Summary of Issues | Strategies | Benefits & Costs | Key Uncertainties | Additional Resources

KEY POINT: *Post-treatment strategies include blending, pH adjustment, regasification and recarbonation.*

SUMMARY OF ISSUES

- Two primary factors contribute to the need for post-treatment:

1. Because the RO process is very efficient at rejecting dissolved solids, desalinated product water has very low levels of alkalinity and calcium, two parameters that are often critical to maintaining chemical stability in the distribution system (i.e. preventing pipeline corrosion). Calcium, carbonate and bicarbonate are key scale-forming constituents that coat the inner lining of distribution piping, helping to prevent corrosion. Because desalinated product water is low in these essential minerals, minerals from the area of higher concentration (i.e., the pipe coating) are transported to one of lower concentration (i.e., the product water), resulting in the need for treatment.

2. The addition of acid in the pretreatment process is a common measure designed to reduce the potential for RO membrane scaling (i.e. the deposition of unwanted particles on the membrane which can cause it to plug). However, this practice also reduces the potential for scale in the distribution system, thereby contributing to the dissolution of the existing protective scale on the piping.

   The addition of acid can also produce undesirable gases. Of primary concern is the production of carbon dioxide (CO_2) at the expense of bicarbonate. The formation of CO_2 simultaneously produces a corrosive gas that largely passes through the RO membrane into the permeate, further reducing scale-forming bicarbonate.

- Therefore, the primary objective of post-treatment is to reduce the corrosive character of the product water, a process called stabilization. Strategies for accomplishing stabilization include:

  - Blending
  - pH adjustment

- Degasification
- Recarbonation

- The choice between these post-treatment processes is project specific and depends on the particular chemistry of the desalinated water and the existing infrastructure. Economics, volume of desalinated water to be treated, availability, quality and cost of locally available chemicals, and ease of operation also play a role (Xu et. al. 2009).
- In addition to stabilization, other post treatment objectives may include disinfection and water quality polishing by removal of specific compounds such as boron, silica, and disinfectant by-products (DBPs) (Xu et. al. 2009).

STRATEGIES

Stabilization

The strategies for accomplishing stabilization are described below and summarized in Table 1.

- **Blending**, the most straightforward approach, involves combining the permeate with another water supply that is higher in pH and mineral concentrations.
    - Because it does not involve any additional treatment process, blending is generally the least expensive stabilization strategy.
    - For brackish water facilities, blending is accomplished via bypassing some fraction of the saline water around the RO process.
    - The compatibility of water sources must be taken into consideration prior to blending. Specific issues that must be investigated are discussed in the "Desalination for Safe Water Supply: Guidance for the Health and Environmental Aspects Applicable to Desalination" (WHO 2007).
- **pH adjustment** involves the addition of a base to increase the pH of the permeate. This helps to reduce the corrosiveness of the water because it:
    - Moderates the potential for desalinated water to dissolve the existing scale in the distribution system piping; and
    - Neutralizes acidity, contributing to system alkalinity and lowering the concentration of undesirable dissolved gases.
      Caveat: Removal of acidity also leads to the potential production of sulfides.

Many sulfide species are very insoluble and can readily precipitate in the distribution system, causing both turbidity and aesthetic problems.

- pH adjustment is advantageous in cases in which the recovery of alkalinity (i.e. converting carbon dioxide to bicarbonate) is important for achieving treated water quality objectives, and in the absence of hydrogen sulfide in the permeate.

- **Degasification** involves the use of forced or induced air flow to eliminate dissolved gases (e.g., carbon dioxide and hydrogen sulfide) from the permeate. An example of a degasification process is a stripping tower.
  Caveat: Removal of carbon dioxide removes a source of alkalinity and scale forming bicarbonate from the permeate.

  - Degasification is advantageous in cases when the recovery of alkalinity is NOT necessary for achieving treated water quality objectives and/or if hydrogen sulfide is present in the permeate.

- **Recarbonation** is the process of increasing carbonate and/or bicarbonate alkalinity via a strategic chemical addition. Examples include:

Calcium carbonate ($CaCO_3$)	→	adds hardness and alkalinity
Sodium carbonate (Na_2CO_3)	→	adds alkalinity
Sodium bicarbonate ($NaHCO_3$)	→	adds alkalinity

  - Recarbonation is advantageous in cases in which alkalinity recovery via pH adjustment is not feasible.

- The appropriate post-treatment process is largely dictated by the permeate water quality. In most cases, this can be accurately predicted by any of the various system models available through membrane manufacturers. In cases in which several post-treatment options may be feasible, the selection of a particular strategy is typically a function of cost.

- Corrosion control is a complex science, requiring considerable knowledge of corrosion chemistry and of the system being evaluated. A variety of water quality criteria have been developed as a guide for developing post-treatment strategies for stabilization of soft and corrosive waters. The criteria are listed in Table 2.

Table 1. Summary of Desal Post-Treatment Options	
Post-Treatment Process	**Use Process When…**
Blending	• Whenever it is feasible (least expensive option)
pH Adjustment	• Recovering alkalinity is a priority • H_2S levels <u>are not</u> significant in the permeate
Degasification	• Alkalinity recovery is not a key objective • H_2S levels <u>are</u> significant in the permeate
Recarbonation	• Alkalinity needs to be increased • Alkalinity recovery via pH adjustment is not feasible

Table 2. Water quality criteria for stabilization of soft and corrosive waters (Xu et al. 2009)

Location/ source	**Alkalinity (mg/L as $CaCO_3$)**	**Ca^{2+} (mg/L as $CaCO_3$)**	**CCPP (mg/L as $CaCO_3$)**	**pH**
Cape Town, South Africa[1]	>50	>50	2–5	
Cyprus[2]	>50		LSI > 0	6.5–9.5
France[3]	70<Alk<120	0.8<Ca/Alk<1.2	LSI>0	
Israel[4]	>80	80-120	3-10 LR<5	<8.5
Sweden[5]	>50	50–150	7.5–9.5	
USA[6]	>40	>40	4–10	
USA[7]	40–80	40–80	4–10	
USA[8]	>80		LSI>0	
World Health Organization[9]	≥40	Total hardness > 50	4–10 LR<5 LSI: 0.5-1.0	6.8–7.3

Note: 1. Loewenthal et al. 2004. 2. Marangou and Savvides 2001 3. Plottu-Pecheux et al. 2001. 4. Lahav and Birnhack 2007. 5. Berghult et al. 1999. 6. Merrill and Sank 1977 7. Ramond 1999. 8. Imran et al. 2005a, 2005b. 9. WHO 2007.
CCPP: Calcium carbonate precipitation potential
LR: Larson ratio
LSI: Langelier saturation index

- **Corrosion inhibitors** can also be used to increase alkalinity and reduce the corrosivity of the desalinated water. However, this method is usually used after corrosion has already occurred. Corrosion inhibitors, such as phosphate and silicate, work to form protective films on pipe walls that limit corrosion or reduce metal solubility. The use of corrosion inhibitors is often more suitable when the water distribution system is made of non-metallic piping (i.e. PVC, fiberglass or HDPE pipe). In this case, the use of corrosion inhibitors can avoid problems with product water turbidity associated the addition of lime or other calcium-based minerals, and can reduce the overall chemical conditioning costs (WHO 2007).

Disinfection and finished water quality objectives

- RO/NF systems can allow the passage of a very small number of microbial pathogens. EDR allows the passage of microbial pathogens. Disinfection may be required to eliminate bacterial growth in distribution system.

- In cases in which primary disinfection is required, consideration must be given to source water quality constituents that may result in the formation of disinfectant by-products (DBPs). For example, because the concentration of bromide can be very high in certain brackish groundwater, the potential for bromate formation in conjunction with the use of ozone as a primary disinfectant is significant.

- Chlorine in various forms (e.g., chlorine liquid or gas; on-site sodium hypochlorite generation, calcium hypochlorite) is by far the most widely used disinfectant for desalinated water.

- Chloramines may be used as a disinfectant if the water is blended with other water sources disinfected with chloramines. If chlorinated desalinated water is blended with chloraminated drinking water produced from a fresh surface water source, mixing of the two types of water may result in accelerated decay of chlorine residuals in the blended water. To avoid such decay the desalinated water is recommended to be chloraminated at higher dosages than the fresh-source potable water/s with which it will be blended (WHO 2007).

Remineralization to Meet Agricultural Needs

- When used for agricultural irrigation, desalinated product water may need to be remineralized prior to application.

- Due to greater rejection of divalent ions compared to monovalent ions, membrane permeate usually has a high sodium-to-calcium and magnesium ratio (sodium adsorption ratio, SAR). The application of desalinated water that has a high SAR can reduce soil permeability and adversely affect the soil structure. For sensitive fruits, the tolerance limit of SAR for irrigation water is approximately 4. For general crops, SAR of 8 to 18 is considered an acceptable level (Rowe and Abdel-Magid 1995). Without addition of hardness, membrane permeates would not be suitable for crop irrigation.

- Calcium, magnesium, and sulfate ions are essential nutrients for crop growth. Lacking such ions in irrigation water can cause deficiency symptoms in crops.

- Remineralization can be achieved by:

  - Calcium and magnesium addition to desalinated water in the form of fertilizers;
  - Dissolving dolomite rock ($CaMg(CO_3)_2$) to meet calcium, magnesium, and alkalinity criteria.

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BENEFITS & COSTS

Benefits

- Proper post-treatment can prevent corrosion of desalinated product water to pipeline materials, including metals and concrete. It avoids the introduction of metals into drinking water and reduction of the lifetime of water-system infrastructure.

- Post-treatment is essential to protect public heath and benefits of end users.

Costs

- Blending is generally the least expensive stabilization strategy (it does not involve any additional treatment processes).

- Recarbonation and remineralization are relatively expensive (because of the addition of chemicals).

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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 greatly on the particular chemistry of the desalinated water and the existing infrastructure.

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ADDITIONAL RESOURCES

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