

Sampled Direct Potable Reuse Water Shows Promising Results

The Raw Water Production Facility in Big Spring, Texas, doesn't discharge its treated wastewater effluent into a natural water body before being reused as a supply source, making it the only operating direct potable reuse facility in the United States. Early testing and analysis of the system show promising results. **BY EVA STEINLE-DARLING, JUSTIN SUTHERLAND, AND ANDREW SALVESEN**

SINCE MAY 2013, the Colorado River Municipal Water District's Raw Water Production Facility (RWPF) at Big Spring, Texas, has been purifying municipal wastewater effluent to be used as a raw water supply by the district's customer cities. RWPF's product water, which undergoes treatment with microfiltration (MF), reverse osmosis (RO), and an advanced oxidation process (AOP) consisting of ultraviolet disinfection and added hydrogen peroxide, is blended with other raw water

supplies, but it doesn't enter a natural system before being delivered to conventional water treatment plants. Therefore, the project created the first direct potable reuse (DPR) system in the United States.

The Texas Water Development Board and WaterReuse Research Foundation funded a study to examine RWPF's treatment performance to evaluate the potential for wider-scale DPR implementation in Texas. The study is ongoing and includes a comprehensive sampling campaign with four major sampling events. Analytes include a large list of trace chemicals

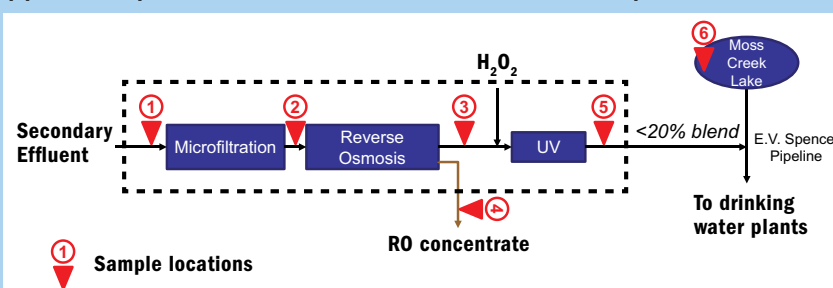
(pharmaceuticals, personal care products, perfluorinated compounds, nitrosamines, conventional disinfection by-products and their formation potentials, and others), pathogens (viruses, protozoa, and bacteria), and chemical and microbial surrogates for better online monitoring. As illustrated in Figure 1, sample locations include plant influent, MF filtrate, RO permeate, RO concentrate, AOP-treated product water, and the surface water used to blend with the effluent.

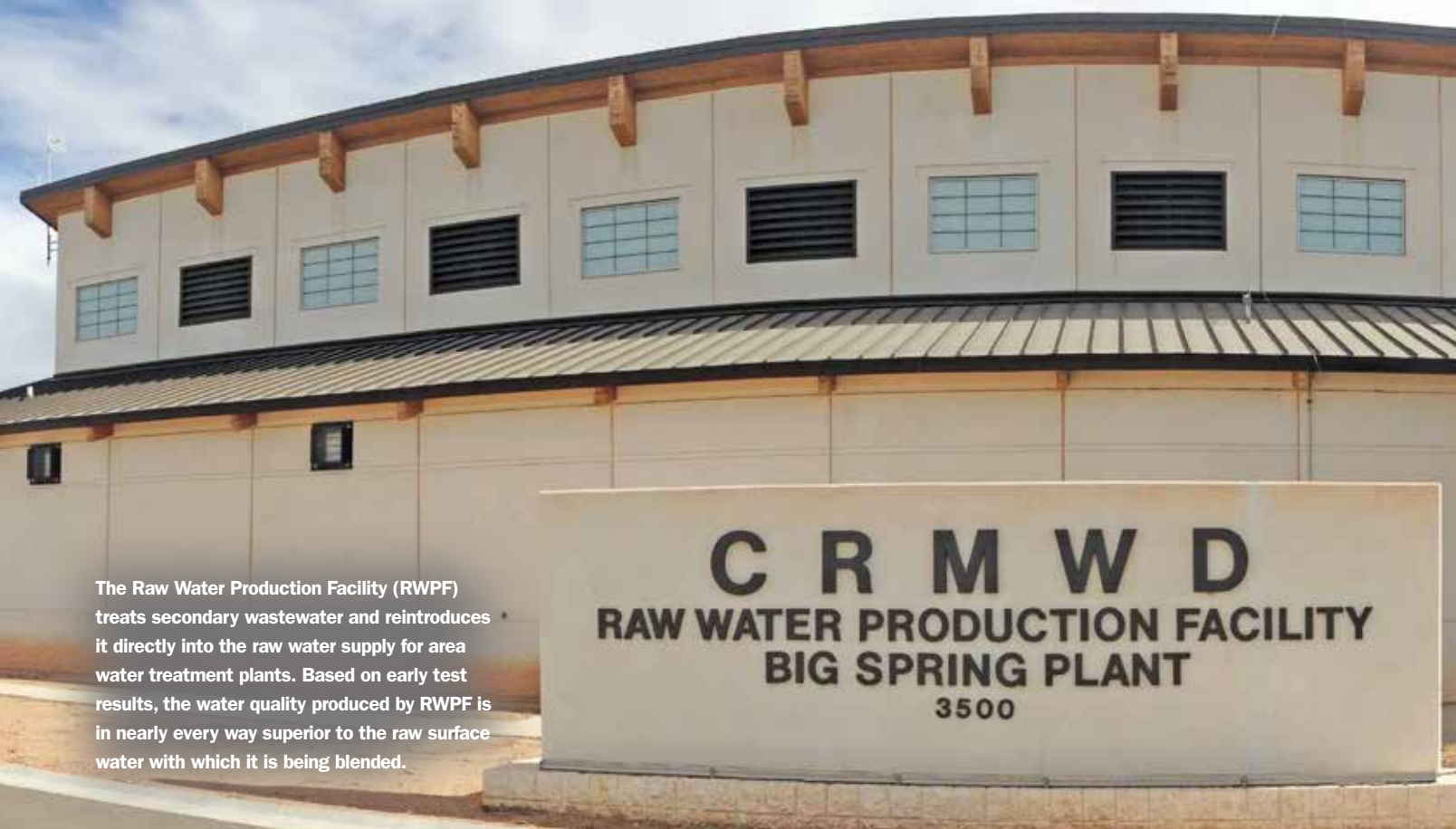
PRELIMINARY SAMPLING

Although the project is still ongoing, with some continued monthly sample collection, the four major sampling events have been completed. This article focuses on the initial sampling event completed in July 2014. The data set came back with only a single pathogen detection (one *E. Coli* sample) out of more than 12 virus samples analyzed for norovirus, enterovirus, and adenovirus; 15 samples analyzed for protozoa (*Cryptosporidium* and *Giardia*); and 74 samples analyzed for *E. Coli*. The virus and protozoa samples were field-filtered to achieve detection limits as low as possible (i.e., until the filters clogged from suspended

Figure 1. Raw Water Production Facility Schematic

The DPR project takes water from the city's conventional wastewater treatment plant. The effluent undergoes an advanced treatment process before it is blended in raw water pipelines and provided to one of five conventional water treatment plants.





The Raw Water Production Facility (RWPF) treats secondary wastewater and reintroduces it directly into the raw water supply for area water treatment plants. Based on early test results, the water quality produced by RWPF is in nearly every way superior to the raw surface water with which it is being blended.

sediments). The two RO permeate samples were filtered for an entire field day and yielded sample volumes of more than 700 liters each, resulting in virus detection limits of 0.0042 most probable number per liter (MPN/L). Although this is still several orders of magnitude shy of the 2.2×10^{-7} MPN/L potable water goal concentration, the results are a step in the right direction and could allow operators to calculate lower log-removal requirements between RO permeate and finished drinking water.

Pharmaceuticals and Personal Care Products. Figure 2 shows a summary of the project's pharmaceutical and personal care product (PPCP) testing for the first major sample event. Concentrations are shown on a logarithmic scale to show the full range of concentrations. Several observations can be made about the data set.

- The secondary effluent feeding the RWPF isn't materially changed with respect to trace constituents by the MF step. This is expected, as all the PPCPs are dissolved constituents and therefore would be expected to pass through the pores of an MF membrane.
- Significant attenuation (two orders of magnitude in most cases) is seen between MF filtrate and RO permeate, indicating the RO membranes are

indeed the workhorse in removing the dissolved organic trace constituents.

- Where present above detection in RO permeate (only sucralose, meprobamate, and triclocarban), the UV-AOP process reduced concentrations further, but only slightly. DEET is the exception, which can be explained by analytical imprecision: The detection limit for DEET in RO permeate and finished water is 1 ng/L; in one case it's detected at 1 ng/L and isn't detected in the other.
- Sucralose, which is present in secondary effluent at concentrations two orders of magnitude higher than any other PPCP compound, is an excellent tracer for these compounds through the treatment train. Sucralose is reduced by two and a half orders of magnitude through RO and slightly more through the UV-AOP process, but it's still present at measurable concentrations.
- In general, the raw water from Moss Creek Lake contains PPCPs at higher concentrations than the finished water from RWPF.

Conventional Disinfection By-products and By-product Formation Potentials. Figure 3 shows disinfection by-product (DBP) formation potentials (FPs). Several

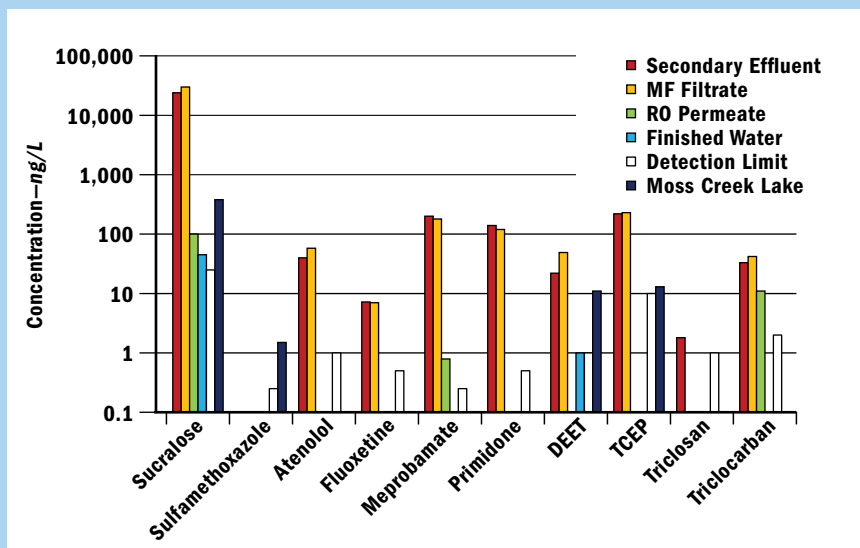
observations can be made about this data set in conjunction with concentrations of actual DBPs measured in the samples (data not shown).

- The RWPF-treated water clearly contains significant concentrations of trihalomethanes, a class of conventional DBPs regulated in drinking water, although concentrations in the finished water didn't exceed regulatory limits. No conventional DBPs were found in the samples from Moss Creek Lake.
- In contrast with the DBP results, the FP results show significantly higher concentrations for Moss Creek Lake than for the finished water.

Regarding DBP FPs, although the exact chemistry is still a subject of active research, DBP formation in response to chemical oxidant exposure is thought to depend on total organic loading, specifically the presence of larger-structured humic and fulvic acids characteristic of natural organic matter (NOM) and its wastewater analog, effluent organic matter. Hence, the presence of significant DBP FPs in the surface water and the secondary effluent compared with their absence in the RO permeate, which has been stripped of all but the smallest dissolved constituents, is unsurprising. Given the long distance water is transported

Figure 2. PPCP Results

RO achieves robust removal of PPCPs.



from the RWPF after blending with the raw water in the E.V. Spence pipeline, DBP FPs are likely a more important indicator of the eventual drinking water quality produced by the conventional water treatment plants downstream than the actual DBPs found in the RWPF product water.

Nitrosamine Concentrations and Formation Potentials. In addition to conventional DBPs, the presence of *N*-nitrosodimethylamine (NDMA) and its FP were also measured at each of the sample locations (except RO concentrate). The samples also were analyzed for the presence of eight

other nitrosamines, of which only *N*-nitrosomorpholine was detected in one location (5.9 ng/L in the MF filtrate, with detection limits ranging between 5–10 ng/L).

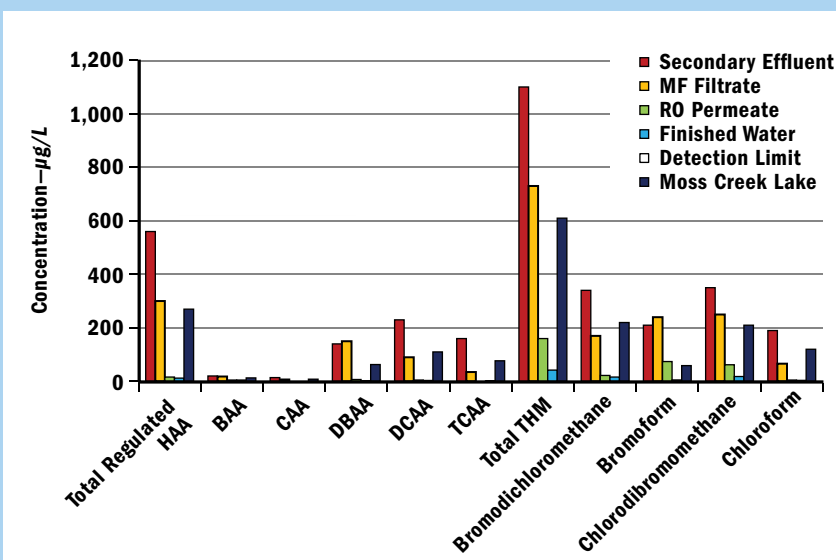
NDMA concentrations decreased from 7.6 ng/L in the secondary effluent to the following: 5.7 ng/L in the MF filtrate, 4.9 ng/L in the RO permeate, and 3.3 ng/L in the finished water. NDMA FPs decreased from 40 ng/L in the secondary effluent to the following: 30 ng/L in the MF filtrate, 6.8 ng/L in the RO permeate, and less than 5.0 ng/L in the finished water. This compares with an NDMA concentration of 3.4 ng/L and an NDMA FP of 16 ng/L in the samples collected from Moss Creek Lake.

Other Trace Constituents. Samples from all locations also were analyzed for 12 perfluorinated compounds, which were detected at concentrations between <1 ng/L and 27 ng/L in the secondary effluent and removed to below detection in the RO permeate. The sample from Moss Creek Lake contained four perfluorinated compounds at concentrations ranging between 4.7 ng/L and 1.1 ng/L.

Samples also were analyzed for five estrogen compounds, none of which were detected at concentrations above detection limits, ranging from 0.4 ng/L to 2 ng/L in any of the locations at the RWPF, including the wastewater effluent. In contrast, the sample collected from Moss Creek Lake contained 0.26 ng/L estrone.

Figure 3. Conventional DBP FP Results

DBP FPs are important indicators of eventual drinking water quality.



PROMISING RESULTS

Additional data from the subsequent sample events aren't yet ready for publication, but they're qualitatively consistent with the results from the first sample event. In all, the results of this study indicate the water quality produced by RWPF is in nearly every way superior to the raw surface water with which it is being blended. Although DPR will never be the best water supply option for everyone, RWPF's excellent study results pave the way for additional DPR projects across the state.