Stabilization of Desalinated Water

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EXECUTIVE SUMMARY

SUMMARY

Desalination of sea or brackish water is an important, rapidly growing source of drinking water around the world. 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 ultimate 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 for the most part unknown.

With a growing number of potable water purveyors turning to desalination processes as a means for augmenting existing drinking water supplies, it is important to understand the behavior of desalted permeate within the distribution system and possible issues that may arise if proper post-treatment of permeate is not practiced. Desalination water is considered corrosive due to its inherently low mineral content and is not suitable for consumption without post-treatment.

Although information regarding the application and effectiveness of brackish and seawater desalination to augment drinking water supplies is readily available with regards to pretreatment, process optimization, energy efficiency and concentrate management, less has been documented and hence is available with regards to post-treatment requirements and secondary impacts. The behavior of desalinated water in the distribution system remains largely non-documented, and potential issues that may arise after introducing desalinated water into existing distribution systems include impacts on internal corrosion control, disinfectants and disinfection by-products, hydraulics, infrastructure maintenance, aesthetics, and customer acceptance.

The research project was conducted to reveal lessons learned, survey the industry practice, and develop concepts and guidelines for the post-treatment stabilization of membrane permeate. The work also to highlighted existing information gaps and identified associated research needs.

POST-TREATMENT

Post-Treatment Is Required

Pure water is considered a reactive chemical. Water that contains little to no hardness would be considered unhealthy for potable use and is often found to be aggressive towards distribution system components. In addition, drinking water that contains no dissolved oxygen 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.

Table ES.1 presents the typical categorization of permeate post-treatment depending on source water type. There are four primary issues concerning the post-treatment water. These relate to blending, remineralization, disinfection and the materials used for storage and transport of the water to the tap. Desalinated water is often blended with other sources that contribute minerals to the final blended water. Seawater as a source for blending is limited due to issues related to corrosivity and taste if the blending levels exceed about 1%. Blending of permeate water with seawater results in the addition of sodium, potassium, calcium, and magnesium to drinking-water but also will contribute bromide and iodide which are DBP precursors. Consideration should be given

Table ES.1
Typical post-treatment processes based on supply type

Supply type	Process	Examples of applicable post-treatment processes
Seawater	RO	1. Recarbonation. 2. Lime addition 3. Calcite bed filtration. 4. pH and/or alkalinity adjustment. 5. Addition of corrosion inhibitors. 6. Primary and secondary disinfection. 7. Blending with fresh water supplies.
Brackish water (surface)	RO, NF, EDR	1. pH and/or alkalinity adjustment. 2. Addition of corrosion inhibitors. 3. Primary and secondary disinfection. 4. Blending with fresh water supplies.
Brackish water (ground)	RO, NF, EDR	1. Decarbonation (degasification) 2. Hydrogen sulfide stripping. 3. pH and/or alkalinity adjustment. 4. Addition of corrosion inhibitors. 5. Primary and secondary disinfection. 6. Blending with fresh water supplies. 7. Bypass blending with raw water supply.
Fresh water (ground)	NF, EDR	1. Decarbonation 2. Hydrogen sulfide stripping. 3. pH and/or alkalinity adjustment. 4. Addition of corrosion inhibitors. 5. Primary and secondary disinfection. 6. Blending with fresh water supplies. 7. Bypass blending with raw water supply.

to the natural minerals present and whether these will result in finished water having unacceptable water qualities in addition to unacceptable taste and odor.

Membranes do not remove small, uncharged molecular contaminants or dissolved gases such as carbon dioxide, hydrogen sulfide and methane. If hydrogen sulfide is present in a source groundwater, it must be removed, typically by packed tower or air stripping processes prior to disinfection and distribution to consumers. If gaseous sulfides are removed in the stripping process, then provisions are also made to remove (scrub) the off-gas sulfides from the air stripping tower to prevent odor and external corrosion issues on surrounding buildings and infrastructure. The stripping of carbon dioxide and hydrogen sulfide raises the pH and reduces the amount of base needed to perform stabilization. Permeate is typically low in calcium, magnesium, alkalinity and may have a low pH if acid was used for pretreatment ahead of the membrane process. Since the permeate is corrosive to downstream piping and appurtenances, alkalinity and pH adjustments are accomplished with bases such as sodium hydroxide, and inhibitors may also be employed for corrosion control purposes.

There is also an issue regarding potential anthropogenic pollutants from a range of sources which need to be considered on a local basis taking into account potential pollution sources and threats. This is the case whenever any external and potentially minimally treated water source is used for blending. Disinfection and filtration of the blending water will be necessary if there is any possibility of microbiological or other regulated parameter contamination, in which case similar considerations regarding the formation of by-products in the blending water apply. Generally, the natural organic matter or TOC content in finished water is very low and the yield of by-products from final disinfection would be expected to be low as a consequence (McGuire Environmental 2004). However, blending with other source waters can prove to be problematic for desalted permeate, should bromide be present, or should the blend not provide enough buffering to the desalted permeate resulting in an unstable finished water.

Chemicals and Post-Treatment Issues

Post-treatment may be achieved by the addition of chemicals as described in the literature. If this is undertaken there are three primary concerns that need to be addressed:

a. The quality of the additives and the introduction of chemical contaminants produced during the manufacture, storage, distribution and transport. Unlike pre-treatment chemicals, there are no downstream processes that will remove undesirable contaminants.
b. Controlling dose rates so that required concentrations are provided. This can prove difficult when dealing with permeate that contains little to no buffering capacity downstream of a membrane process, as without buffering rapid pH changes can occur with minimal dose of acid or base chemical.
c. Preventing or minimizing unwanted chemical reactions following chemical addition. This issue is similar to blending. Localized changes can occur at dosing points leading to fouling problems on a micro-scale, particularly when by-pass or blending is considered.

Brackish and Seawater Post-Treatment Methods

Post-treatment of the permeate water from the desalination processes can include several unit operations, each dependent upon the source water type and desalination method. Considerations of post-treatment, based on literature findings, include:

- Stabilization by addition of caustic hydroxide alkalinity is the most widely used approach for brackish desalinated permeate in order to provide corrosion control for metallic pipelines and distribution systems, although this method is often accompanied by the addition of corrosion control inhibitors. Stabilization can also be achieved by carbonate alkalinity adjustment, remineralization by blending with source water(s) and the use of caustic soda-carbon dioxide or calcite bed contactors have been reported.
- The enhanced removal of specific compounds (i.e., boron, silica, NDMA, etc.) is site specific and source dependent.
- Sodium hypochlorite and chlorine gas are most widely used for disinfection of desalinated water. However, the use of chloramines instead of chlorine for residual disinfection is more advantageous when product water must be conveyed over long distances (over 100 km), or when stored for long periods of time (several days) due to the significantly lower decay rate of chloramines compared to free chlorine.

- Use of ozone as a disinfectant for desalinated water is limited as this practice has the potential of forming bromate as a disinfection by-product.
- Blending of desalinated water for remineralization is suitable with brackish water, but only feasible to up to about 1% with seawater. The raw water used for blending should be pretreated for chemical and microbial control prior to mixing with the desalinated water.

The primary desalination water plant post-treatment unit operations for potable water supplies reliant upon brackish groundwater are the following (AWWA 2007; Duranceau, 1993):

- Carbon dioxide removal (degasification or decarbonation);
- Hydrogen sulfide removal (stripping) and odor control treatment (scrubbing);
- Alkalinity recovery, pH adjustment, stabilization and corrosion control; and,
- Disinfection.

Alternative treatments reported for use in seawater desalination post-treatment applications include (Withers 2005):

- Addition of carbon dioxide and excess lime;
- Filtration of carbon dioxide dosed permeate through limestone bed contactors;
- Application of sodium carbonate and hydrated lime;
- Application of sodium bicarbonate and calcium sulfate;
- Application of sodium bicarbonate and calcium chloride;
- Blending with a native low-salinity water source or by-pass blending.

Remineralization can be categorized into a series of four treatment processes: (1) chemical addition without lime or limestone; (2) carbon dioxide addition followed by limestone bed contactors for dolomitic dissolution, (3) carbonic acid addition followed by lime dosing; (4) blending with water containing high mineral content.

CONCLUSIONS

Literature Review Findings

A review of relevant literature indicated that post-treatment is required for desalted permeate, and would include consideration of possible impacts from blending, remineralization, disinfection, storage and distribution. Stabilizing permeate water is accomplished by effectively controlling aspects of post-treatment. Most of the literature pointed to the use of various chemical treatments to achieve post-treatment goals. Literature indicates that there are several considerations that should be taken into account when deciding post-treatment strategies, including the quality of the chemicals added, controlling dosage rates, and minimizing unwanted chemical reactions within the distribution system. It was found that primary post-treatment unit operations includes degasification (decarbonation) for CO_2 removal, air stripping for H_2S removal, alkalinity and pH adjustment for stabilization, corrosion control, and disinfection. Post-treatment unit operation performance is dependent on the source water type and the desalination process. Stabilization of finished water can typically be accomplished through the addition of carbonate alkalinity, the

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