The Application of Membrane Technology in Wastewater: Implementation of a Wastewater Reuse Strategy

Karla Kinser, PE, MWH, Denver, Colorado
Larry Webb, City of Rio Rancho, New Mexico
Bill Landin, PE, MWH, Colorado Springs, Colorado

Background

The City of Rio Rancho is the fastest growing and fourth largest city in New Mexico. The City currently relies heavily on groundwater for water supplies. To sustain its long-term water needs, the City has undertaken a feasibility study to develop a Water Reuse Strategy that will significantly expand the use of reclaimed water, reduce groundwater withdrawals, and provide advanced treatment for aquifer recharge. Membrane treatment processes are proving to be promising technologies for wastewater purification and reclamation. This phase of the study involved pilot testing of an Integrated Membrane System (IMS) process. The process consisted of membrane bioreactors (MBR) to provide tertiary treated water followed by reverse osmosis (RO) to provide purified water that can be injected into the groundwater. In this time of sustained growth and prolonged drought in the arid Southwest, it is incumbent upon managers and policy makers to find ways to fully conserve and properly use all available water supplies. The pilot study was started in May, 2004 and completed in December, 2004.

Purpose and Goals

The reclaimed water pilot testing will achieve the following research needs for the City of Rio Rancho.

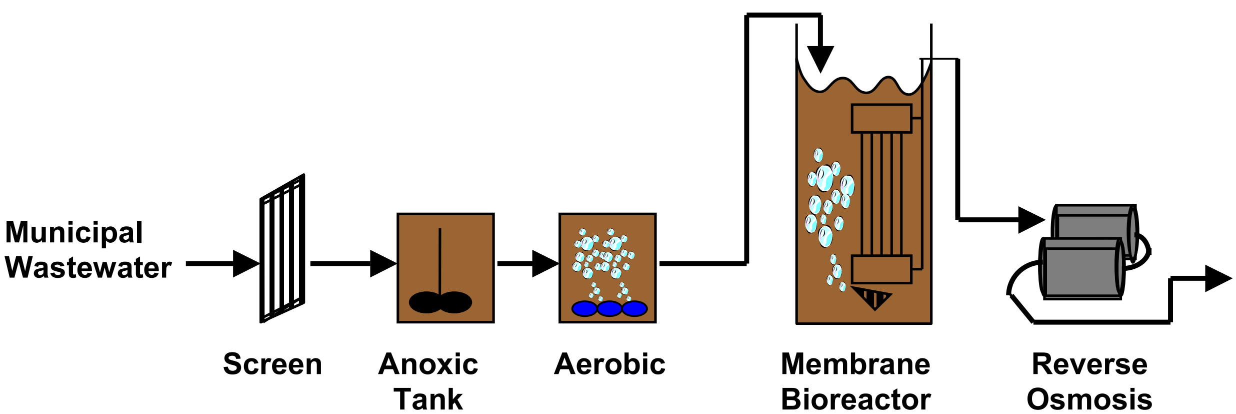
- Demonstrate that MBR effluent meets reclaimed water quality goals for commercial, landscape irrigation and industrial uses as well as surface water discharge requirements.
- Demonstrate the proposed IMS system (MBR→RO) meets water quality goals for Safe Drinking Water Act and New Mexico Water Quality Control Commission standards for groundwater recharge.
- Provide Training to City of Rio Rancho Wastewater Treatment Operators on modern technologies (MBR and RO).
- Evaluate pretreatment and post treatment (including disinfection) requirements and concentrate disposal options for the IMS.
- Develop cost estimates (capital and O&M) for the proposed water reuse train.

Materials and Methods

Pilot testing was conducted at the City of Rio Rancho Wastewater Treatment Plant No. 2 (WWTP #2). This facility currently utilizes a conventional activated sludge process to treat approximately 3.0 MGD of municipal wastewater. The existing plant consists of influent headworks (grit removal and mechanical screening), anoxic and aeration basins, conventional clarifiers, and ultraviolet disinfection.

Treatment at the pilot study consisted of prescreening, anoxic and aerobic basins, MBRs, and reverse osmosis. The pilot study arrangement that was used for testing is shown in Figure 1. Feed for the pilot study was diverted from the coarse screened influent from WWTP #2 at a splitter box prior to the anoxic basins.

Figure 1: Rio Rancho IMS Pilot Study Schematic



Screening Equipment

A Roto-Sieve (RS) Model 6013-11 drum screen was used for prescreening during this study. The RS 6013-11 screen is a rotating drum screen with 0.8 mm perforation. During operation the feedwater from WWTP #2 splitter box is fed into the screen, and then filtered and discharged at the opposite end of the screen. Screened particles are retained within the drum and exit the screen at the feed end via a hopper.

Membrane Bioreactors and Biological Treatment Basins

After prescreening, the screened wastewater was pumped to the anoxic basin and then gravity fed to the aerobic basins. These basins were sized and arranged to mimic the biological nutrient removal of WWTP #2. The solids retention time of the basins was approximately 9 days with a hydraulic retention time of 6.5 hours. The dissolved oxygen in the anoxic zone was maintained below 0.2 mg/L and above 2 mg/L in the aerobic zones.

From the aerobic basins, wastewater was split and pumped to two Zenon membrane bioreactors in parallel. Two MBRs were operated in parallel to provide at least 14 gpm of feedwater to the reverse osmosis units. The MBR units each had one ZW500 cassette submerged in the ZenoGem unit where it was agitated with coarse air diffusers. One unit contained a 500c cassette and one unit contained a 500d cassette. During pilot testing the units were operated at a target flux of 15 gfd. Wastewater was filtered through the fibers, and blended permeate from both units pumped to the reverse osmosis pilot units. Waste activated sludge (WAS) was recycled back to the WWTP #2 anoxic basin. Maintenance cleans were initiated at least once/week to ensure a continuous operation.

A schematic of the Zenon MBR pilot units tested during this study is shown in Figure 2. Each pilot unit is equipped with a 185-gallon ZenoGem membrane unit. Batch wasting was performed from the anoxic tank to maintain a constant sludge age. One ZW 500c membrane cassette, containing 3 membrane elements, was submerged in each of the ZenoGem units for a total membrane area of 1500 ft^2.

During operation, coarse air was used to scour the membranes and was cycled on/off at set intervals (typically 10 seconds). The 500c or 500d membrane is a reinforced hollow fiber membrane with nominal pore size of 0.04 micron.

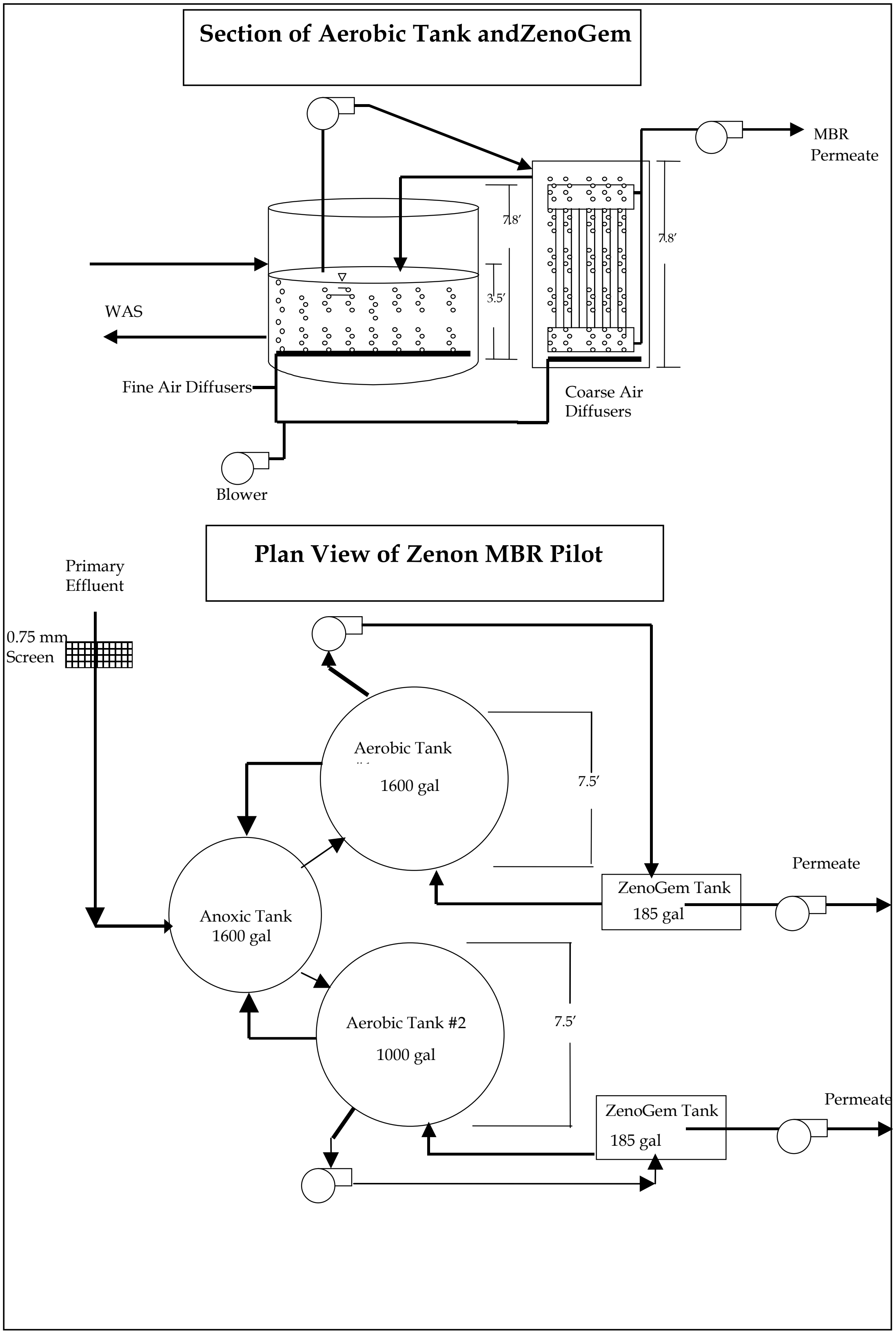


Figure 2: Schematic of MBR units

Reverse Osmosis Pilot Units

A reverse osmosis (RO) pilot system was used during this study to treat effluent from the MBR. The RO pilot system was contained within a forty-five foot long semi-trailer which houses the plant and an enclosed laboratory/office area, all of which is HVAC controlled. For this study, the process was configured with two single stage treatment trains to allow for the simultaneous evaluation of RO membranes from two different suppliers. Each train consisted of one pressure vessel (Code Line Pressure Vessel – Model U4B) containing (6), four-inch diameter by forty-inch length spiral wound membrane elements. The overall process included chemical feed systems for chloramines and scale inhibitor prior to the membranes and a membrane cleaning system. On-line analytical measurements included pH, conductivity, flowrate and pressure. Data acquisition was performed on all analytical, flow and pressure measurements via a personal computer and data acquisition software.

The reverse osmosis (RO) testing in this study consisted of two phases. The first phase compared four RO element manufacturers where two were tested in parallel at a time at 50% water recovery. The second phase consisted of operating one RO element manufacturer at a water recovery of 75%. The first phase of RO testing consisted of comparing the performance of GE Osmonics, Saehan, Toray, and Hydranautics membranes. The membranes were tested in two parallel trains, where each train consisted of one pressure vessel loaded with 6 membrane elements. Both trains were operated at a constant flux of 10 gfd for one month for each pair of manufacturers. Per the manufacturer recommendations, the RO influent was dosed with 2 mg/L antiscalant and 2 mg/L combined chlorine.

Water Quality Testing

During the pilot testing, water quality samples were collected and analyzed to demonstrate that the MBR and RO processes met applicable water quality criteria for water reuse.

During pilot testing the MBR process was evaluated to meet reclaimed water quality standards and applicable requirements for irrigation, industrial and commercial uses. A specific list of agencies and requirements is provided below:

- New Mexico Environment Department (NMED) Class 1A Reclaimed Water Quality Standards.
- Industrial Water Quality Monitoring.
- NPDES.

During pilot testing the MBR →RO process was evaluated to determine if it meets water quality standards for the ground water discharge. A specific list of agencies and requirements is provided below:

- Safe Drinking Water Act Standards (SDWA) and 20.7.10 (NMAC).

- New Mexico Water Quality Control Commission Standards, 20.6.2 (NMAC).
- Draft Policy Requirements for Aquifer Recharge Using Reclaimed Domestic Wastewater, (NMED, March 2004).

Additionally, the MBR → RO system was evaluated for removal of endocrine disrupters, pharmaceuticals and other chemicals commonly found in wastewater. Although the human health and ecological significance of these compounds is not well understood, regulators in some states have begun to establish monitoring requirements for a selected subset of these compounds for recharge projects.

Results

The results of the pilot study revealed that the MBR plant will successfully provide consistent high quality tertiary treated water for future industrial, commercial and irrigation non-potable applications. Further treatment of the reclaimed MBR tertiary water with reverse osmosis will meet all federal and state regulations. Phase 1 of the pilot testing, where the four RO manufacturers were tested, indicated that all manufacturers produced high quality effluent which met all federal and state regulations. The differences between the effluent conductivity were the primary indicator of different treated water quality (i.e. salt rejection at a given flux). The GE Osmonics membranes were selected for the testing at 75% water recovery due to the lowest feed pressure required and the lowest conductivity permeate. Figure 3 illustrates the conductivity achieved for the RO membrane under a constant 10 gfd flux.

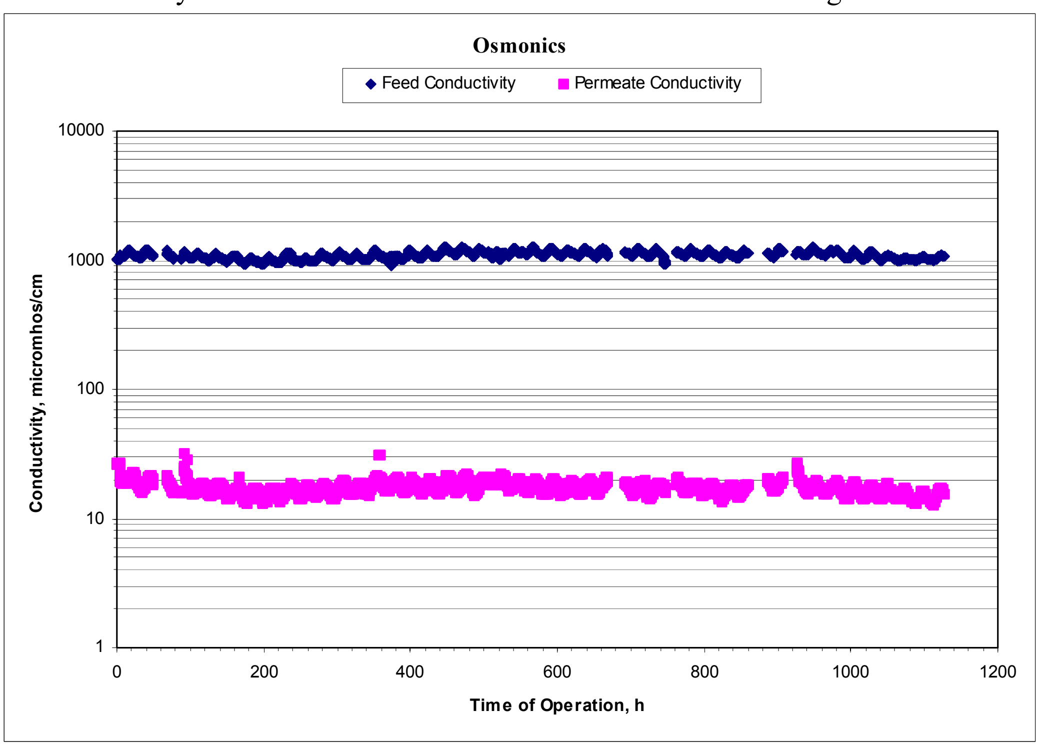


Figure 3: GE Osmonics Feed and Permeate Conductivity at 50% Recovery

Overall, water quality data from the MBR effluent have shown excellent removal of coliform and other constituents that makes the water acceptable for any future industrial, commercial and irrigation non-potable applications and as a feed water for RO treatment. Table 1 illustrates the relative concentrations of several constituents in the permeate for the four membranes tested. Constituents not shown were below the detection limit.

Table 1: RO Effluent Concentrations for 4 Manufacturers at 50% Recovery

Constituent	**RO Effluent**				***Unit***
	Osmonics	**Hydranautics**	**Saehan**	**Toray**	
General					
PH	6.6	6.4	6.6	6.5	PH
Total dissolved solids	15	18	19	<10	mg/L
Conductivity	18	40	32	25	Umhos/cm
Boron	0.43	0.3	0.43	0.28	mg/L
Chloride	<1.0	<1.0	1.6	<1.0	mg/L
Nitrate nitrogen	0.66	0.5	1.5	0.44	mg/L N
Radium 228	<0.79	<0.544	<1.0	<1.09	PCi/L
Diethylphthalate	<0.5	0.65	<0.5	<0.5	ug/L

All data for this study is not complete at the writing of this paper. Preliminary data received from the Phase 2 testing included the results of the 75% water recovery runs on the GE membranes as well as testing for removal of emerging contaminants. All data indicate that these membranes will remove all contaminants of concern at this recovery.