Alternative Technologies for Indirect Potable Reuse in Southeast Florida

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The implementation of ocean outfall legislation in Florida has created a groundswell of reuse master planning and process investigation in the southeastern portion of the state. Municipalities must prepare to shut down their ocean outfalls and reuse 60 percent of the outfall baseline flow for a beneficial purpose by 2025.

The City of Hollywood (City) owns and operates the Southern Regional Wastewater Treatment Plant (SRWWTP) that utilizes an open ocean outfall to discharge secondary effluent. As part of legislation passed in 2008, the City is required to implement 20.4 mil gal per day (mgd) of additional reuse "on an annual basis" beginning in 2026, based on outfall flows from 2003-2007. This requirement excludes the existing irrigation system, which provides public access irrigation water to golf courses within the City.

In response to this impending deadline, the City investigated options for reuse required under the new law. Three options were initially identified:

- Expanding the public irrigation system
- Recharging the Biscayne aquifer
- Recharging the Floridan aquifer

Serving coastal cities with a high groundwater table, the City's SRWWTP has a salty effluent, rendering it unsuitable for irrigation reuse without reverse osmosis (RO) treatment; additionally, the required irrigation piping network would need to be extended well beyond city limits, escalating the estimated cost of implementing the mandated reuse to $1 billion. Effluent going into the Biscayne aquifer, the predominant source of drinking water for all of southeast Florida, would require a costly suite of advanced treatment, including microfiltration (MF), RO, and ultraviolet advanced oxidation processes (UV-AOP) before injection into the high-quality aquifer, with total dissolved solids (TDS) < 500 mg/L.

After a review of the legislation, discussions with regulatory agencies, and exploration of available options, the Floridan aquifer recharge was identified as a potentially more cost-effective and environmentally-friendly direction for the City (Figure 1).

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Due to the brackish quality of the Floridan aquifer (TDS > 500 mg/L), alternative treatment processes using ultrafiltration, ion exchange, ozone, and UV-AOPs, as well as biofiltration, were examined as an alternative to the full-advanced treatment approach of MF/RO and UV-AOP that are currently the

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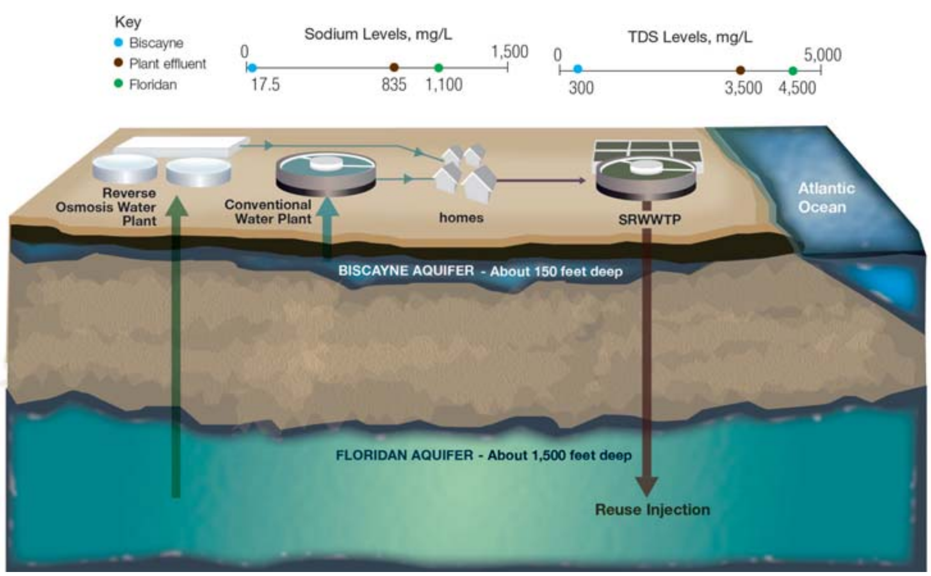

Figure 1. The Floridan aquifer is a deeper, more saline body of water, with high levels of total dissolved solids, requiring reverse osmosis membrane treatment to achieve potable water quality. Recharging the Floridan aquifer (rather than the Biscayne) means that reverse osmosis treatment may not be needed in the reuse treatment scheme, drastically reducing power consumption, mitigating carbon footprint, and saving significant capital dollars.

When faced with an imposed reuse mandate, the City of Hollywood developed a treatment approach that demonstrates emerging contaminant oxidation without reverse osmosis, which has the potential to greatly reduce costs and carbon emissions.

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customary treatment in potable reuse applications. Due to its inherent salinity, raw water from the Floridan aquifer requires nanofiltration (NF) or RO membrane treatment to achieve potable quality, allowing the City to consider less-expensive recharge process schemes at the reclamation facility without redundant RO or NF membrane treatment. If successfully permitted, this reuse project utilizing Floridan aquifer recharge could potentially save the City about $100 million dollars in capital costs over Biscayne aquifer recharge and about $800 million in capital costs over irrigation-level treatment and expansion of the public access irrigation system.

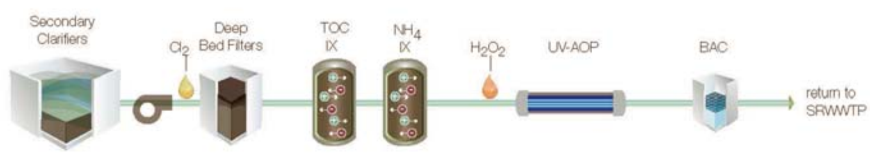
Pilot Study Program Objectives and Guidelines

Based on the specific characteristics of the SRWWTP effluent and the aquifer water quality, a customized plan of study was developed to achieve acceptable emerging contaminant oxidation using treatment technologies that are more cost-effective and have a smaller carbon footprint than MF/RO/UV-AOP treatment. The goal of the pilot project was to demonstrate the ability to reliably produce water that satisfies regulated primary and secondary drinking water standards (with the exception of certain constituents naturally present in the Floridan aquifer, such as sodium and chloride) and removes unregulated emerging contaminants.

After considering the impacts associated with Broward County code compliance, the project team approached the County with the treatment concept. The Broward County Environmental Protection and Growth Management Division (BCEPGMD) suggested that certain water quality requirements for aquifer recharge may be waived based on demonstration of reasonable emerging contaminant oxidation. As a result, the pilot study was designed to meet this goal using alternative treatment technologies that are fully protective of the environment, have reduced carbon emissions, and are more cost-effective, while being predicated on regulatory waivers for chemical oxygen demand (COD), TDS, chloride, sodium, and phosphates. Two treatment strategies were employed, as depicted in Figure 2.

1: UV-AOP

This process scheme included secondary-treated effluent from the SRWWTP, followed by deep bed filters (DBF), ion exchange (IX) for total organic carbon (TOC) removal, IX for ammonia removal, UV-AOP, and biological activated carbon (BAC) filters.



2: Ozone/UV

This process scheme includes secondary-treated effluent from the SRWWTP, followed by DBF, IX for TOC removal, IX for ammonia removal, ozone, BAC filters, and UV.

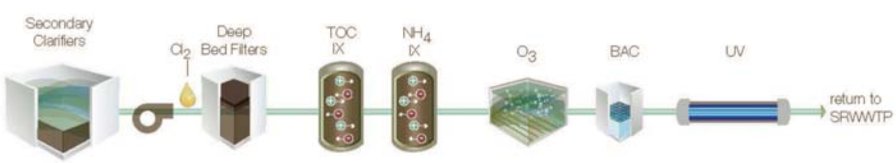


Figure 2. Pilot Treatment Strategies

Table 1. Emerging Contaminant Indicator Compounds

Compound	Functional Group	Guideline Value
1,4-Dioxane	---	3 µg/L
Atrazine	(I) Nitro Aromatic	3,500 ng/L
Carbamazepine	(C) Nonaromatic with Carbon Double Bonds	73.5 ng/L
Dilantin	(G) Alkyl Aromatic	73.5 ng/L
Fluoxetine	(D) Deprotonated Amine	3,395 ng/L
Gemfibrozil	(F) Alkoxy Aromatic	15,050 ng/L
Iopromide	(H) Saturated Aliphatic	1,750,000 ng/L
Naproxen	(E) Alkoxy Polyaromatic	45,500 ng/L
NDMA	---	10.0 ng/L
Sulfamethoxazole	(B) Amino/Acyl amino Aromatic	150,500 ng/L
Triclosan	(A) Hydroxy Aromatic	105,000 ng/L

Approach to Evaluating Undefined Contaminant Removal

Since Florida currently does not have emerging contaminant regulations, California's Title 22 Groundwater Replenishment Reuse Draft Regulation was used to determine the efficacy of the different treatment schemes. A list of emerging contaminants was developed based on the California Department of Public Health (CDPH) Title 22 Groundwater Replenishment Reuse Draft Regulation (2011, and updated March 28, 2013). The CDPH draft regulation focuses on indicator compounds from nine functional groups, requiring demonstration of a log removal for five of the nine functional groups, as follows:

- 0.5-log removal for at least three indicators in functional groups (A) through (G)
- 0.3-log removal for at least one indicator in functional groups (H) or (I)

Removal as a basis for determining treatment reliability is limited in that it relies on in-

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The pilot was operated for a duration of 10 months, not including construction and startup.

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fluent concentrations, which can be low for emerging contaminants and are often below detection limits, thereby understating removal. As a result, log removal should be used alongside other guidance markers for treatment reliability. Therefore, for this pilot study, the drinking water guideline values presented in the Australian Guidelines for Water Recycling document and the "comparison values" presented in the WateReuse Foundation report (WRF-05-005, 2010) were used alongside log removal to determine the efficacy of the process schemes for emerging contaminant oxidation.

For the pilot study, indicators for each functional group were chosen, as presented in Table 1, based on initial testing of the secondary effluent to allow determination of log removal to the greatest extent possible. Though not included in any of the Title 22 functional groups, N-nitrosodimethylamine (NDMA) and 1,4-dioxane are considered emerging contaminants, which may be regulated in the future, and thus were also monitored as part of this study, since destruction/removal of these compounds is almost entirely governed by UV photolysis and advanced oxidation, respectively.

Table 2. Pilot Process Summary Results of Key Regulated Parameters

Parameter	Current Limit (mg/L)	Pilot Effluent Averages (mg/L)	
		Strategy 1 (UV-AOP)	Strategy 2 (Ozone/UV)
BOD_5	5	2.0	3.4
TSS	5	3.4	3.5
TN	10	7.3	7.9
Nitrite	1	0.7	0.7
TOC	3	1.1	1.1
TOX	200	85.1	82.6
Chloride	250	1,400	1,400
Sodium	160	776	767
TDS	500	3,480	3,460
Phosphates	0.01	1.2	1.2
COD	10	14	16

Red Background: Based on demonstrated emerging contaminant removal, waivers will be sought from the BCEPGMD.

It should be noted that the California regulations are designed to be protective of low TDS groundwater that is consumed directly as drinking water upon withdrawal without any additional treatment or disinfection (e.g., via private wells). Thus, the California regulations provided a conservative point of comparison for the Hollywood pilot study, which tested treatment strategies tailored for the recharge of a high TDS aquifer where desalting (high pressure membranes) will be required before use as drinking water. The membrane processes will further remove other constituents that may remain in the recycled water.

The pilot test was operated for a duration of approximately 10 months (not including pilot construction, startup, and decommission). Throughout the study period, the pilot plant operated 24 hours a day, seven days a week, with the exception of scheduled monthly equipment cleanings. The pilot used portable treatment system containers on site at the SRWWTP, treating secondary effluent from the facility and returning the final process water to the head of the plant after sampling.

Results

Pilot-scale testing of both novel approaches demonstrated that an effluent quality that complies with state regulations and removes emerging contaminants can be achieved, while offering additional benefits to the public and the environment by way of substantially reduced costs and carbon emissions.

Both piloted treatment strategies successfully oxidized emerging contaminants well below the targeted limits. All primary and secondary drinking water standards were met, with the exception of those indicted in Table 2. Presented in Table 2 are pilot process results for key regulated parameters and those parameters in which waivers will be sought based on the demonstrated emerging contaminant removal and the expected water quality of the receiving water body (Floridan aquifer).

The pilot test found that both strategies are viable options for recharge in Broward County to satisfy the new state reuse requirement. The 20-year present value of the treatment necessary for full compliance with state recharge regulations is estimated to be $190 million, while full treatment compliance with Broward County regulations has an estimated present value of $590 million. However, this pilot testing achieved an effluent quality that complies with state regulations and removes yet-to-be-regulated emerging contaminants at a present value in the range of $290-330 million, which is half the cost of currently established full-advanced treatment methods utilizing MF/RO/UV-AOP (Figure 3). The annual operation and maintenance (O&M) costs of the piloted treatment strategies ($6.8-8 million annually) would also be half that of MF/RO/UV-AOP treatment methods ($16.2 million annually). This approach offers additional benefits to the public and the environment by way of substantially reduced carbon emissions. Meeting Broward County standards through full-advanced treatment would release an estimated 26,000 tonnes of annual carbon emissions, while the piloted treatment schemes would release less than half as much (12-14,000 tonnes).

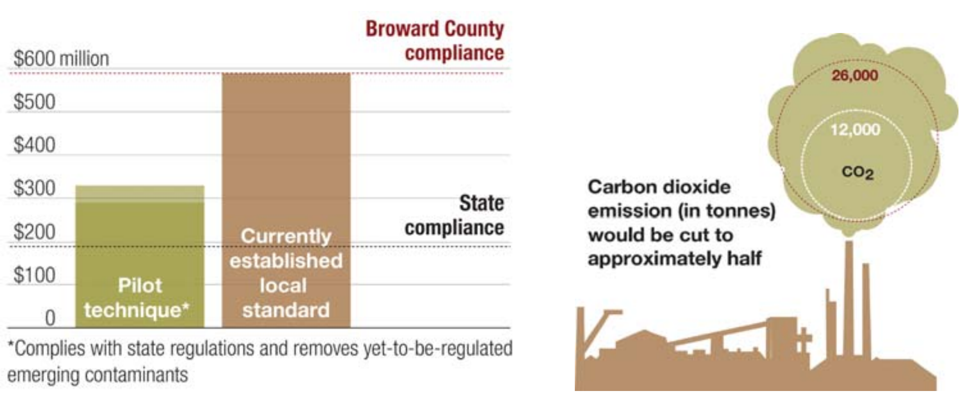

Figure 3. Pilot Technique Present Value and Carbon Emissions

Future Applications

As growing demand strains existing drinking water supplies and increasingly stringent wastewater effluent standards lead to more advanced wastewater treatment, indirect potable reuse is becoming a feasible scenario for more utilities. A majority of potable reuse schemes in operation or being planned in the United States make use of AOPs and RO to ensure maximum contaminant removal. This pilot developed two potable reuse schemes where RO or NF membranes are not incorporated at the reuse facility, potentially reducing carbon emissions and saving municipalities significant capital and O&M costs.

The City is currently debating the public policy implications of various treatment options and their impacts on the appropriate regulatory agencies. Utilization of a tailored approach to reuse promises a solution that is the most protective of public health and the environment.