Comparing Conventional and Pelletized Lime Softening Concentrate Chemical Stabilization [Project #4283]

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OBJECTIVES:
The objectives of this project were to (1) demonstrate at pilot scale that both conventional and pellet softening Intermediate Concentrate Chemical Stabilization (ICCS) technologies can effectively remove inorganic membrane scale forming constituents (silica, barium, calcium, etc.) and enhance the overall reverse osmosis (RO) system recovery to about 92.5 to 95.5%; and (2) compare the pellet vs. conventional ICCS reactors in performance, chemical and power consumption, process footprint, residual quantity, capital, O&M and life cycle costs, environmental impacts, and application potential.

BACKGROUND:
Nearly all available water resources with good quality are fully utilized in the southwest United States. Advanced treatment processes, such as RO, are currently being used to desalt the brackish groundwater, surface water, and reclaimed water sources. Most two or three-stage brackish water RO systems operate at approximately 85% recovery or less, losing 15% or more water as a high salinity concentrate stream. Technologies that can recover more from the few available resources and reduce the volume of the wasted concentrate are key interests.

APPROACH:
To maximize water recovery and continue the development of reliable water supplies for its customers, the City of Phoenix is investigating brackish water desalination and concentrate management technologies for its future Western Canal Water Treatment Plant (WCWTP). The WCWTP Water Quality Sampling and Testing Project (referred to as “Phase Phoenix” hereafter) was conducted to further investigate the feasibility of this potentially effective concentrate volume reduction strategy identified in the WCWTP Master Plan. This strategy utilizes ICCS of RO concentrate followed by a secondary RO system to improve the overall system recovery from 85% to about 92.5 to 95.5%.

The Phase Phoenix pilot testing was conducted using microfiltration surface water pretreatment skids, a two-stage primary RO system, a conventional softening ICCS reactor, a sand filter, and a single-stage secondary RO system. The test results demonstrated the feasibility of achieving 94% overall recovery on brackish surface water and groundwater.
The Phase Phoenix testing results show that, effective as it is in removing membrane scale forming constituents, conventional softening based ICCS requires a significant amount of lime to raise the concentrate pH to above 10.5 to achieve effective removal of silica through the precipitation of magnesium hydroxide. This process also generates a large volume of chemical sludge, which would require subsequent solids handling in full-scale application, such as dedicated gravity thickener and/or dewatering centrifuges. Previous research studies and bench scale data obtained at Arizona State University suggested that the use of fluidized bed pellet softening reactor could reduce chemical addition, reactor footprint, and the volume of solid residuals, and might even improve the overall RO system water recovery.

The tailored collaboration study presented in this report (referred to as “Phase TC” hereafter) investigates pellet ICCS as a means to lower chemical and energy input required to achieve high overall RO recovery rate (92.5 to 95.5%). In addition, this phase of pilot testing extends the secondary RO run time from Phase Phoenix 600 hours to about 1,000 hours. The extended run hours are intended to test whether such high recovery RO performance is sustainable with reasonable fouling and scaling rate and manageable cleaning frequency.

ICCS is a relatively new treatment process in the United States. By advancing the previous Phase Phoenix research on the conventional softening ICCS technology, this research explores the opportunity to improve the process efficiency using fluidized bed pellet softening ICCS. Treatment costs, chemical usage, residual handling, and energy consumption for the two ICCS technologies are compared. The comparison based on pilot scale testing provides insightful information for full-scale application regarding economic and energy associated with ICCS technology.

RESULTS/CONCLUSIONS:
It is important to point out that the pilot testing data presented in this report are only valid for water sources with similar water quality to the tested water. Utilities considering implementing ICCS should conduct water quality testing and examine how to apply a similar comparison approach to their site-specific water quality and planning constraints.

Conventional Lime Softening ICCS Pilot Testing

A two-stage primary RO system was used to treat both brackish groundwater and surface water sources to achieve a sustainable recovery of 85%. The recommended flux rates were 15 gfd for the brackish groundwater and 12 gfd for the brackish surface water. During the 2,800 hour pilot operation, the primary RO treated feed water with conductivities ranging from 1,500 to 2,600 μS/cm, and consistently produced high quality water. No chemical cleaning on the primary RO system was conducted during the course of pilot testing.

The conventional lime softening ICCS process is capable of stabilizing the primary RO concentrate for both groundwater and surface water sources. At a target pH of 10.5, the ICCS process can remove approximately 65 to 76% silica, 86% barium, 84% strontium,
and 77% calcium. Lime is preferred versus caustic soda based on the chemical costs of lime and acid required for pH adjustment after ICCS. The ICCS technology was able to successfully handle the water quality variations between brackish surface water and groundwater.

The conventional ICCS allowed the subsequent secondary RO pilot skid to be operated at 60%. It is expected that the maximum recovery that can be achieved based on maximum saturation limits of sparingly soluble salts using a full-scale secondary RO design that is not constrained hydraulically like the pilot skid would be 70% with conventional ICCS process. Effective as it is, the conventional ICCS technology required a high dose of chemicals and produced a large volume of residuals. Refer to Chapter 2 and Chapter 4 for details.

Pelletized Softening ICCS Pilot Testing

The pellet softening ICCS was successfully pilot tested during the testing. High recovery (92.5%) was achieved on brackish groundwater using dual RO system and the pellet softening ICCS. Over 70% calcium and 50% silica were removed, allowing the secondary RO pilot skid to recover 50% from the primary RO concentrate. It is expected that the maximum recovery that can be achieved based on maximum saturation limits of sparingly soluble salts using a full-scale secondary RO design that is not constrained hydraulically like the pilot skid would be 60% with pellet ICCS process. Refer to Chapter 3 for details.

Process Comparison

Process footprint, chemical usage, and residual handling requirements for the conventional softening and pellet softening ICCS are compared in Table ES.1 in the report.

In summary, the convention softening ICCS reactor requires a significant amount of chemicals. The process generates a large volume of residuals, which in turn have to be handled properly. An ideal application for the conventional ICCS process may be at a brackish surface water treatment facility that already has residuals handling systems in place.

The pellet softening ICCS could be ideal for wellhead or centralized groundwater desalting facilities where a smaller footprint for the ICCS reactor and residuals handling facilities is important. A major advantage of the pelletized softening reactor is its ability to produce highly pure, nearly dry pellets. Due to their excellent composition, the pellets can normally be recycled or reused for various applications, resulting in little or no solid waste disposal. Even if the pellets have to be disposed of by other means, the advantage of low-volume secondary waste production still remains: water-free pellets, not bulky sludge. However, the performance of the pelletized softening could be impacted by site specific water quality and the process is less effective in removing silica compared to the conventional ICCS. Water quality assessment and modeling tools are available to select
conventional versus pelletized ICCS and assess the impacts of water quality on design and operational parameters. But pilot testing is recommended, especially for pelletized softening. Refer to Chapter 4 for details.

**Life Cycle Assessment**

To fully evaluate the environmental impacts of the concentrate volume reduction technologies, the Western Canal Tailored Collaboration Study included a life cycle assessment (LCA) for implementing a 10-mgd brackish groundwater desalination facility utilizing primary RO, conventional or pellet softening ICCS, and secondary RO in the area of Phoenix, AZ. In general, the study demonstrates that Option 2 pelletized softening ICCS lowers environmental impacts due to reduced consumption of chemicals and energy and reduced residuals handling requirements. Refer to Chapter 5 for more details.

**Fouling Characterization**

When conventional softening ICCS was used to stabilize the primary RO concentrate, the post-ICCS secondary RO membranes were fouled more severely during the surface water phase than the groundwater phase membranes. When groundwater was the feed source, the post-ICCS secondary RO membranes were fouled more severely during the Phase TC (pelletized softening ICCS) than the Phase Phoenix (conventional softening ICCS). Fouling occurring in both groundwater and surface water phases can be attributed to silica (SiO₂ or aluminum silicates) and the colloidal material, but co-presence of the natural organic matter and the colloidal silicates in the surface water also worsen the fouling. Refer to Chapter 6 for more discussion regarding the fouling characterization and means to help control fouling.

**Beneficial Reuse**

Developing an economical and environmentally acceptable strategy to beneficially use the pellets wasted from a pelletized softening process helps to further reduce the residual disposal costs of the ICCS technology and the overall salinity management costs. Sizes, chemical compositions, and toxicity characteristics of the pellet samples were documented in Chapter 7, providing a basis for evaluating the reuse potential. The reuse potential of pellets as concrete aggregates and as nutrient supplements was briefly investigated.

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