2016).

The city has been treating wastewater for more than 45 years. The country has no wastewater guidelines, so the city established its own. Between 1964 and 1968, the Windhoek City Council, National Institute for Water Research, and Council for Scientific and Industrial Research, performed a DPR pilot study. The Goreangab Water Reclamation Plant began producing high-quality effluent for DPR using only domestic sewage as the world's first DPR project (Lahnsteiner, et al., 2018; Sanchez-Flores, et al., 2016). The fully automated plant, run by three trained operators per shift, continuously monitors water purity. The plant is producing 21,000 cubic meters (5.5 million gallons) per day (Lahnsteiner, et al., 2013), 28% of city demand, at a cost about 37% lower than the cost of potable water from surface water sources, providing blended water to customers (Van Rensberg, 2016; Lahnsteiner, et al., 2018; Lahnsteiner, et al., 2013).

The plant's treatment train consists of powdered activated carbon pre-ozonation, enhanced coagulation and flocculation, dissolved air flotation, dual media filtration, main ozonation, biological activated carbon filtration, granular activated carbon adsorption, ultrafiltration, chlorine disinfection, and stabilization with caustic soda (Lahnsteiner, et al., 2013).

In 2015, the city created its *Drought Response Plan* that includes media information dissemination, water restrictions and monitoring, tariff programs, weather forecasting and further drought predictions, facility tours, school water education programs (Department of Infrastructure, Water and Technical Services, 2015; Van Rensberg, 2016). As Lahnsteiner et al. (2015), noted, “It is all the more remarkable that this success story has been achieved in a country with limited technical and financial resources. In other words, it is quite exceptional that a developing country like Namibia leads the way in potable water reuse.”

Appendix C: Toowoomba, Australia, IPR, and lessons learned for DPR

In Australia, use of recycled water for drinking purposes is subject to many national guidelines (Hurlimann & Dolnicar, 2010). In 2005, Toowoomba, located in eastern Australia, and home to about 95,000 people (Walker, 2022), relied on surface water from dams, and was experiencing a major water crisis. Minimal water use restrictions began in 2003, reaching a much higher level in 2006. Those high restrictions were still in effect in 2010 (Hurlimann & Dolnicar, 2010).

The Twowoomba City Council announced the *Water Futures Initiative*, and submitted an IPR proposal to the National Water Commission. The project had significant local, regional, and state political support. The Council expected funding to be approved later that year. At a club meeting, a month before the proposal was submitted, the mayor told attendees that “they would soon be drinking sewer water” (Scruggs, et al., 2019).

In response to that comment, Citizens Against Drinking Sewage (CADS) was formed by a wealthy property developer, former mayor, and past president of the Chamber of Commerce.

The group's town forum and newspaper advertisements erroneously led citizens to believe that water reuse was dangerous before proponents had the opportunity to publicly discuss its benefits using science and facts (Hurlimann & Dolnicar, 2010). By February 2006, CADS had obtained 10,000 signatures on a petition against IPR (Scruggs, et al., 2019).

The City Council began a 10-week public relations campaign before a July 2006 referendum, when 62% of Toowoomba citizens rejected the IPR program. Complicit in the defeat was the *Courier-Mail* newspaper, which consistently complained about the project's technology, claiming that IPR included pesticides and heavy metals. The paper also implied that the lack of information from government officials was a cover-up, and that the project was too expensive.

But the need for a new water source remained. In 2008, a pipeline connecting Toowoomba's Lake Cressbrook with Brisbane's Wivenhoe Dam was completed, at a cost higher than the proposed IPR project (Tortajada & Nambiar, 2019). Toowoomba received its first water from the pipeline in 2019 (TripleMMM, 2019). Toowoomba's *Regional Council Water Vision 2050 Annual Report: Direct Potable Reuse*, published in 2020, states that community acceptance of DPR is very low (Engeny Water Management, 2020), likely due to the negative publicity of IPR years earlier.

Appendix D: San Diego, IPR, and what a difference education makes

By 1990 up to 90% of San Diego's water supply was imported (Scruggs, et al., 2019). During the 1990s, San Diego tried to implement a potable reuse project, led by staff from the city wastewater division, who had little interaction with the community. The local media referred to the project as "toilet to tap," reporting that the proposed water source was contaminated. Water department staff did little to correct the misconceptions. In 1998, city council and state assembly candidates criticized incumbents for supporting the project, accusing them of targeting African American communities with the prospect of unsafe water. The project was halted (Smith, et al., 2018).

The city learned its lesson. In 2009, the city started the *Water Purification Demonstration Projec*t to show residents that IPR was safe and that a large-scale project could provide a reliable drinking water supply. The project was renamed *Pure Water San Diego*. The city hired a public information officer, explained to the public why alternative drinking water sources were necessary, demonstrated the water's purity, and enlisted the support of academics and medical professionals to work with the media to ensure that water messages were factual and clear (Environmental Protection Agency, 2019).

The public can tour the facility to learn about IPR technology and taste purified drinking water (Environmental Protection Agency, 2019). Surveys conducted by the San Diego County Water Authority demonstrated a substantial shift in public opinion of IPR between 2004 and 2011. In 2004, 45% of residents opposed using advanced treated recycled water, but by 2011, that number fell to 11% (Environmental Protection Agency, 2012), with many respondents requesting that highly purified water be used directly, rather than being released into the ground or a storage facility before use (Tortajada & Nambiar, 2019). DPR projects, take note.

Appendix E: Wichita Falls DPR learns from Big Spring DPR

In 2012, Wichita Falls reservoirs were at less than 20% capacity, groundwater was unavailable, and water managers recognized that DPR was the only option remaining. The city had already installed an AWTF system to treat a brackish lake for IPR. Turning to Big Spring for advice, the city began the 27-month permitting process with TCEQ. Anticipating approval, a 13-mile above-ground pipeline was built to transport effluent from the wastewater treatment plant to the AWTF system at a cost of $13 million. The system came online in July 2014, providing 18.9 million liters of potable water per day, one-third of the city's daily demand. The drought ended a year later and the system was converted back to IPR, delivering treated wastewater to Lake Arrowhead (Scruggs, et al., 2020).

The Wichita Falls DPR program encountered almost no opposition. The water utility had an excellent reputation and a 40-year history of operating an IPR (Environmental Protection Agency, 2019). Before the process began, city officials received support from professors, local doctors, and the media, which broadcast a press conference at the depleted reservoir to demonstrate how scarce water was. They discussed conservation efforts, introduced the DPR project, and emphasized public safety. Town meetings and YouTube videos further educated the public about the project. The water utility set up a call-in line to respond to community concerns, but very few used it (Scruggs, et al., 2020).

Appendix F: El Paso: America's first permanent DPR treatment plant

In 1991, El Paso Water (EPWater) implemented a 50-year water plan to diversify its water resources. In 1985, the utility began using IPR, gaining the trust of its customers. In 2014, EPWater surveyed its customers about using highly treated wastewater into its drinking water system. Before any outreach efforts, the utility found that 84% of its customers approved. After outreach efforts, another survey showed that 90% of respondents favored a DPR project (Brown, 2019).

EPWater conducted a feasibility study funded by the U.S. Bureau of Reclamation, operated a nine-month pilot program, and hired an engineering firm, ARCADIS, to implement an innovative four-step membrane technology: RO, UV disinfection with advanced oxidation, and granular activated carbon filtration technology. The utility was already using these processes, but not combined in a single treatment train (Brown, 2019).

EPWater's advanced water purification facility proposal was approved by TCEQ. The utility received a U.S. Bureau of Reclamation $3.5 million grant to cover 25% of the costs for design and pilot testing, with EPWater providing the remaining 75%. As of 2019, 30% of the design was completed (Brown, 2019).

This is the second DPR plant in the world that will provide customers with a permanent DPR source. The plant is being designed with an auditorium and hallway where residents can learn about and see the treatment process, and a room where they can sample the purified water. Plant operators are using virtual reality headsets to visualize the completed facility while learning to identify safety issues (Brown, 2019).

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