Where Wastewater Treatment Ends and Drinking Water Begins: Evaluating the Viability of Potable Reuse in Florida

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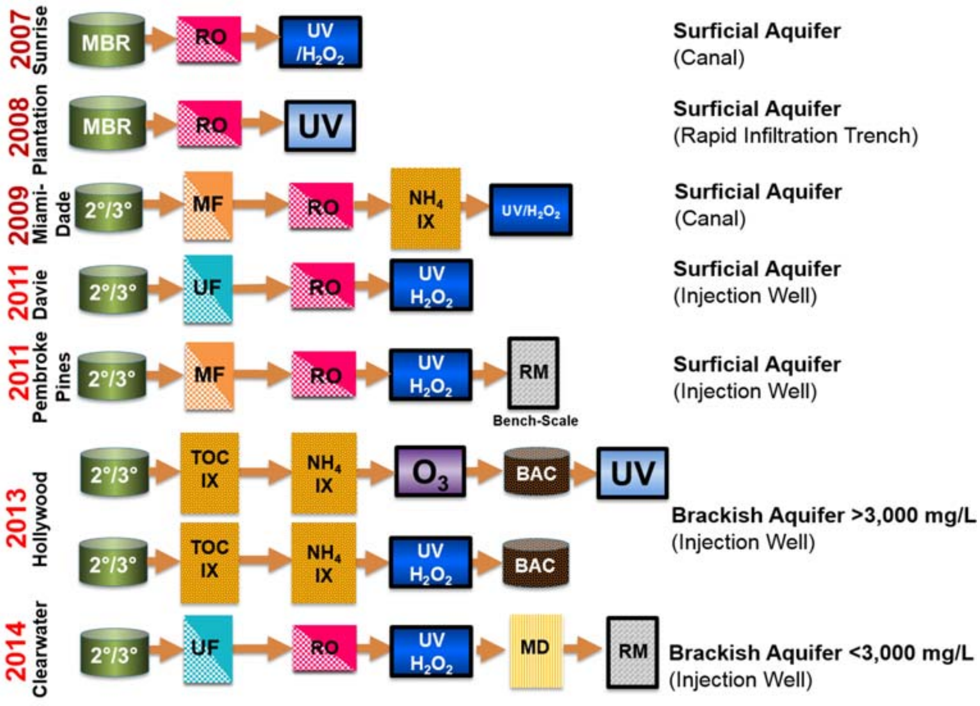
Florida's Challenges

As Florida's population continues to grow, along with demand for additional water supply and concerns regarding surface water nutrient changes, the state will face an increasing need for innovative water supply source and management solutions, which will, in some cases, include potable reuse. Over the last 50 years, municipal water treatment has advanced in response to an increased understanding of the importance of water quality to public health, and water quantity to meet increasing challenges placed on the state's resources by a population that has more than tripled, from 5.7 million in 1964 to more than 19 million in 2014. In that year, Floridians used more than 2,300 mil gal per day (mgd) of potable water. In fact, most of the state's population lives inside a "water resource caution area."

In 2013, Floridians generated over 1,603 mgd of sewerage flow to wastewater treatment facilities. Florida leads the nation in reuse of wastewater, capturing over 44 percent of the flow (719 mgd) for beneficial reuse. This means that most of the state's wastewater is still lost as a resource, presenting the opportunity for potable reuse to take advantage of the wastewater that is not beneficially reused. Increasing concerns about nutrient discharges and saltwater intrusion have placed an emphasis on recovering more benefit from the untapped 56 percent of wastewater flow.



MBR-Membrane bioreactor, RO-reverse osmosis, UV/H2O2-ultraviolet advanced oxidation with hydrogen peroxide , UV-ultraviolet disinfection, 2°/3° – secondary or tertiary wastewater treatment, MF-microfiltration, NH_4 IX-ammonia-ion exchange (cationic), UF-ultrafiltration, RM-remineralization, TOC-IX-TOC ion-exchange (anionic), O_3 – ozone, BAC – biological activated carbon, MD – membrane degasification

Figure 1. Seven Recent Florida Potable Reuse Pilots

In the past ten years, at least seven communities have pilot-tested potable reuse technology. Many of these communities were driven by the Ocean Outfall Rule, which will come into effect within the next 10 years; other communities were driven by concerns about limited alternative water supplies, like brackish reverse osmosis (RO), minimum flows and levels (MFL), or other regulatory issues. The new challenges Florida is facing are leading to a historically unprecedented transition that will change the way water is used.

This article discusses the positive impact of potable reuse on Florida's water future, considering seven recent potable reuse pilots, cost comparisons of alternative water supply (AWS) treatment methods, and a concluding discussion on the prospects of direct potable reuse (DPR), which is a technically and financially viable option that will help to enhance the state's approach to integrated water management. While other less costly water management alternatives (e.g., rapid infiltration basins, nonpotable salt water intrusion barriers, etc.) may exist in some circumstances, the financial viability of potable reuse is expected to improve further, with future innovations and increased regulatory drivers to eliminate surface water discharges, driving its adoption across the state.

Florida Potable Reuse Pilot Studies

Summary of Pilot Studies and Treatment Results

Within the past 10 years, several Florida communities have undertaken pilot studies of potable reuse, including Sunrise, Plantation, Miami-Dade County, Davie, Pembroke Pines, Hollywood, and Clearwater. All of these studies were examples of indirect potable reuse (IPR), where purified water would be returned to the surficial aquifer or a deeper brackish aquifer. Six out of seven of these pilot studies were conducted in southeast Florida and driven by the pending Ocean Outfall Rule, which calls for reductions in nutrient discharges by 2018 and elimination of ocean outfall discharges by 2025 (except for peak flows). Collectively, the results of these pilot studies demonstrate that potable reuse is a technically viable water supply enhancement option for Florida.

Figure 1 provides a timeline of the potable reuse pilots, beginning with Sunrise in 2007 and continuing through the most recent pilot study, Clearwater, in 2014; the treatment train utilized for each treatment process is also shown. It should be noted that all of the pilot studies, except Hollywood, utilized the full advanced treatment (FAT) train, consisting of microfiltration/ultrafiltration (MF/UF), RO, and ultraviolet advanced oxidation (UV AOP). Hollywood tested multiple non-FAT-based treatment trains, as indicated by the ozone and UV AOP trains shown in Figure 1. Unlike the other treatment trains, Hollywood included the planned recharge into a brackish aquifer with >3,000 mg/L total dissolved solids (TDS).

Notably, all seven treatment trains demonstrated the ability to consistently produce water that exceeds the Flroida Department of Environemntal Protection (FDEP) primary and secondary drinking water standards. Treatment requirements for groundwater recharge (IDR) are summarized in F.A.C. 62-610.563. As of early 2016, the City of Clearwater is taking the next step in its groundwater recharge program by designing the first full-scale FAT potable reuse process in Florida (3 mgd).

Nutrients are part of the reason the FAT train was considered for the other southeast Florida utilities. The RO was necessary to achieve a total phosphorus concentraton of <10 parts per billion (ppb), which can only be achieved effectively through RO. Nitrogen (ammonia) removal can be a challenge for potable reuse treatment trains since ammonium (NH_4^+) is difficult to remove by RO, and ammonia (NH_3) passes freely through RO. Consequently, Miami-Dade and Hollywood incorporated ion exchange into their treatment trains to reduce ammonia concentrations.

Microconstituent Occurrence and Removal

Microconstituent removal is an area of interest and concern for potable reuse. As analytical methods have improved in recent decades, it is now possible to detect the presence of compounds at parts per billion (µg/L) and parts per trillion (ng/L) levels that may not be of significance to human health or the environment. A total of 231 microconstituents were sampled collectively across the seven Florida potable reuse pilot studies. It's important to note that the particular microconstituents sampled varied from pilot to pilot, and no single pilot study sampled all 231 microconstituents.

Review of reported results for the reclaimed water entering the potable reuse treatment processes showed that a total of 50 microconstituent compounds were identified across the seven pilot studies. A summary of these results can be useful for utilities interested in knowing what microconstituents have been detected most frequently in the influent at Florida potable reuse pilots. The compounds, all of which were detected at the influent of two or more pilot studies, included the following: N-nitroso-dimethylamine (NDMA) at (five) locations, caffeine (four), carbamazepine (four), sulfamethoxazole (four), gemfibrozil (three), fluoxetine (three), N,N-diethyl-m-toluamide (DEET) at (three), tricolosan (three), atrazine (two), dilantin (two), and acetaminophen (two). The following compounds were detected at the influent of a single pilot study: tris (1-chloro-2-propyl) phosphate (TCPP), meprobamate, ibuprofen, 1,7-dimethylxanthine, phenol, carisoprodol, 4-methylphenol, cholesterol, iohexal, cotinine, naproxen, progesterone, diethanolamine (DEA), atenolol, 2,6-di-tert-butylphenol, hexachlorocyclopentadiene, dehydronifedipine, indole, diazepam, lopressor, dichlorobenzene 1,4, methylparaben, azinphosmethyl, acesulfame-k, triclocarban, primidone, sucralose, 1,4-dioxane, sulfamethoxazole, trimethoprim, tris (2-chloroethyl) phosphate (TCEP), triphenylphosphate, testosterone, estrone, 4-androstene-3,17-dione, diuron, esterone, and tris (2-butoxyethyl) phosphate (TBEP).

Looking beyond the influent to the potable reuse treatment train, a summary of the detections of microconstituents at various points in each standard treatment train used in Florida potable reuse pilots is shown in Figure 2. While every reclaimed water has a different profile of microconstituents, this summary is useful for Florida utilities interested in identifying compounds that are more likely to show up at various points in the potable reuse treatment train. It is important to note that the presence of a compound in the figure only indicates that it was measured above the detection limit at one or two pilot studies. For actual concentrations of the microconstituents refer to the individual pilot study reports, which are listed in the references.

In Figure 1, it should be noted that six out of the seven pilot studies are represented by the top FAT train, whereas two non-FAT treatment trains from the Hollywood pilot study are shown separately. The NDMA is the most commonly detected microconstituent (disinfection byproduct) at the end of each treat-

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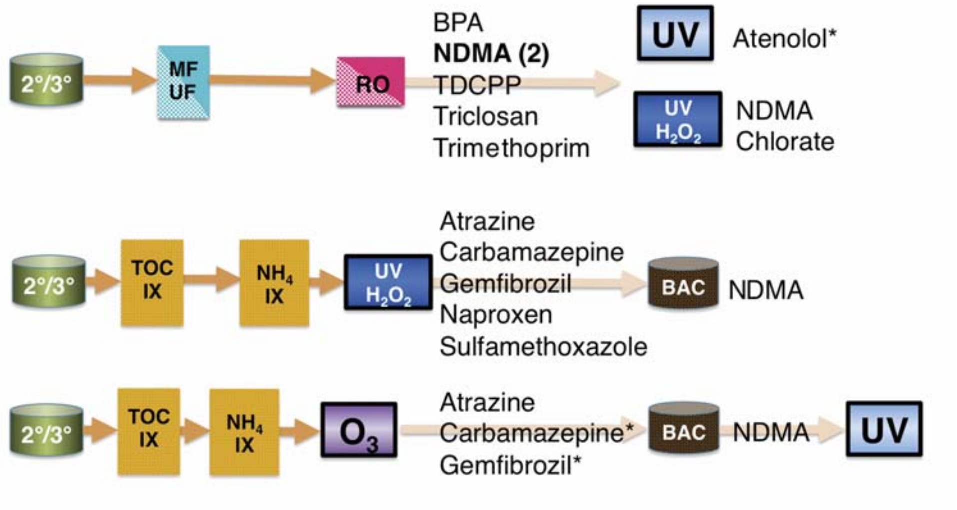

LEGEND- "Constituent (#)" – # indicates number of projects with this contaminant reaching this location in train, if no number, observed in location for only one (1) project
* Removed with higher ozone dose, or with addition of peroxide

Figure 2. Trace Compounds Detected at Various Points in Potable Reuse Treatment Trains

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ment train. In California, NDMA is subject to a 10 ng/L notification level. The standard method to reduce NDMA is through UV photolysis. Atenolol was observed in one of the FAT treatment trains when peroxide was found to be temporarily underfed at the UV AOP (Mercer et al, 2015). Chlorate was also found in one of the FAT treatment trains and may be a byproduct of sodium hypochlorite addition. It's also worth noting that the compounds that pass through the RO treatment process, including Bisphenol A (BPA), tris (1,3-dichloro-2-propyl) phosphate (TDCPP), triclosan, and trimethoprim, are different than the compounds observed in the non-FAT process before granular activted carbon (atrazine, carbamazepine, gemfibrozil, naproxen, and sulfamethoxazole). Note that these constituents were then removed below detection limit by UV AOP or biologically activated carbon (BAC).

While not shown in Figure 2, it should be noted that total nitrogen and trihalomethanes (THMs) are two substances that can often pass through potable reuse treatment processes due to their low molecular weight and low/no molecular charge. Utilities should keep these constituents in mind when planning potable reuse, especially DPR, and take appropriate measures to mitigate prevent formation of these compounds or increase removal as appropriate (Mercer et al, 2015).

Mitigating the Potential for Arsenic Release Through Post-Treatment

Arsenic release emerged as a major concern in Florida aquifer storage and recovery (ASR) operations, especially after the arsenic maximum contaminant level (MCL) was reduced to 10 µg/L. Like ASR, IPR consists of introducing a treated water into groundwater, and therefore has similar potential to induce arsenic release if certain post-treatment of the purified water is not provided. Post-treatment was only demonstrated at two of the seven pilot studies: Pembroke Pines and Clearwater. Pembroke Pines conducted extensive sidestream/bench scale testing of remineralization for the purified FAT water (Bloetscher et al, 2013). Clearwater conducted extensive pilot-scale testing and rock-core leaching tests to identify the impacts of remineralization and dissolved oxygen removal on mobilization of arsenic and other trace metals (Mercer et al, 2015).

Post-treatment is important for IPR to minimize impacts in aquifer recharge projects and protect the injected purified water from leaching of naturally occurring trace metals, such as arsenic and molybdenum. Figure 3 illustrates the composition of a rock sample taken from the Floridan aquifer in Clearwater, which is primarily composed of a calcium-based (limestone/dolomite) mineral with interspersed iron sulfide (pyrite) particles. Arsenic is concentrated within the pyrite minerals and in the limestone matrix. Therefore, in selecting post-treatment in Florida for IPR (groundwater recharge), it is important to understand the concentration of arsenopyrite, and if present, to provide calcium carbonate stabilization to remove oxidants in order to keep iron sulfide stable by preventing oxidation to iron sulfate. In the case of the Clearwater pilot, calcium carbonate stabilization was provided through addition of carbon dioxide and a hydrated lime slurry. Oxidant removal was accomplished through membrane degasification, which removed dissolved oxygen down to ppb levels and through sodium hydrosulfide (NaHS) adition, which quenched monochloramine instantly, and peroxide over several minutes (Mercer et al, 2015).

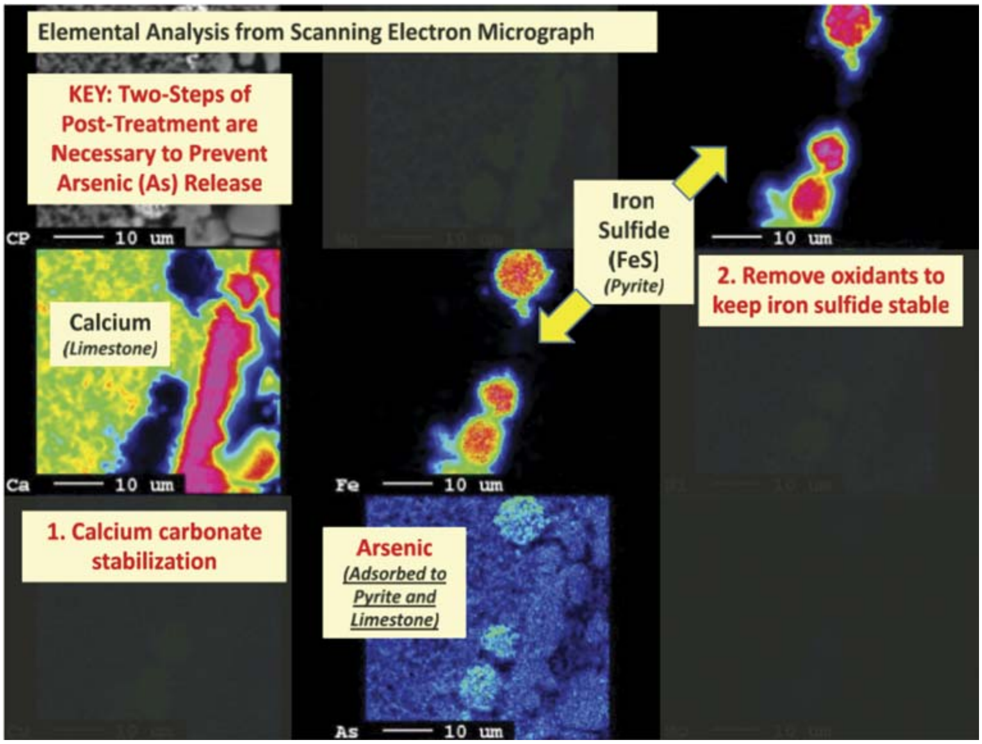

Figure 3. Elemental Analysis From a Scanning Electron Micrograph of a Rock Sample From the Floridan Aquifer, Indicating the Need for Post-Treatment. *(Adapted from Image Courtesy: Indewater, Florida Geological Survey)*

Cost of Potable Reuse Among Other Water Supply Options

The ultimate factor driving the adoption of potable reuse in Florida will be its cost relative to other alternative water supplies, and cost avoidance of other integrated water management projects in the context of the utility regulatory environment. Multiple recent reports have indicated that potable reuse can be a financially viable water supply/management option. Potable reuse will ultimately thrive wherever the incremental life cycle costs of implementing potable reuse are lower than any other feasible option; that is, when potable reuse represents the next cheapest source of water supply for a utility/or next cheapest approach to integrated water management. During the recent drought years across the United States, several utilities in Texas reached this point, where potable reuse was a more cost-effective option than importing water through pipelines. A similar situation exists in much of Southern California, where no more water is available to import and seawater desalination is slow to permit and costly to implement. The first IPR processes were implemented in California as seawater intrusion barriers used to protect existing groundwater supplies that were being overdrawn. Failing to implement IPR (with saltwater intrusion barriers), while maintaining overdrafts of water, would have meant the eventual loss of a valued groundwater resource.

Florida is in excellent standing compared to these other states in that there is not yet a severe crisis of water shortages. Therefore, it has been able to take an aggressive, planned approach to the implementation of potable reuse, among many other integrated water management tools. This thoughtful planning approach is exemplified by the recent Senate Bill 536, "Report on Expansion of Beneficial Use of Reclaimed Water, Stormwater, and Excess Surface Water" (FDEP 2015), and the statutorily mandated water supply planning by each of the state's water management districts.

Traditionally in Florida, brackish groundwater treated with RO has been the alternative water supply of choice, and there are concerns in some areas that even the brackish groundwater supplies are being tapped near sustainable limits, manifested by increases in brackish water TDS over time. As of 2010, brackish water RO made up approximately 7 percent (165 mgd) of the state's total public potable supply, which is 2,300 mgd (USGS, 2014). In a situation where traditional groundwater supplies are fully utilized, and brackish RO is either fully utilized, or unavailable, Florida utilities can consider the following: purchasing water from their neighbors, surface water treatment (if available), potable reuse, or seawater desalination (considering the costs). In addition, as exemplified by the Ocean Outfall Rule and Numeric Nutrient Criteria, the discharge of treated wastewater to the environment has come under increasing scrutiny, which, in the case of several southeast Florida utilities, means a requirement to beneficially reuse a large portion of the wastewater that would have been released to tide.

A number of recent reports have shown that potable reuse can be a financially viable and cost-competitive water supply alternative. Despite the potential for differing assumptions behind the different cost estimates, there is a notable consistency in costs among sources. A review of water supply options in California (Tchobanoglous, 2014) indicated that both IPR and DPR would generally be cheaper than seawater desalination, and in some cases, be cost-competitive with brackish groundwater desalination or imported water. The WateReuse Association's recent "Framework for Direct Potable Reuse" (Figure 4) indicated that seawater desalination costs in California far exceeded the cost of potable reuse and brackish groundwater supplies (Tchobanoglous et al, 2015).

Looking at estimated costs within Florida, a recent report from the St. Johns River Water Management District (SJRWMD, 2014) evaluated costs for direct potable aquifer recharge ($3.11-$3.69/kgal) IPR and direct reuse ($3.85-$3.91) DPR (Figure 5) within the range of costs (~$2.25-$6.00/kgal) for IPR/DPR (Tchobanoglous, 2014). All three studies indicated seawater desalination as the most costly water supply option.

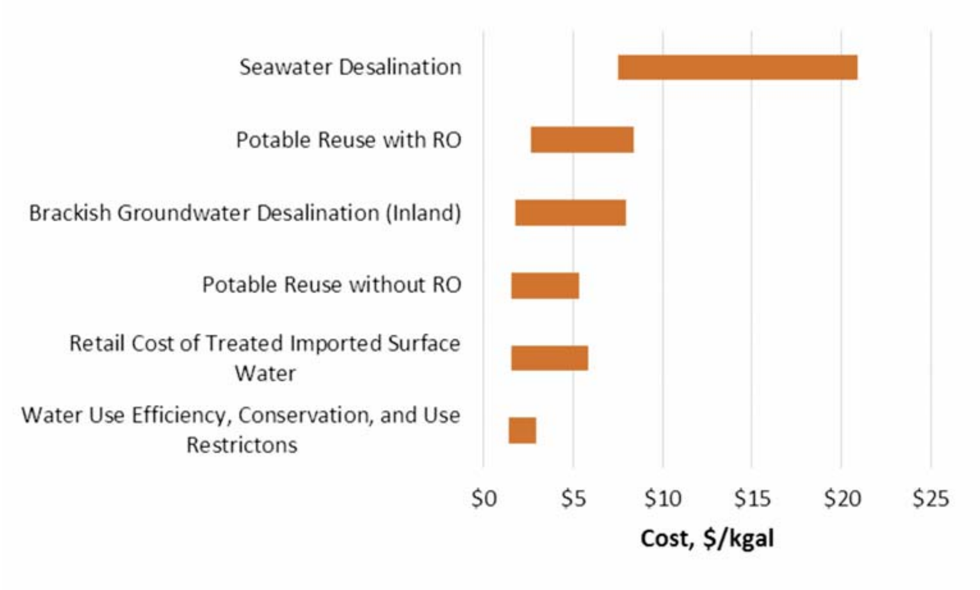

Figure 4. Range of Life Cycle Cost of Water Supply Alternatives in California
(Source: Tchobanoglous et al, 2015)

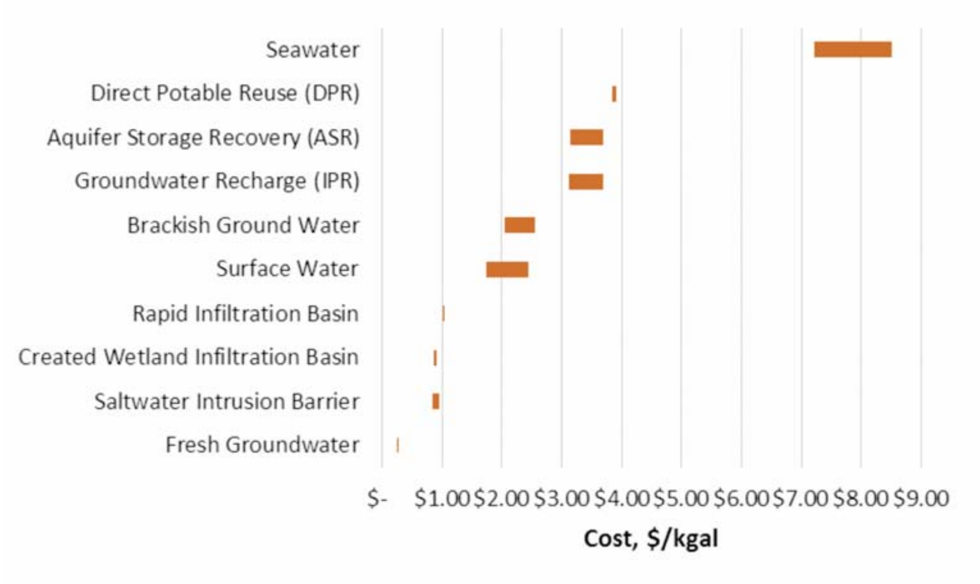

Figure 5. Life Cycle Cost ($/kgal) of Water Supply Alternatives Within the St. Johns River Water Management District
(Source: SJRWMD, 2014)

Saltwater intrusion barriers, such as the 2-mgd Southern Hillsborough Aquifer Recharge Program (SHARP), are a lower-cost aquifer recharge option. The lower cost is due to the limited treatment requirement for principal treatment and disinfection, as long as the target aquifer is between 1,000 mg/L and 3,000 mg/L and the target aquifer is not to be used as a drinking water source (F.A.C. 62-610.563[2]).

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Looking at the estimated cost of various levels of treatment at the Hollywood project (VanEyk et al, 2014), projected life cycle costs range from $2.15/kgal for an alternative treatment train ("Alternative 2b," two-stage IX, ozone, BAC, and UV disinfection) to $3.84/kgal for a FAT treatment train. It should be noted that the alternative non-FAT treatment scheme, as piloted at Hollywood, would require a waiver from Broward County for TDS, chemical oxygen demand (COD), chloride, sodium, and phosphates; however, there did not appear to be any allowance in the Hollywood costs for post-treatment to mitigate arsenic release. Nevertheless, these data illustrate a consistency with the other cost estimate sources.

Notably, since many of the southeast Florida pilot studies have taken place, more utilities, such as Miami-Dade, that were considering discharge to the surficial aquifer, are now rethinking that approach and planning to recharge deeper brackish aquifers because of reduced costs. By switching from a Biscayne Aquifer (fresh) recharge ($10.40/gpd capital cost) project to a Floridan aquifer (brackish) recharge project ($2.78/gpd capital cost), Miami Dade County anticipates a significant reduction in the capital cost to construct its reuse management option. With the Floridan aquifer recharge option, Miami-Dade anticipates that a waiver on total nitrogen (TN) limits to the Floridan aquifer will be required. While these costs do not take into account the potential nutrient removal benefit of potable reuse, if the value of a two-for-one water supply/nutrient removal treatment were considered, potable reuse may be a lower life cycle cost option than other water supply alternatives.

Besides being cost-competitive, potable reuse offers several potential benefits to Florida utilities: it can protect environmental resources by significantly reducing surface water discharges (IPR via groundwater recharge) and even discharges to groundwater (DPR), it is attractive as a "drought-proof" water supply that is not subject to seasonal limitations, and a utility may also choose potable reuse to obtain control over its own water supply and reduce purchases of imported water.

The Challenge of Effective Potable Reuse Operations

Identifying and Sharing Operational Lessons Learned is Key

An important but often under-discussed aspect of successful potable reuse processes is operations. Much attention has been given to potable reuse treatment technology and removal of contaminants; however, an equally important concern is how to maintain effective treatment while managing inevitable process upsets, especially with DPR. Potable reuse processes can be unfamiliar to many operators and therefore pose new challenges to maintaining stable operations. Potable reuse operations often focus on "critical control points," which are process targets that can be measured to provide assurance that the integrity of the purification processes is being maintained. The WateReuse Research Foundation is pursuing multiple projects to address this issue, including "Development of Operations and Maintenance Plan and Training and Certification Framework for DPR Systems" (WRRF-13-13).

There are several potential operational challenges that can be encountered while running a potable reuse process, including UF membrane cleaning, UF membrane fiber breaks, variable ammonia/nitrogen loads, control of THMs, control of TN, RO membrane fouling, protecting RO membranes from chlorine damage, monitoring and maintaining UV lamps and peroxide, chemical dosing and kinetics of chlorine and peroxide quenching, dissolved oxygen removal and arsenic release, and dosing of calcium stabilization chemicals (Mercer et al, 2015). Sharing of best practices and operational lessons learned will be crucial as more Florida utilities begin implementation of potable reuse.

Operator Certification and Training

Another uncertainty introduced by potable reuse processes is how to structure operator licensing for potable reuse treatment processes. The FDEP's current operator licensing system includes classifications for water operators and wastewater operators; however, the future classification and credentials of a potable reuse treatment plant operator is less well-defined. Training materials and courses will need to be developed to provide operators with the education needed to operate the new processes involved in potable reuse; the DPR operations specialty certifications could be appended to existing certifications, requiring a blend of training and experience hours (WRRF-13-13). One potential approach could be to create an all-inclusive water treatment plant operator license that would include treating any type of Florida water to potable standards. Other statutory and regulatory changes will need to be discussed and enacted.

Direct Potable Reuse

Florida, Texas, and California

To date, none of the potable reuse pilot systems in Florida have been tested for DPR and all pilots have been operated under the assumption of IPR. While Florida currently has regulations for IPR through groundwater recharge and discharge to surface waters, there is currently no Florida regulation to guide the implementation of DPR. Historically, regulators have proceeded with extreme caution due to the unknown long-term health effects of low levels of organics and heavy metals. In addition, because of the source of the water, there are concerns about the potential effects of unknown or unidentified compounds. Historical drought conditions and population growth in Texas and California have led regulators to take more action to move the implementation of DPR forward. Florida should consider the example of other states and the importance of process integrity monitoring when considering DPR.

Faced with the prospect of dry reservoirs in some communities, Texas has approved several communities for DPR on a case-by-case basis, without implementing a single rule applicable to all. Faced with a recent drought situation, the City of Wichita Falls, Texas, implemented emergency DPR, transferring purified water to its existing drinking water treatment plants for further treatment and final distribution. With reservoir levels restored, the city returned to IPR via its local reservoir. At present, only Texas and North Carolina have regulations specifically addressing DPR.

In contrast, California has taken a more measured approach, most notably through the California Direct Potable Reuse Initiative sponsored by the WateReuse Research Foundation and supported by multiple donors. The initiative is sponsoring several research projects to develop monitoring tools to help monitor the integrity of each barrier in the purification process. The California Department of Public Health (CDPH) was mandated to complete its assessment of DPR and provide a report to the California Legislature by the end of 2016, recommending how the state should or should not proceed with DPR. To date, the WateReuse Research Foundation has sponsored over 19 research projects looking at some of the key barriers to implementing DPR and identifying solutions. What this means for Florida utilities is that there is a rapidly increasing body of knowledge on DPR methods that will provide sound science to support decision making, and potentially, implementation of DPR as an alternative water supply in Florida.

Moving Forward With Direct Potable Reuse: Demonstration Testing of Process Integrity Monitoring

Because DPR does not provide a months- or years-long travel time like IPR does in a target aquifer or surface waterbody, process integrity monitoring will be critical to achieving high reliability in operations of the process. Effective process integrity monitoring tools can help utilities identify and respond to potential problems more quickly, minimizing what is known as the response retention time. Compared to IPR, DPR may have potentially lower costs due to the elimination of recharge wells and associated post-treatment; however the potential cost savings could be offset by the additional monitoring requirements for DPR.

Before any Florida utility proceeds with a DPR program, it would be advisable for that utility to construct a demonstration facility to collect important data for use in establishing regulations for the plant and identifying best practices for continuous on-line integrity monitoring. Before developing uniform regulations for DPR, it is likely that the state will permit the first few DPR projects on a case-by-case basis, referencing accepted standards of practice.

Conclusion

As Florida's population continues to grow, along with demand for additional water supply and concerns regarding nutrient charges, the state will face an increasing need for innovative water management solutions, which will, in some cases, include potable reuse, which is a technically viable process for Florida that can be fiscally viable given individual utility circumstances.

The technical viability of potable reuse in Florida has been demonstrated by seven recent potable reuse pilot studies. The financial viability of potable reuse is well attested by multiple sources, indicating that potable reuse is usually cost-competitive with brackish groundwater desalination and is almost always less expensive than seawater desalination. If the added nutrient removal benefit of potable reuse is valued, the fiscal viability of potable reuse may be even greater in some situations. Special consideration for post-treatment is required in the case of groundwater recharge (IPR) to mitigate arsenic release. While most potable reuse projects in Florida have focused on IPR, introduction of DPR will require careful demonstration studies showing how process integrity monitoring can effectively verify reliability of the treatment barriers.

The broad implementations of potable reuse face hurdles in fiscal viability, potable reuse operations, and concentrate disposal/management. Although potable reuse is not always the right solution, improvements in technology, accumulation of operating experience, and innovative approaches may help potable reuse better overcome each of these hurdles. While Florida has not yet faced the critical water shortages experienced in California and Texas, as population growth puts an increasing demand on its water resources, potable reuse will be an important and viable tool that Florida utilities can use as a part of their integrated water management approach.

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