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optimum permeate blending

Post-treatment options in water desalination

Communities throughout the U.S. face a variety of environmental infrastructure challenges, not the least of which is the U.S. Environmental Protection Agency's (EPA) Safe Drinking Water Act (SDWA). Continuing advances in regulatory mandates and increasing demands related to aesthetic criteria for consumer water quality have driven the water community to seek new water supplies and treatment technologies that meet these criteria.

Potential water quality impacts of particular importance when addressing water quality compatibility involve: regulatory compliance, public health effects, the chemicals used to provide disinfection and the factors affecting the corrosiveness of the water distributed to customers.

Post-Treatment Considerations

In general, the permeate from the membrane desalting process produces permeate water that is considered chemically unstable and low in mineral content, which can lead to corrosion within the distribution system. The mineral composition of the water is significantly changed and then partially reconstituted to achieve stable finished water that can be distributed in pipes. Whether or not the composition of the finished water has a positive or negative impact on the viability of distribution system components, distributed water quality and health of long-term consumers of desalinated water supplies remains mostly unknown.

Water that contains little to no hardness would be considered unhealthy for potable use, and water that contains no dissolved oxygen (DO) may be offensive and taste flat. Consequently, post-treatment of membrane-desalinated water is required prior to storage and distribution for municipal water purveyors and must include disinfection.

When applying nanofiltration (NF) and reverse osmosis (RO) technologies, it is important to produce finished water that is compatible with the existing distribution system. Problems can arise if the finished water contains too little alkalinity, hardness, DO or sulfur turbidity. NF-RO processes effectively remove disinfection byproduct (DBP) precursors, pathogens, salts and other solutes from the water. Important substances that are necessary to produce water that is stable during distribution (e.g., carbonate alkalinity) also are removed from the water.

For municipal water systems, post-treatment is required for the permeate flow stream before distribution to the water community. The choice and sequence of post-treatment operations typically are determined by regulatory requirements, which can impact the design of the system and finished water quality criteria. The need for post-treatment typically depends on chemical stability, microbiological stability and palatability, color, odor and taste.

In brackish groundwater, permeate dissolved gases typically are removed using aeration. Forced-draft aeration is commonly used for this purpose; it involves pumping permeate water to the top of a tower where the water flows by gravity through randomly packed media. Air is then blown into the bottom of the tower, which blows upward, taking dissolved gases stripped from the liquid phase as it travels countercurrent to the flow of water.

Hydrogen sulfide removal is important from both aesthetic and operational aspects. Aesthetic benefits include avoidance of problems associated with taste, odor and turbidity that could result if left untreated. Carbon dioxide removal through aeration benefits the finished water by raising the pH and stabilization with respect to calcium carbonate; however, this carbon dioxide represents a useful source of alkalinity that can be recovered to stabilize the finished water.

NF-RO permeate can be remineralized in several ways. Examples of a few options available to the designer include calcite contactors; lime coupled with carbonic acid addition; sodium hydroxide with carbonic acid addition; addition of sodium hydroxide and blended phosphate corrosion inhibitor; and blending treated permeate with raw groundwater.

Calcite contactors are relatively simple processes whereby permeate passes through a calcium carbonate-based medium that slowly dissolves over time, and are useful in smaller desalting plants. The dissolution increases alkalinity with the added benefit of imparting an equivalent amount of hardness. Permeate can be treated to different levels by varying the contact time, pH and media granule size.

As for lime (or sodium hydroxide) and carbonic acid addition, this technique is effective but not widely practiced due to labor-intensive chemical feed equipment and residual turbidity from impurities present in the raw lime chemical. Using hydrated food-grade lime can reduce the secondary turbidity impact. A more effective method is the use of sodium hydroxide in combination with carbonic acid.

Typical brackish water remineralization is accomplished with the use of sodium hydroxide and corrosion control inhibitor (blended or zinc orthophosphate) in most municipal applications.

Process Bypass Blending

Often RO permeate is stabilized by blending a small portion of the source water into the product water—the purpose of which is to help in stabilizing the product water, thereby reducing water corrosivity. Blending permeate with raw groundwater is the least-cost remineralization technique and is accomplished by routing a portion of the raw groundwater around the NF-RO process and blending it with permeate. The amount of alkalinity and hardness that can be added is often times limited by other parameters, such as chlorides, DBP precursor (nonpurgeable dissolved organic carbon) and bromide.

Water blended to produce an alkalinity level to reduce the corrosion of iron components could result in increased corrosion of copper components. Furthermore, blending of permeate with native waters for post-treatment purposes could be limited by the amount of iron and manganese concentrations present in the native water, as these constituents can cause taste, odor and stains, and would limit overall blend ratios.

Blending Into System Infrastructure

As water is transported through a distribution system, physical, chemical and microbiological transformations may occur that result in degraded water quality. Aged water distribution systems typically have achieved some state of quasi-equilibrium, and as a result have minimal problems.

Changes in water quality and

Table 1. Relative Probability of a Water Quality Issue in a Distribution System Affecting a Utility's Regulatory Compliance

Regulation	Relative Probability
Surface Water Treatment Rule(s)	Very Low
Consumer Confidence Reports	High
Phase I VOCs	Low
Phase II SOCs and IOCs	Low
Phase IIA Fluoride	Low
Phase V SOCs and IOCs	Low
Radionuclides	Low
Lead and Copper Rule (LCR)	High
Total Coliform Rule (TCR)	High
Disinfectant Byproducts (D/DBPs)	Low
Secondary Standards	High

conditions, however, can affect water distribution systems significantly, particularly if new water supplies or different water supplies are used to supplement water resources for the community. This is often the case when existing groundwater supplies are converted to a mixture of surface water and desalted source waters. These interactions occur in the bulk phase and surfaces in contact with the water column. When blending water from multiple sources, it is helpful to use a multi-objective technique to evaluate the optimum blend for a particular distribution system requirement.

Water Quality Risks

A summary of the expected regulatory impacts on water purveyors, after blending or replacing a current water supply with desalted permeate, is listed in Table 1 (see page 17). The probability of having issues concerning a water purveyor's compliance with the provisions of the Surface Water Treatment Rule (SWTR) are shown as very low in Table 1. If the water purveyor has produced historically safe water and desires to integrate advanced treatment into their system, then the resulting blended water will be of higher quality in terms of SWTR regulations.

Experience has shown that when a dramatic change in steady-state conditions occurs in an aged and mature water distribution system, an impact to the water chemistry will occur within the distribution system. This often occurs when utilities introduce or blend permeate water sources into their existing water supply. It is not uncommon for the distribution system to experience fluctuations in pH and water chemistry due to high DO concentrations and low alkalinity. This can result in destabilization of the mineral and biofilm coating known to exist inside the distribution piping system.

Customers may experience increased copper and lead concentrations at the consumer tap; red, black or turbid water; and water having objectionable tastes or odor. The expected impact will place the consumer at greater relative risk to distribution system-related compliance items, namely the total coliform rule (TCR), lead and copper rule (LCR) and secondary standards for iron, turbidity, color and odor as shown in Table 1.

Utilities should consider the effects of introducing permeate water into their water supply and its effects of DBP regulations. It is anticipated that bromide from the desalted permeate water would likely increase brominated forms of DBPs, specifically dibromochloromethane, bromodichloromethane, bromoform and bromate, if utilities attempted to maintain free chlorine residual without some form of advanced treatment. In that case, a "high" risk of regulatory violation would be projected. The low risk for D/DBP noncompliance presented in Table 1 is based on the assumption that water purveyors would maintain chloramine disinfection unless advanced treatment is provided.

There is a high probability associated with violation of secondary standards concerning iron, turbidity, color, odor and corrosivity when introducing a new permeate water supply into a utility's distribution system. As stated, permeate water can destabilize mineral coatings known to exist on the inside of pipe walls, causing red, black or turbid water with objectionable tastes or odor. As a result, it is anticipated that consumer confidence reports (CCRs) may be impacted because of additional contaminant monitoring under the revisions of the SDWA relative to the contaminant candidate list (CCL).

If any of the CCL chemicals being monitored in the system are detected above a detection limit, they must be added to the CCR for that specific community. These are chemicals for which no standard has been established. A greater potential exists for surface waters to contain some of these candidate compounds; however, the membrane process would have removed such contaminants.

Relative Risks & Impacts

Water quality parameter-related problems include lead and copper, high turbidity, *Cryptosporidium* and *Giardia* and bad taste and odor. Although some of these have a low probability of occurring, they carry a high risk to public health if an event were to occur. Potential impacts on the distribution system and water treatment facilities cannot be ignored, particularly if recurring events require pipe replacement in the distribution network and optimization or replacement/abandonment of water treatment facilities in favor of advanced drinking water treatment processes.

Water purveyors should adhere to an understanding that establishment of community water quality goals and performance objectives regarding the operation of a water distribution system are important for successful consumer confidence. This is particularly the case when integrating new unit processes operations that, when blended into existing water distribution infrastructure, adversely alter water quality and public perception.

Consideration of the probability of adverse impacts and the identification to the degree of risk (relative) for each regulated water quality parameter should be evaluated prior to implementation of integrating advanced water treatment technologies in existing water system distribution systems. Through the continuous refinement of disinfection and corrosion control, utilities can establish corrosion optimization when they embrace programs that specifically address this blending issue—maintaining a noncorrosive, nonoffensive environment within its distribution system—while controlling DBP formation. MT

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