KEY POINT: A primary goal of post-treatment is to protect public health through disinfection and mineral addition.

SUMMARY OF ISSUES

- Product water from desal plants is characteristically low in mineral content, alkalinity and pH. Therefore, desalinated water must be conditioned (post-treated) prior to final distribution and use.

- The goal of post-treatment is to protect public health (by disinfection and mineral addition), and to safeguard the integrity of the water distribution system. Typically, post-treatment of product water includes one or more of the following processes (WHO 2007):
  - Stabilization by addition of carbonate alkalinity;
  - Corrosion inhibition;
  - Re-mineralization by lime addition or blending with high mineral content water;
  - Disinfection and distribution system residual maintenance;
  - Water quality polishing for enhanced removal of specific compounds

For more information on technical issues and common post-treatment technologies, see related PIM cell discussion.

Desal Product Water Quality

As noted above, membrane processes produce high quality water by removing most contaminants and impurities from the feed water. Post-treatment processes, including stabilization, corrosion inhibition and re-mineralization, are designed to offset the aggressiveness of this highly purified water. In some cases, further post-treatment may be necessary to remove specific contaminants (e.g., boron or perhaps bromide) from the product water. The following sections provide an overview of desalinated water quality, and post-treatment needed to safeguard water quality for human health and irrigation.
Disinfection By-products (DBPs)

- DBPs consist of a wide variety of chemicals that form when disinfectants (e.g. chlorine, ozone) added during the treatment process react with natural organic and inorganic matter in the source water and/or distribution systems. Several of these DBPs have been shown to cause cancer and reproductive and developmental effects in laboratory animals (U.S. EPA Microbial and Disinfection By Product Rules). DBPs for which regulations have been established for drinking water include trihalomethanes, haloacetic acids, bromate, and chlorite (WHO 2007).

- Typical DBPs are not a significant issue for desalinated waters because the total organic content (TOC) and precursor concentrations in the source water are much lower than in typical natural drinking water sources. Post treatment blending may introduce additional TOC into the product water, which can subsequently react with disinfectants during treatment (Cotruvo pers. comm. 2009).

- Because the concentration of bromide is very high in seawater (~65 mg/L) compared to more conventional potable water sources, the potential for bromate formation in conjunction with the use of ozone or chlorine as a primary disinfectant, can be significant. Even if 99.5% of the source water bromide is removed in the desal process, the resulting concentration of about 300 \( \mu \text{g/L} \) in the permeate can be oxidized to form bromate at levels that could potentially exceed the federal standard of 10 \( \mu \text{g/L} \) under the Stage 1 Disinfectants / Disinfection Byproducts Rule (D/DBPR).

- The presence of iodide in seawater exhibits a similar propensity of iodinated DBP formation as bromide. However, there is less than 1 ppm of iodine in seawater and only a few micrograms are likely to pass through the membrane, possibly producing a few micrograms of organoiodides. Although there is some speculation about organoiodides DBPs, this is unlikely to be a major issue due to the low concentrations (Cotruvo pers. comm.. 2009).

Boron

- Boron has been contaminant of concern for desal of seawater and groundwater. When boron is present in the source water, single-pass RO processes do not remove the majority of boron at typical operating pH ranges; thus, boron (as borate or boric acid) can be found at milligram-per-liter levels in the finished water.
Because of the low occurrence of boron in most groundwater and surface water, the EPA has decided not to develop a maximum contaminant level for boron but has issued a draft Health Advisory for this contaminant of 5 mg/L (USEPA 2008). The EPA has encouraged affected states to issue guidance or regulations on boron as appropriate. The World Health Organization (WHO) is about to raise its drinking water quality guidelines with respect to boron from 0.5 mg/L to 2.4 mg/L. This higher value is still conservative compared to several national guidelines (e.g. Canada and Australia have adopted boron guidelines of 4 – 5 mg/L). Given these guidelines (and the studies behind them), boron will generally not be a health risk issue in the future (Cotruvo pers. comm. 2009).

Boron has herbicidal properties and is highly toxic for some crops. Boron concentrations above 2 mg/L are toxic for all but the most tolerant crops (Xu et. al. 2009). Adverse effects on some types of plants can occur at about 0.5 mg/L, especially in a dry climate where limited rainfall occurs (Cotruvo pers. comm. 2009).

**Emerging Organic Contaminants**

Source water subjected to wastewater discharge and contaminated surface run-off, may contain trace concentrations of organic contaminants including endocrine disrupting compounds, pharmaceutically active compounds, personal care products, and various industrial or household chemicals (Castle et al. 2005).

These types of contaminants are not likely to be found in seawater to a significant extent, but they may be present in some ground brackish waters, and would be present in processed wastewater used for water recycling. RO processes are extremely effective at removing most of these types of raw water contaminants, with molecular weights above about 100 Daltons. Low molecular weight solvent type molecules can traverse membranes.

Although the concentrations are minute (ppt) and no health risks have been identified, there has been increasing public concern regarding the treatment efficiencies associated with removing these emerging compounds from drinking water (Xu et. al 2009). However, desal processes are among the most effective technologies for removing these types of contaminants (and are significantly more effective than conventional drinking water treatment processes) (Xu et. al. 2009).
Side effects of highly purified water

- Product water from desal plants is characteristically low in mineral content, alkalinity and pH. Due to its highly purified nature, desalinated water is often corrosive and can react with distribution facilities, household plumbing and metal fixtures; resulting in deteriorated pipes and increased metal content in drinking water. This reaction could result in high cost impacts, and aesthetic problems, such as bitter or flat water-taste, stains around basins/sinks, and potentially elevated levels of toxic metals (Xu et. al. 2009).

- The side effects of highly purified water generated by desal include the removal of ions (e.g. calcium, magnesium and sulfate) that are essential to plant growth. Without proper post-treatment of desalinated water intended for agricultural use, this can cause deficiency symptoms in crops. For example, the water from Israel’s national water carrier typically contains dissolved Mg$^{2+}$ levels of 20 to 25 mg/L, while the product water from the Ashkelon desal plant has no Mg$^{2+}$. After farmers used the desalinated seawater for irrigation, magnesium deficiency symptoms appeared in crops, including tomatoes, basil, and flowers, and had to be remedied by fertilization (Xu et. al. 2009 cited from Yermiyahu et al. 2007). Because desalinated water is often blending with other water sources, the concentrations of these basic ions in the final water delivered to farmers may be highly variable. If the missing ions required for agriculture are not added during post-treatment at the desal plant, farmers will need sophisticated, independent control systems to cope with the variable water quality. Such systems can be intensive in capital investment and operation costs however, low cost technologies are being developed that can recycle calcium and magnesium from membrane reject brines (Xu et. al. 2009 from Yermiyahu et al. 2007; Cotruvo pers. comm. 2009).

- Chemicals of beneficial interest in drinking water can include calcium, magnesium, sodium, chloride, lead, selenium, potassium, boron, bromide, iodide, fluoride, chromium, and manganese. Seawater is rich in ions like calcium, magnesium, sodium, chloride and iodine, but low in other essential ions like zinc, copper, chromium and manganese (WHO 2007). Many natural waters are also low in dissolved minerals.

- Desal processes significantly reduce ions in drinking water that may be beneficial to human health (e.g. calcium, magnesium, sodium, zinc, copper, fluoride, etc.). Individuals that consume only low mineral or desalinated water may be consistently receiving smaller amounts of some nutrients relative to people who consume water from more traditional sources (and thus are disadvantaged if their diets are not sufficient). When desalinated water is stabilized by the addition of lime or in some cases, blending, some of these ions are automatically replenished (WHO, 2005; WHO 2006, WHO 2007). Further studies are needed to determine whether the lack of mineralization of drinking water can
have detrimental long term physiological effects, particularly in conjunction with significant dietary deficiencies.

**Regulatory implications of desalinated water quality**

Differences in desalinated product water compared to drinking water from traditional sources can impact a utility’s ability to comply with the Disinfectants/Disinfection Byproducts (DBPR), Lead and Copper or Total Coliform (TCR) Rules, or Secondary Maximum Contaminant Levels (SMCL) for iron and manganese. Table 1 below summarizes some of these impacts.

**Table 1. Regulatory implications for desalinated product water quality**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Characteristic of Desalinated Water</th>
<th>Implication</th>
<th>Potential Regulatory impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bromide</td>
<td>Typically higher than treated fresh water. Low toxicity.</td>
<td>Formation of brominated DBP species</td>
<td>Possible violation of DBPR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced stability of monochloramine residual</td>
<td>Possible loss of disinfectant</td>
</tr>
<tr>
<td>Chloride</td>
<td>Sometimes higher than treated fresh water</td>
<td>Possible increased corrosion rates</td>
<td>Minor taste</td>
</tr>
<tr>
<td>Mineral content</td>
<td>Low, little alkalinity or hardness</td>
<td>Increased corrosion rates</td>
<td>Possible Lead and Copper Rule violation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potential for destabilization of pipe scale (red water)</td>
<td>Possible TCR violation; may exceed iron or manganese SMCL</td>
</tr>
<tr>
<td>pH</td>
<td>Typically low</td>
<td>Increased corrosion rates</td>
<td>Possible Lead and Copper Rule violation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potential for destabilization of pipe scale (red water)</td>
<td>May exceed iron or manganese SMCL</td>
</tr>
</tbody>
</table>

*Source:* Adapted from HDR SDWA Newsletter, Summer 2009; Cotruvo pers. comm. 2009.
STRATEGIES

Water quality testing

Typically, carefully planned studies, such as pipe loop corrosion studies, or DBP formation potential tests, are required to understand the complex chemical interactions in the blended water and between the blended water and components of the distribution system (HDR 2009).

Water Safety Plans

To assist water supply planners in consistently ensuring the safety of their drinking-water supply, WHO has developed the systematized Water Safety Plan (WSP) approach. The WSP is a comprehensive risk assessment and risk management approach to water safety planning that encompasses all of the steps in the water supply train from source water catchments to the consumer.

The WSP concept draws upon principles and concepts of prevention, multiple barriers and quality management systems such as Hazard Assessment Critical Control Points (HACCP) as used in the food industry. Desal treatment processes are usually more comprehensive and effective than standard water technologies so they are particularly suited to WSP applications.

A WSP has three key components guided by health-based targets (drinking water standards and guidelines), and overseen through surveillance of every significant aspect of the drinking water system. The three components are (WHO 2007):

- System assessment to determine whether the system as a whole (from source to consumer) can consistently deliver water that meets health-based targets. This includes assessment of design criteria for new systems as well as modifications.

- Measures to monitor and control identified risks (and deficiencies) and ensure that health-based targets are met. For each control measure, appropriate operational monitoring should be defined and instituted that will rapidly detect deviations.

- Management plans describing actions to be taken during normal operations or incident conditions, and documenting the system assessment (including system upgrades and improvements), monitoring, and communication plans and supporting programs.

The primary objectives of a WSP are the minimization of contamination of source waters, reduction or removal of contamination through appropriate treatment processes, and prevention of contamination during processing, distribution and storage. These objectives are equally applicable to and can be tailored to large piped supplies, and to small community supplies in a
more streamlined way. The objectives are met though the interpretation and detailed implementation of the key phrases: ‘hazard assessment’ and ‘critical control points’, in a systematic and documented planned methodology for the entire life of the system.

Detailed expansions of the WSP concept can be found in the WHO Guidelines for Drinking Water Quality (WHO 2004) and in other writings including detailed discussions of WSPs for distribution systems.

**BENEFITS & COSTS**

Post treatment costs are mainly driven by target product water quality and the final use of the desalinated water. However, if the permeate has to be polished to achieve high levels of boron removal or removal of specific constituents, than these costs may increase beyond this range (Vouchcov 2005). For many inland facilities using groundwater as the source for the desal process, minimal treatment (and associated costs) is required.

**KEY UNCERTAINTIES**

The water chemistry issues associated with post-treatment are generally well understood and methods of altering chemical conditions are feasible and generally available. The exact process used will depend to some degree on any unique contamination chemicals and mostly on protection of the distribution system and plumbing infrastructure.

**ADDITIONAL RESOURCES**


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