Research Office
Legislative Council Secretariat

Fact Sheet

Seawater desalination technologies

FS07/14-15

1. Introduction

1.1 Desalination is a process of removing dissolved salts from seawater to produce fresh water for consumption. There are two major types of desalination technologies around the world, namely membrane desalination and thermal desalination. The former technology features the use of a special filtre (membrane) to produce desalinated water, whereas the latter technology involves the boiling/evaporation of seawater to give off water vapour which, on condensation, yields salt-free liquid water.

1.2 Reverse osmosis ("RO") is a predominant form of membrane desalination. For thermal desalination, the most commonly adopted technologies are multi-stage flash evaporation ("MSF") and multi-effect distillation ("MED")[1]. RO is currently the most widely used method for desalination. In 2012, it accounted for 63% of the desalination production capacity worldwide, followed by MSF (23%) and MED (8%).[2]

1.3 Developed countries such as France, Germany and Spain have led the technologies in the global desalination market. France and Germany make heavy use of their abundant natural water resources, but they have also invested in the development of desalination technologies and related products for export. Spain, a leading exporter of desalination technologies, also makes use of the technologies to produce desalinated water for domestic consumption.[3] This fact sheet aims to provide the Panel on Development with information on the different features of the RO, MSF and MED technologies.

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1 MSF is more commonly used in energy-rich countries such as Saudi Arabia and Kuwait. MED is the oldest technology and countries that have adopted this technology in recent years include India and the United Arab Emirates.

2 The remaining 6% desalination capacity was taken up by electrodialysis, hybrid technologies (i.e. combination of thermal and membrane processes) and other technologies. See Bennett, A. (2013) and The Saudi Arabian Water Environment Association (2013a).

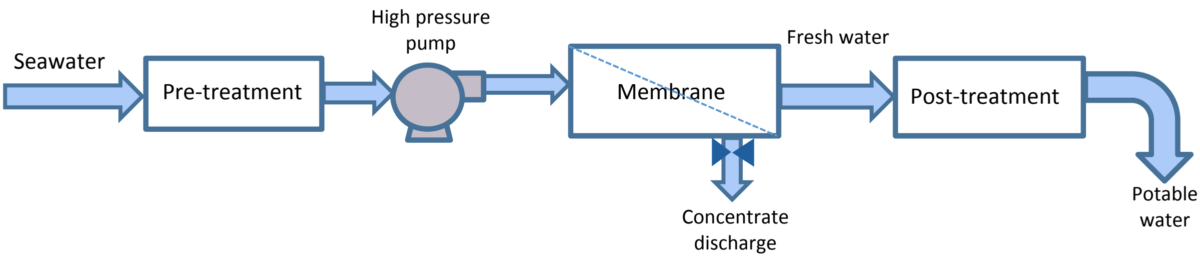
3 For example, Torrevieja Desalination Plant, the largest desalination plant in Spain, came on stream in recent years with an annual capacity of 80 million cubic metre. It employs the RO technology to produce desalinated water, of which half is used for domestic consumption and the other half for irrigation purposes.

2. Three major seawater desalination technologies

Reverse osmosis

2.1 RO is a desalination process with the use of semi-permeable membranes which allow the passage of water molecules but not the dissolved salts. In an RO process, seawater is firstly pre-treated to remove suspended solids. Sufficient pressure is then applied with the use of high pressure pumps to force water passing through the semi-permeable membranes, leaving the dissolved salts behind. Desalinated water then undergoes post-treatment, such as pH adjustment[4] and disinfection, to make it suitable for drinking. The above process is depicted in **Figure 1**.

Figure 1 – Basic process of reverse osmosis



Source: Banat, F (2007).

Multi-stage flash evaporation

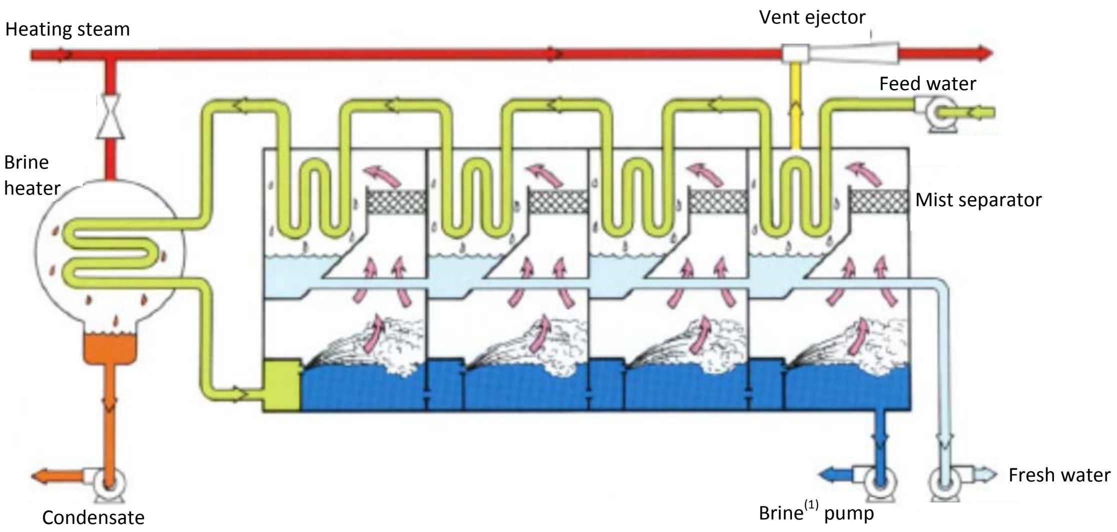
2.2 MSF is a type of thermal desalination which has already been in use since around 1960s. The first desalination plant in Hong Kong, which was built in the 1970s, adopted the MSF technology.[5] MSF facilities consist of a number of chambers connected to one another, with each successive chamber operating at a progressively lower pressure. Source water/pre-treated water (i.e. feed water) first passes from back to front through a tubing system to the brine heater, where water is heated under a high pressure. The heated water then enters the first chamber at reduced pressure, causing it to boil rapidly with a portion evaporating into vapour (**Figure 2**). In each successive

[4] The term pH is used to indicate how acidic or basic a substance is. The pH scale ranges from 0 to 14 and the normal pH range of drinking water is 6-8.5. pH adjustment aims to adjust desalinated water to a range suitable for drinking.

[5] The plant was shut down in 1982 due to the relatively higher production cost of desalinated water as compared with importing water from Dongjiang.

chamber which operates at a reducing pressure, the same process repeats. The vapour generated by evaporation is converted into fresh water by condensation.

Figure 2 – Basic process of multi-stage flash evaporation



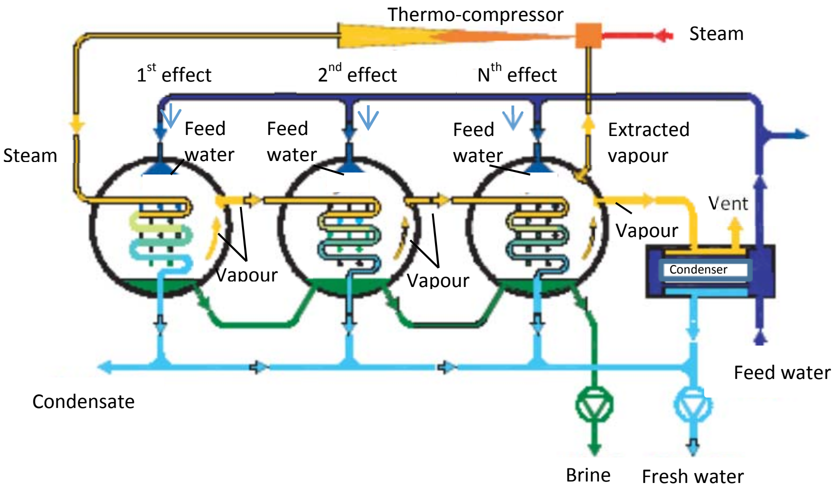
Note: (1) Brine is the high salty solution after partial evaporation.
Source: Lahmeyer International GmbH (2003).

Multi-effect distillation

2.3 Similar to MSF, MED is an evaporation process going through a series of chambers (also known as "effects"), with each successive chamber operating at a progressively lower pressure. Yet MED differs from MSF in that the vapour formed in one chamber condenses in the next chamber with the heat released acting as a heating source. In addition, feed water is sprayed over the tube bundle on top of each chamber in a typical MED process. As shown in **Figure 3**, external steam is introduced in the first chamber and feed water evaporates as it absorbs heat from the steam. The resulting vapour enters through the tube to the second chamber at a reduced pressure. The heat released by condensation causes the feed water in the second chamber to evaporate partly. The process repeats in the third chamber and so on. In each chamber, the vapour condensing into fresh water inside the tube is then pumped out.

2.4 The efficiency of MED can be raised with the addition of a vapour thermo-compressor. As indicated in Figure 3, the thermo-compressor extracts part of the steam generated in the final chamber for recycling use. The extracted steam will be mixed with the external steam for compression under a high pressure, which then acts as a heating source in the first chamber.

Figure 3 – Basic process of multi-effect distillation



Sources: Australian Department of the Environment (2002) and Veolia Water Technologies (2006).

3. Comparison of the three major desalination technologies

Reverse osmosis

3.1 The RO technology has been increasingly adopted for seawater desalination during the past decade or so, attributable to its improved performance in terms of energy consumption and reliability.[6] RO desalination generally consumes less energy than thermal desalination. In addition, its water recovery rate is relatively higher, as one tonne of desalinated water can be produced with an input of 2.5-3.2 tonnes of seawater.[7]

6 See Ludwig, H (2010).
7 See The Saudi Arabian Water Environment Association (2013b).

3.2 However, RO membranes are typically made of cellulose acetate or other composite polymers, which are susceptible to fouling[8] that may lead to shorter membrane lifetime and lower quality of desalinated water. Replacement of membrane is considered costly. In order to minimize fouling, thorough pre-treatment of seawater to remove particles and organic matter is required, which adds to the cost of fresh water production. Moreover, a higher level of skills is required for the operation of an RO facility.

Multi-stage flash evaporation

3.3 MSF is relatively simple to operate as it requires much less seawater pre-treatment and the level of skills required for plant operation is also lower. It has an added advantage of being capable of treating a large volume of water and producing high-purity water.

3.4 Nevertheless, MSF is very energy intensive and energy cost indeed accounts for the bulk of the plant operation cost. Since a considerable amount of thermal energy is needed, some desalination facilities are integrated with power plants to make use of their excess heat energy produced. Besides, water recovery rate of MSF is lower than the RO technology. Production of one tonne of desalinated water requires an input of about 8-10 tonnes of seawater.[9]

Multi-effect distillation

3.5 MED is the oldest water desalination technique. Similar to MSF, MED requires minimum pre-treatment of seawater and is able to produce high-purity water. Yet it has a higher water recovery rate than MSF. About 5-8 tonnes of seawater are required to produce one tonne of desalinated water. However, MED compares unfavourably with the RO technology in terms of higher energy consumption and lower water recovery rate.

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8 Fouling means accumulation of particles such as bacteria onto the membrane surface or inside the membrane pores.

9 See The Saudi Arabian Water Environment Association (2013b).

3.6 The strengths and weaknesses of the RO, MSF and MED technologies are summarized in the **Table** below:

Table – Comparison of the three major desalination technologies

	RO (membrane-based technology)	**MSF and MED (thermal-based technologies)**
Strengths	• lower energy requirement • higher water recovery	• relatively simple to operate • capable of producing high-purity water
Weaknesses	• membrane susceptible to fouling • requirement for thorough seawater pre-treatment	• higher energy requirement • lower water recovery

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Research Office
Information Services Division
Legislative Council Secretariat
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Tel: 2871 2122
