# ENVIRONMENTAL IMPACT OF SEAWATER DESALINATION PLANTS

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## Summary

Desalination plants cause environmental pollution of local effects. Disposal of desalination effluents is considered a serious environmental problem. In this article, a discussion of impact of the effluents from the desalination plants into the seawater environment was presented. Some monitoring results on Jeddah desalination plant were reviewed.

## 1. Introduction

Enormous amounts of seawater are desalted every day around the world. The total world production of fresh water from the sea was approximately 2621 mgd (9.92 million $m^3$ $day^{-1}$) in 1985 (Libertt et al. 1985). Desalting processes are normally associated with the rejection of high concentration waste brine from the plant itself or from the pretreatment units as well during the cleaning period. In thermal processes, mainly multistage flash (MSF), thermal pollution occurs. This increases seawater temperature, salinity, water currents and turbidity. These in turn, deteriorate the marine environment and cause fish to migrate, while enhancing the presence of algae, nematodes, and tiny molluscs. Sometimes micro-elements and toxic materials are present in the discharge brine.

This article discusses the impact of these effluents from desalination plants into the seawater environment. Water and air pollution will also be considered and some monitoring results from a Jeddah desalination plant are reviewed.

## 2. Pollutants from Desalination Plants

Pollution may be defined as the presence of one or more contaminants in the biosphere in such a concentration as may be injurious to human, plant or animal life, or unreasonably interfere with the comfortable enjoyment of life. The biosphere consists of the atmosphere, hydrosphere, and lithosphere. Therefore, air pollution, water pollution, and solid or liquid wastes are defined in accordance with the corresponding parts of the biosphere.

In desalination plants, all these types of pollution can take place depending on the desalination process used and the location of the desalination plant. In coastal plants, water pollution is the main problem. In inland plants, attention must be paid to the disposal of the rejected concentrated brine. If plants are of the MSF type, air pollution problems can arise as a large amount of fuel is burned to generate the necessary energy for desalting.

Air pollutants arising from the fuel combustion are carbon monoxide, nitrogen oxides, unburned hydrocarbons and sulfur oxides. Fired heaters in the desalination plants and power stations are the major source of sulfur oxides. It is usual for fuels with a high sulfur content to be used.

## 3. Thermal Impact

Water pollution from desalination plants is caused by the disposal of hot saline brine. On a daily basis, world seas receive $3.86\times10^{7}$ kcal ($1.53\times10^{8}$ Btu) and $4.5\times10^{16}$ tons of minerals from desalination plants (Al-Mutaz 1987).

The rejected brine affects the sea salinity and turbidity and causes water currents, as well as increasing seawater temperature. In addition to the thermal and saline pollution of the rejected brine, toxic effects may be experienced due to the use of different chemicals in the desalination pretreatment and posttreatment processes.

Sabri, McLagan and Hagensonh (1980) have evaluated the safety, health, and environmental (SHE) considerations for RO, MSF, and ED plants using value impact analysis techniques. They utilized a pseudoquantitative scale with high (H = 3), medium (M = 2), and low (L = 1). RO and ED are seen to be preferred to MSF from a SHE point of view. Their results are shown in Table 1.

The thermal pollution of a 1.59 mgd (6000 $m^3$ $day^{-1}$) MSF desalination plant is illustrated in the thermal balance of Figure 1. The temperature rise is about 9°C. The total discharge brine is 1980 t $h^{-1}$ (0.55 $m^3$ $s^{-1}$) with an approximate salinity of 12.6 per cent.

| **Effect** | **RO** | **MSF** | **ED** |
|---|---|---|---|
| Noise | H | M | L |
| Waste effluent | M | H | M |
| Product water impurity | | | |
| Micro-elements | L | H | L |
| Toxic material | M | H | M |
| Air pollution | L | H | M |
| Industrial risk | L | H | M |
| Total score | 10 | 17 | 10 |

Table 1. Rating of various desalination processes (Sabri et al. 1980).

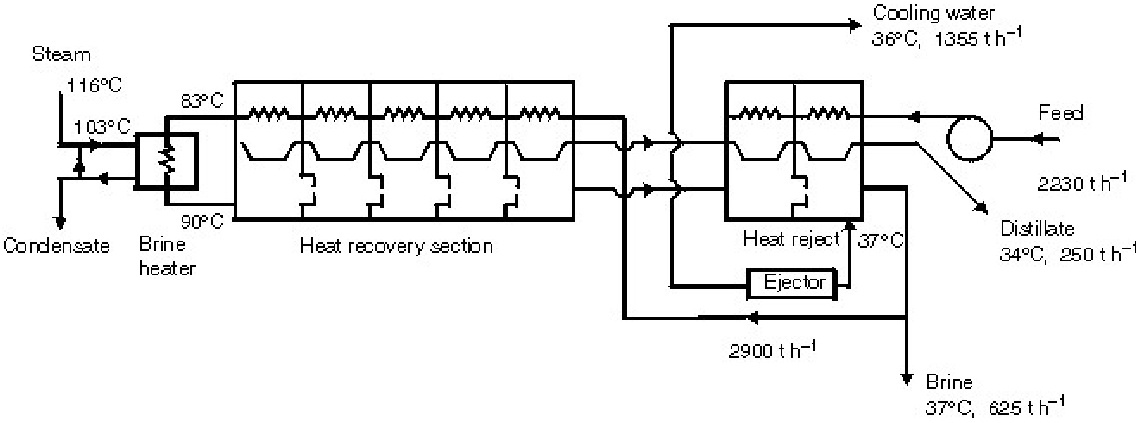

Figure 1. Heat balance on MSF desalination plant.

To reduce the thermal impact of a desalination plant, different discharge arrangements have been used. Normally, seawater is fed to the desalination plant from about 50 m off the coastline at a depth of approximately 12 m. Effluent is discharged at about the same distance away from the intake point. The possible discharge design arrangements include:

1. Diffusion by multi-port nozzle.
2. Diffusion by vertical upward nozzle.
3. Diffusion by horizontal nozzle.

(A temperature rise of 1°C affects an area of 8000 $m^2$, 6500 $m^2$ and 450 $m^2$ respectively in the first, second and third arrangements.)

The fundamental equations for discharge brine can be described by a three-dimensional numerical model. This model consists of the following (Japan International Agency 1979):

1. Kinematic equation:

$$\frac{\partial U_i}{\partial t}+\frac{\partial}{\partial x_j}(U_iU_j)=-\frac{\partial \phi}{\partial x_i}-g\frac{\Delta\rho}{\rho_o}\delta_{3i}+A_hV^2U_i+A_z\frac{\partial^2 U_i}{\partial x_3^2} \qquad (1)$$

2. Mass conversation equation:

$$\frac{\partial}{\partial x_i}U_i=0 \qquad (2)$$

where

$U_i$ = $i$th velocity component
$x_i$ = $i$th direction component
$t$ = time
$\phi$ = ratio of pressure to density (=P/$\rho$)
$g$ = acceleration due to gravity
$\delta_{3i}$ = 1 for $i$ = 3, 0 for $i$ = 1, 2
$A_h$, $A_z$ = lateral eddy viscosity and vertical eddy viscosity respectively
$\rho_0$ = reference density of discharged water
$\Delta\rho$ = density difference between ambient seawater and plume

For the calculation of discharged brine, an equation of state for seawater, $\rho = \rho\ (S, T)$, is used where $S$ is salinity and $T$ water temperature.

3. Density conservation equation:

$$\frac{\partial \rho}{\partial t}+U_i\frac{\partial \rho}{\partial x_j}=\frac{\partial}{\partial x_j}\left(\frac{K_j}{\rho}\frac{\partial \rho}{\partial x_j}\right) \qquad (3)$$

where

$K_j$ = eddy thermal diffusivity.

For a density calculation expressed using the above fundamental equations, the following Knudsen's formula can be used:

$$\sigma_o=-0.069+1.4708\ \mathrm{Cl}-0.001570\ \mathrm{Cl}^2+0.0000398\ \mathrm{Cl}^3 \qquad (4)$$

where $\sigma_0$ is density at 0°C and Cl is the chlorinity (%).

Then, salinity $S$ is correlated with the chlorinity Cl as follows:

$$S=1.80655\times \mathrm{Cl} \qquad (5)$$

Density $\sigma_0$at an arbitrary temperature $t$ is:

$$\sigma_t=\sum\nolimits_t+(\sigma_o+0.1324)\,[1-A_t+B_t(\sigma_o-0.1324)] \qquad (6)$$

where $\Sigma_t A_t$ and $B_t$ are functions of temperature only.

The component of the coefficient for eddy viscosity in the direction rectangular to the axis is taken as follows:

$$A_r = C\, l_r W_{\max} \tag{7}$$

where

$l_r$ = mixing length, equal to the plume half radius
$W_{\max}$ = plume centerline velocity
$C$ = constant equal to 0.0256

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**Bibliography and Suggestions for further study**

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