PROCESS SELECTION

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Contents

1. Introduction

1.1. Background

The selection of which desalting process to use is dependent on many factors. Key among these are the site specific items, such as plant location, local costs, etc. Other factors affecting the selection of process type include:

- Feedwater quality and availability
- Pre-treatment
- Process considerations
- Product water quality
- Post-treatment
- Concentrate disposal
- Economics
- Regulatory requirements
- Construction requirements

This section attempts to show how each of these factors affect the selection of a desalting process.

The desalting processes discussed in this section included only those that have attained commercial acceptance and include:

- Multi-stage flash (MSF)
- Multiple effect (ME)
- Vapor compression (VC)
- Reverse osmosis (RO)
- Electrodialysis (ED)

1.2. Purpose

This section outlines the methodology employed for selecting the desalting process to use for the removal of minerals from a water supply.

2. Source Water

2.1. Introduction

Feed water supplies can be obtained from surface water impoundments or from ground water aquifers. The volume of the feed water source must be such that the desalting plant operation can remain at design capacity over the service life of the unit. Typically, a 20-year service life is expected for desalting processes.

2.2. Water Quality

The water quality is defined as the amount of water available for treatment. This factor sets the maximum size of the treatment process (capacity). For example, in most instances for a ground water supply the volume of the supply, and its ability to recharge itself, will normally result in a recommended "safe" withdrawal rate. That is, a constant rate that does not result in depleting the supply over the service life of the plant. Surface water supplies are normally readily recharged and, in most cases, are not under the restrictions of ground water supplies. Seawater will, of course have no limits as to capacity.

The calculation of the volume available for treatment of the surface water supply is straightforward. The establishment of the volume of the ground water supply is more difficult to predict, but normally can be established with some certainty by hydraulic modeling. Volume, however, is not the only concern when judging the availability of a water supply. The second concern is the quality of the supply.

2.3. Water Supply

The single most important consideration when designing the demineralization process is the water quality. The quality of the water will determine the process requirements, such as the pressure, and recovery.

The type of process to be used for the treatment of a particular water supply will depend upon the amount of organic and inorganic materials to be removed from the supply. Normally, surface water (excluding seawater) contain small concentrations of inorganic constituents but have a high organic content. Ground water supplies on the other hand, contain high concentrations of inorganics while the organic content is low. The specific amounts of the constituents to be removed set the process design requirements.

Inorganics are made up of positive ions (e.g., calcium, magnesium, etc.) and negative ions (e.g., bicarbonates, chlorides, etc.). These are quite soluble in water and their source is from the weathering, erosion and dissolution of the materials of the Earth's surface. Also, from volcanic activity releases constituents such as hydrogen sulfide, hydrogen chloride, etc. from the Earth's interior. These constituents are dissolved in the Earth's water systems and eventually flow into the sea. Also, as the Earth's surface relative to the ocean has shifted in elevation this has caused large quantities of seawater to be trapped inland. This trapped water contains deposits of rock, gypsum, limestone, and other constituents. These are eventually re-dissolved by rain and once again return to the sea.

This continual load of dissolved solids coupled with the evaporation of the sea's surface produce a concentration of dissolved solids in the sea of approximately 35 000 mg l^{-1}. The seawaters make up about 97 per cent of the world's water, which is constantly recycled by evaporation and condensation to produce rain.

2.4. Process Removal Capabilities

The product water quality from the desalting process varies with process type. The membrane processes will also vary as the feedwater quality changes.

2.4.1. Thermal Processes

The thermal processes (i.e., MSF, VC and ME) are quite good at removing dissolved minerals from water. Typically, a unit that is in good mechanical condition and is operated properly can achieve a water quality of less than 1.0 mg l^{-1}, when treating water of any quality including seawater. The removal of organics, including volatile organics is also quite good. Although volatile organics can be expected to evaporate with the pure water, there is little chance of them redissolving in the product water if the venting system is designed and operated properly. Volatile organics can be expected to be removed along with the "sweep" steam used to ensure the removal of other non-condensible gases.

Pathogens and bacteria may also be killed in the high temperature plants (i.e., those operating at temperatures of 190°F or more). However, their removal in low-temperature plants (i.e., those operating at 160°F or less) is questionable. The application of disinfectants in the pre-treatment or post-treatment systems, will destroy these agents. Thus, there is little chance of these contaminants entering the potable water system.

2.4.2. Reverse Osmosis

The reverse osmosis (RO) process is capable of removing all constituents in feedwater with the exception of a small number of the volatile organics. The amount of minerals removed, however, is dependent upon the membrane used. For example the NF membrane has an approximate overall rejection rate of 70 per cent whereas, seawater membranes reject minerals on the order of 99 per cent or more.

2.4.3. Electrodialysis

The electrodialysis systems only remove ionized or charged constituents from waters. Examples of minerals dissolved in the feedwater by this process are calcium, magnesium, etc. No other substances are removed.

2.4.4. Comparison

Table 1 gives a comparison of the removal capabilities of each process for various constituents.

Desalination process				
Constituent	**Thermal**		**Membrane**	
	Low temperature*	**High temperature****	**Reverse osmosis**	**Electrodialysis**
Inorganics	3	3	3	3
Organics (TOC)	3	3	3	0
Synthetic Organics	3	3	3	0
Volatile Organics	2	2	1	0
Bacteria	1	3	3	0
Viruses	1	3	3	0

Ratings: 3 = satisfactory; 2 = fair; 1 = poor; and 0 = unsatisfactory.
* Low temperature = 150-190°F (65-88°C)
** High temperature = 210-235°F (100-115°C)

Table 1. Process separation comparison.

2.5. Feed Water Classification

For this discussion, feed water characteristics are divided into three categories:

- Fresh water
- Brackish water
- Seawater

Each of these waters is composed of a different amount of mineral content described as total dissolved solids (TDS). Fresh waters are those with a TDS of up to 1000 mg l^{-1}. Brackish waters have a wide range of mineral content. This range extends from the maximum concentration of fresh water to the concentration of seawater. Seawater has a typical (standard) TDS concentration of 35 000 mg l^{-1}. These waters are given the characteristics shown in Table 2:

Type	**Total dissolved solids**
Fresh	**Less than 1000 mg l^{-1}**
Brackish	1000 to 35 000 mg l^{-1}
Seawater	35 000 mg l^{-1} or more

Table 2. Feed water characteristics.

At TDS concentrations above 35 000 mg l^{-1}, waters are generally classified as brines. The concentrations of these water exceeds that of seawater.

2.6. Surface Water Supply

Surface water supplies take their supply from lakes, rivers, streams and the sea. The intake system is composed of an intake pipe and an intake structure. The types of intakes include:

(a) *Open intake*. The open intake is composed of an intake structure which contains the feed water pumps and an intake chamber designed to effect good flow to the pump. The intake structure can also contain auxiliary equipment as required to remove debris, such as trash racks and traveling screens, if required. The water supply to the intake structure is conveyed by a channel or similar open conveyance system.

(b) *Pipe type intake*. The pipe type intake structure is the same as that for the open intake. This type of intake differs from the open intake by the type of water conveyance system. In the pipe type intake a pipeline is laid from the intake structure to the point of water intake. At this point a terminal is provided for the initial screening of the supply. This can be constructed of concrete or a screen can sometimes suffice.

(c) *Ranney collector*. A Ranney collector is constructed on the shoreline. It is composed of a caisson that is sunk into the underlying water table. Perforated pipes are then placed in a radial direction extending from the caisson bottom. Thus, it resembles a well supply system. This type of supply is particularly beneficial to the RO process because the water supply from such a system will not contain colloidal material.

2.7. Ground Water

Ground water supplies are, of course, taken from wellfields. Wellfields are composed of a number of wells sunk into the ground water aquifer. They are sized and located such that the withdrawal of water from the aquifer does not cause undue drawdown problems in the aquifer.

3. Pre-treatment

3.1. Introduction

The amount of pre-treatment required depends upon:

- The desalting process used
- The operating temperature
- The type of source water used (ie, surface or ground water)

The extent of pre-treatment required for each process and source water type is summarized in Table 3. In the thermal systems, the higher the operating temperature, the more complex the pre-treatment required. Also, for RO system, surface water supplies require considerably more pre-treatment steps than do ground water supplies.

3.2. Pre-treatment Goals

The raw water to each process must be treated to meet certain water quality requirements before being emitted to the process. These requirements are necessarily different for each process type. Table 4 lists these requirements. Of the processes listed, the RO system requires the highest water quality. This results from the requirement that the colloidal content be quite low. Colloids can lodge in the membrane pores causing an irreversible performance loss.

Process	**Operating temperature**	**Source type***	**Pre-treatment requirements****
Multistage flash	190	S or G	Polyphosphate addition
Multistage flash or Multiple effect	235	S or G	Acid or polyelectrolyte addition, degasification*** and deaeration
Multiple effect	160	S or G	Polyphosphate addition
Vapor compression	Ambient	S or G	None
Vapor compression	190	S or G	Polyphosphate addition
Reverse osmosis	Ambient	G	Scale inhibitor and/or acid addition cartridge filter
Reverse osmosis	Ambient	S	Polymer addition filtration, (one or two step) Cartridge filtration scale inhibitor and/or acid addition
Electrodialysis	Ambient	S or G	Scale inhibitor and/or acid addition

* S = Surface water; G = Ground water.
** In addition, surface waters normally require chlorination.
*** Degassification is not required when using polyelectrolyte treatment only.

Table 3. Pre-treatment requirements.

Goal	**Thermal distillation**		**Reverse osmosis**			**EDR**
	HT[b]	**LT**[c]	**CA**[d]	**CTA**[e]	**PA**[f]	
Suspended solids	None	None	None	None	None	None
Turbidity, NTU	NL[g]	NL	<0.5	<0.5	<0.5	<2.0
Silt density index	NL	NL	<0.3	<0.3	<0.3	NL
Temperature, °F	NL	Nl	86	86	95	110
Oxygen ($mg\ l^{-1}$)	<.005	<.005	NL	NL	NL	NL
Bicarbonate ($mg\ l^{-1}$)	0.0	0.0	NL	NL	NL	NL
Residual chlorine ($mg\ l^{-1}$)	NL	NL	<2.0	<1.0	0.0	0.0
Iron ($mg\ l^{-1}$)	NL	NL[h]	NL[i]	<0.7	<0.1[h]	<0.2
Manganese ($mg\ l^{-1}$)	NL	NL	NL	<1.3	<0.1	<0.2
Strontium ($mg\ l^{-1}$)	NL	NL	DT[j]	NS[k]	<15.0	<1.0
Barium ($mg\ l^{-1}$)	NL	NL	NL	NS	<0.1	<1.0
Silica ($mg\ l^{-1}$)	NL	NL	<135.0	<100.0	<150.0	NL

Table 4. Process feed water quality goals[a].

[a] Before entering process. [b] High temperature operation. [c] Low temperature operation. [d] Cellulose acetate. [e] Cellulose triacetate. [f] Polyamide. [g] No limit. [h] No limit for copper nickel construction, no metals for aluminum construction. [i] No limit for iron in the

ferrous state. [j] Maximum amount depends on the pre-treatment used. [k] Not specified.

3.3. Surface Water Supplies

Surface water supplies consist of some sort of intake chamber connected to the source water by pipeline or channel. This type of intake can be cost effective as a method for transferring the raw water to be treated. Pre-treatment of the raw water for this type of supply is straight forward with the exception of RO systems.

RO systems must be nearly completely free of colloidal constituents prior to the water entering the process. However, surface water systems contain a significant amount of colloids. Thus, for RO systems, the colloidal content must be reduced. This can be accomplished using filtration such as dual media or coarse and dual media filtration, microfiltration or ultrafiltration. The dual media and/or coarse filtration systems can be of the pressure type for small systems. For large flow rates, gravity filtration is normally used. At the present time, the microfiltration and ultrafiltration systems are more costly than the conventional systems. But as these newer filtration systems are developed they are expected to become more cost effective.

Figure 1 gives the diagrammatic sketch of the pre-treatment system using gravity filtration for RO systems. This assumes that a two stage system is used.

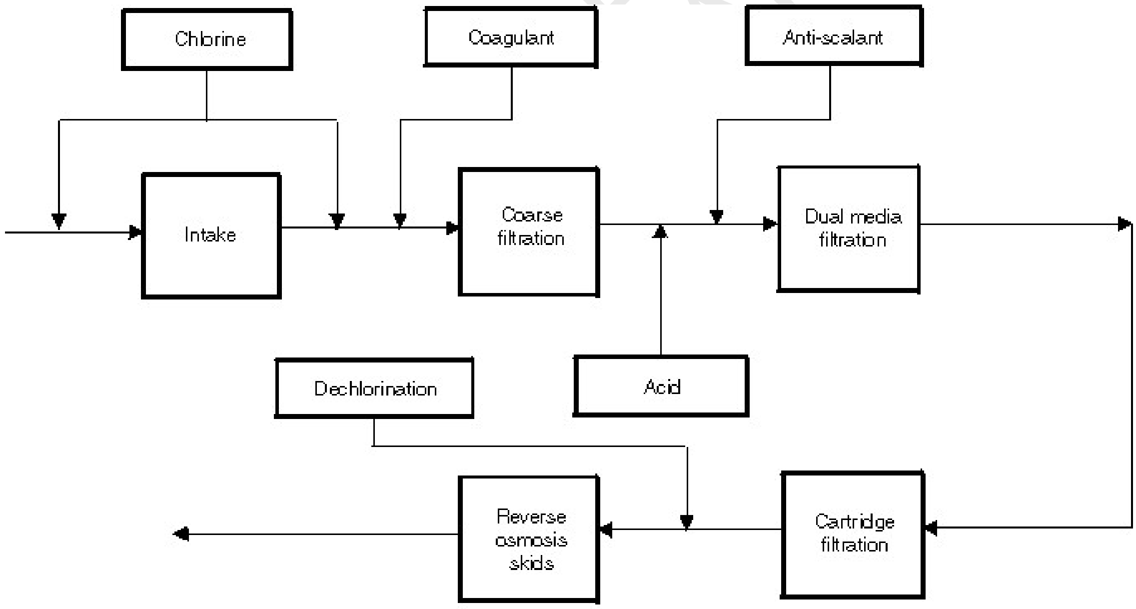

Figure 1. Reverse osmosis pre-treatment diagrammatic surface water system.

3.4. Ground Water Supplies

Ground water supplies offer the advantage of natural filtration of the raw water. Thus, for the RO process, further filtration is not required for the pre-treatment of this type of supply.

3.5. Artificial Ground Water Supplies

An artificial ground water supply can be constructed that acts like a well supply. This is the Ranney collector system. Use of this type of intake offers the benefit of filtration as with the well system.

3.6. Scale Prevention

The scaling of membrane or tubing surfaces must be controlled in order to maintain plant performance. This is carried out by a further pre-treatment step by the addition of chemicals that act as scale inhibitors or prevent scale formation. For example, the addition of acid as a pre-treatment step will prevent calcium carbonate and magnesium hydroxide scale formation. The use of polymers or polyelectrolytes products do not prevent scale from forming, they simply provide a site for the scale to form on preferentially to the membrane or tubing surface.

Scale inhibition chemicals normally used for scale control are listed in Table 5.

Process	**Chemical**	**Scale control**					
		$CaCO_3$	**MgOH**	**$CaSO_4$**	**$BaSO_4$**	**$SrSO_4$**	**CaF**
LTMSF	Polyphosphate	Y[a]	Y	NA[b]	NA	NA	NA
HTMSF	Acid and/or polyelectrolyte	Y	Y	NA	NA	NA	NA
LTME	Polyphosphate ion trap[c]	Y	Y	NA	NA	NA	NA
HTME	Acid and/or polyelectrolyte	Y	Y	NA	NA	NA	NA
RO	Acid and/or polymer	Y	Y	Y	Y	Y	Y
ED/EDR	Acid and/or polymer	Y	Y	Y	Y	Y	Y

[a] Y = yes.
[b] NA = not applicable.
[c] Required for plants using aluminum tubing materials.

Table 5. Pre-treatment chemicals.

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