Reverse Osmosis Treatment Facilities: Innovative Post-Treatment Stabilization Solutions

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Because of tightening restrictions on the use of freshwater resources, utilities have increasingly turned to reverse osmosis (RO) membrane technologies to tap brackish water resources. The RO process removes calcium and bicarbonate/carbonate ions, so the resulting permeate has unacceptably low levels of calcium hardness and alkalinity. Without additional treatment, the RO permeate would be unappealing aesthetically, poorly buffered against changes in pH, and aggressive to infrastructure components.

Rendering the decarbonated RO permeate suitable for distribution requires pH adjustment and the addition of calcium and alkalinity. A cost-effective option for post-treatment stabilization of the permeate is blending a percentage of a freshwater containing sufficient levels of calcium hardness and alkalinity, but utilities must prepare for the possible deterioration of the blend source water quality or reductions in its permitted use.

The Collier County Northeast Water Treatment Plant (NEWTP) project utilized several approaches to handle these two possibilities. The Collier County project team was given the challenge of designing a standalone water treatment facility. As part of this charge, the design for the post-treatment stabilization system kept an eye to the future and built in flexibility to potential changes in the water quality or availability of the raw water resources.

Approach

The NEWTP has a freshwater resource, the Lower Tamiami Aquifer, that will provide blending water with sufficient levels of native calcium and alkalinity for post-treatment stabilization. Freshwater aquifers in Florida are heavily monitored and regulated by the water management districts, so there are no guarantees that water available today will be available in years to come; therefore, the project team looked to provide flexibility should the Lower Tamiami water become unavailable in the future.

Providing post-treatment stabilization without a freshwater blend source would normally require adding chemical combinations such as carbon dioxide or calcium chloride and sodium hydroxide. These systems can suffer from residual turbidity, maintenance problems, and high operational costs, or they can add unwanted chlorides to the finished water, so the Collier County team sought a better, more innovative alternative.

Natural Limestone Contactor

If sufficient freshwater is not available in the future, the alternative is to construct natural limestone contactors (LSCs) to replace the freshwater blend. The LSC uses natural limestone and carbon dioxide (pH adjustment) to add calcium hardness and alkalinity to the brackish-water RO permeate. The future limestone contactors design criteria are presented in Table 1.

The following provisions are included in the facility design to provide for the constructability of the limestone contactors in the future:

- Electrical loads for future limestone contactors and transfer pumps in the design of the electrical transformers and switchgear.
- Space for construction of the limestone contactors in an appropriate location.
- Laydown and staging area for the LSC construction in the future.
- Connections on yard piping for future installation of LSCs.

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Natural limestone contactors are more commonly found outside the United States. Often LSC installations are utilized where importing chemicals for post-treatment stabilization may be cost prohibitive, such as the Bahamas or other remote areas. One of the largest LSC municipal scale installations is located on the island of Aruba, where natural coral is utilized as the source of limestone.

Critical issues to consider during limestone contactor design are:

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Table 1: Limestone Contactor (Future)
Collier County – Northeast Water Treatment Plant

Description	**Unit**	**Phase 1**	**Phase 2**	**Phase 3**
No. of Beds	No.	4	7	10
No. of Reliability Beds		1	1	1
Percent of Permeate Treated	%	75	75	75
Flow per Bed	gpm (mgd)	1,735(2.5)	1,735(2.5)	1,735(2.5)
Bed Dimensions:				
Length x Width	ft x ft	60 20	60 20	60 20
Area per Bed	ft^2	1,200	1,200	1,200
Limestone Bed Depth	ft	8	8	8
Surface Loading Rate	Gpm/sf	1	1	1
Superficial Velocity	cm/min	5.9	5.9	5.9
Empty Bed Contact Time (EBCT)	Min	5.5	5.5	5.5
Bed and Underdrain Headloss	ft	2.3	2.3	2.3
<u>LIMESTONE CONTACTOR TRANSFER PUMPS (FUTURE)</u> Type: Vertical Turbines in Closed Bottom Cans				
Number of Pumps (Total)	No.	3	5	7
No. of Reliability Pumps	No.	1	1	1
Total Flow Rate	gpm (mgd)	5,210(7.5)	10,410(15.0)	15,620(22.5)
Flow Rate Per Pump	gpm (mgd)	2,605(3.8)	2,603(3.8)	2,603(3.8)
Total Dynamic Head (TDH)	ft H_2O	32	32	32
Motor Horsepower				
Per Pump	Hp	40	40	40
Total	Hp	120	200	280
Drive: Variable Frequency (VFD)	!	!	!	!

[a] Limestone effective particle size 0.8 mm (worst case)

Table 2: Freshwater Anion Exchange System Design Criteria
Collier County – Northeast Water Treatment Plant

Description	Units	Phase 1	Phase 2
Type: Fixed-Bed Vertical Pressure Vessel			
Number of Vessels (total)	No.	5	9
Vessels (reliability)	No.	1	1
Flow per Vessel	gpm (mgd)	868 (1.25)	868 (1.25)
Color Removal Efficiency	%	90	90
TOC Removal Efficiency	%	60	60
H_2S Removal Efficiency	%	60	60
Influent pH (Target)	pH	> 8	> 8
Influent Color	C.U.	20	20
Influent TOC	mg/L	4	4
Influent H_2S	mg/L	1.5	1.5
Effluent Color	C.U.	2	2
Effluent TOC	mg/L	1.6	1.6
Effluent H_2S	mg/L	0.6	0.6
Regeneration Brine Tank			
Type: Vertical HDPE			
Number of Tanks		1	1
Regeneration Pump			
Flow	gpm	350	350
TDH	ft H_2O (psig)	46 (20)	46(20)
Number of pumps (Total)	No.	!2	2
Pumps (Reliability)	No.	1	1
Motor Load (Each)	Hp	7.5	7.5
Driver: Constant Speed			

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- Availability of NSF-approved limestone.
- Headloss characteristics of available limestone (particle diameter specific).
- Limestone storage and feed design characteristics.
- Controlled bypass capability for achieving target finished water hardness and alkalinity.
- Pre-LSC pH adjustment for dissolution rate control (carbon dioxide should be used instead of sulfuric acid to avoid sulfate-based scale formation and alkalinity consumption).

Anion Exchange System

Before being blended with the RO process permeate, the Lower Tamiami freshwater requires treatment to remove hydrogen sulfide and color. Because free chlorine will be used to oxidize residual hydrogen sulfide, the reduction of disinfection byproduct (DBP) precursors is required. A fixed-bed anion exchange system was designed to meet the treatment requirements.

The anion exchange resin will remove color, DBP precursors, and some hydrogen sulfide from the freshwater supply. Caustic soda will be added upstream of the anion exchange beds to provide optimum removal of sulfide (predominately as HS^- at pH > 8.0). When the anion exchange resin in an individual, fixed-bed vessel is exhausted with respect to the target constituents, it will be taken off line and regenerated with a sodium chloride (brine) solution, which will replace the adsorbed ions with chloride.

Design criteria for the anion exchange system are shown in Table 2.

Resin Selection

An NSF Standard-61 certified resin is specified for the anion exchange system. Strong Base Anion (SBA) resins are capable removing the target constituents in the project freshwater supply and are available in a wide variety of compositions and architecture.

Because of the strongly basic attributes of Type I SBA resins, they tend to remove natural organic matter (NOM) more efficiently than Type II/acrylic. The less-basic Type II resins are not as effective in attracting the weakly ionized NOM; however, Type II/acrylic resins are for the same reasons more effective during regeneration cycles at returning to the baseline operational capacity because of reduced attraction properties, allowing the NOM to be released more easily.

Other criteria for the SBA resin selection include:

- **Type I**
  - High NOM removal efficiency, reduced regenerative capacity
- **Type II/Acrylic**
  - Reduced NOM removal efficiency, increased regenerative capacity
- **Odor Throw**
  - Objectionable/fishy odor
  - Type I w/highest incidence
- **Required Regeneration Rate** (cycles per day)
- **Resin Life Expectancy**

SBA resin selection is a function of the initial water quality and the finished-water quality goals. Pilot testing of SBA resins is recommended to assure the site-specific water quality is properly matched to the resin media. Improperly matched resins may be effective initially, but they may have long-term performance issues.

Raw Water Resources

The NEWTP will produce finished water using three potential water sources:

- *Lower Tamiami Aquifer*: A “freshwater” (i.e., non-brackish) supply characterized by high hardness, high color and total organic carbon (TOC), with some hydrogen sulfide.
- *Hawthorn Zone 1 Aquifer*: Currently identified as a freshwater supply in the vicinity of the NEWTP site, with moderate hardness, some hydrogen sulfide, low color, and low TOC; however, potential deterioration of the Hawthorn Zone 1 supply through increasing salinity is possible over time.
- *Lower Hawthorn Aquifer*: A brackish supply with high total dissolved solids (TDS), high hydrogen sulfide, low color and low TOC.

The primary supply for the NEWTP is the brackish Lower Hawthorn Aquifer, which requires treatment to remove salinity (sodium chloride), other dissolved salts, and hydrogen sulfide. The proposed treatment process is an RO membrane system for removing salts, followed by air stripping (degasification) to remove hydrogen sulfide. The freshwater supplies will be used for blending with the RO membrane permeate to achieve a stable, non-corrosive finished water with an acceptable hardness and alkalinity.

Results

The anion exchange system will provide a freshwater blend source to stabilize the RO permeate with reduced DBP precursors and hydrogen sulfide. Should the freshwater blend source become unavailable for blending, LSCs will provide post-treatment stabilization from NSF-approved natural limestone. The three aquifers available to the facility provide flexibility in an ever-changing environment. The

Post-Treatment Stabilization

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NEWTP design will further ensure a reliable potable water supply for Collier County with its ability to react to changing water quality.

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