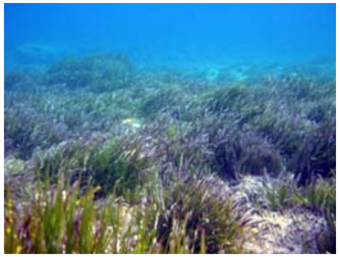
# DES Environmental Considerations



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# Desalination Environmental Issues

Environmental issues related to desalination are a major factor in the design and implementation of desalination technologies.

All desalination processes generate a low-salinity product stream and a high-salinity concentrate stream. Disposal of the concentrate, or waste stream, is the most significant environmental consideration for desalination facilities.

The composition of the concentrate stream varies drastically, according to the desalination process used. Therefore, the environmental impact of the concentrate also varies significantly.

An acceptable desalination plant is expected to meet environmental regulations;
- be cost-effective in terms of construction,
- operation and management, as well as the
- costs associated with monitoring and permit fees.

Some major environmental concerns include issues related to **location of desalination plants** and **water intake structures**, and **concentrate management** and **disposal**.

# Environmental Issues

## Plant location

Plant location is a crucial parameter for the estimation of environmental impacts. Possible risky scenarios can be:

- Brine discharged in a **closed basin**, with **low mixing** processes and/or **long turnover times** (e.g. Red Sea or small seas in general);

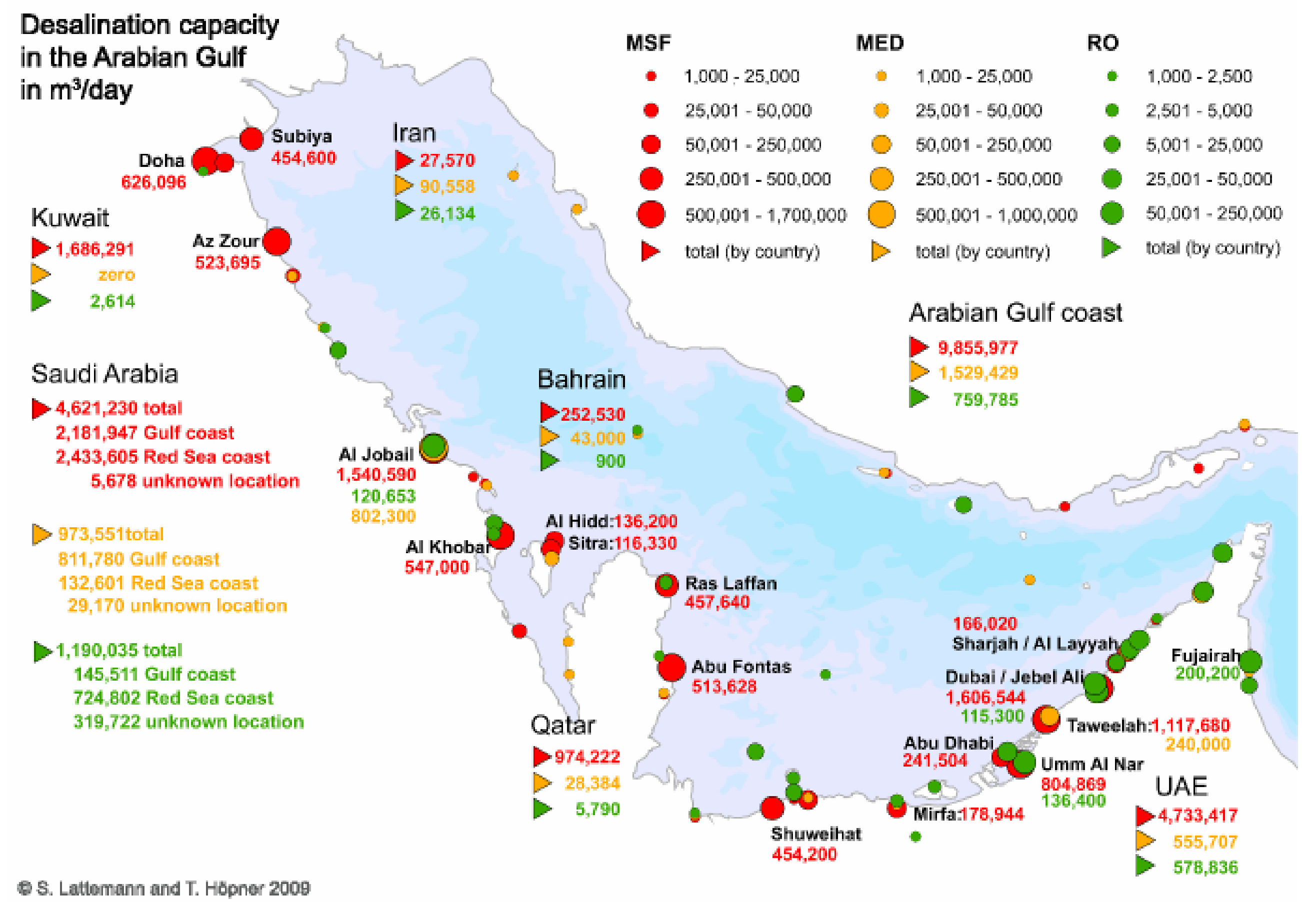
- Brine discharged close to **sensible environments**, like coral reefs, or natural reserves (e.g. some Australia shore lines, small island in the Mediterranean sea, etc.);

- Very **high concentration of desalination plants**, or other industrial activities, **in a certain area** (e.g. Persian/Arabian Gulf)

# Environmental Issues

## Plant location

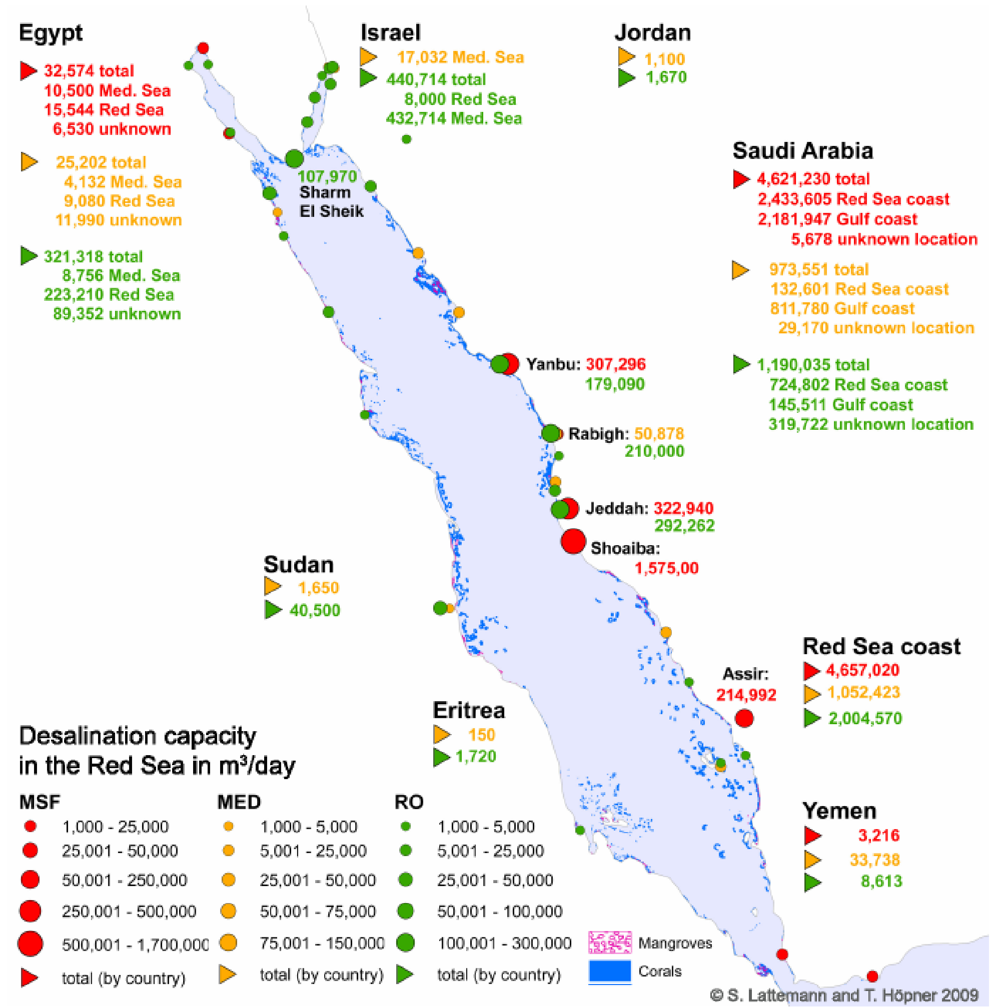
Arabian Gulf Coast



# Environmental Issues

## Plant location

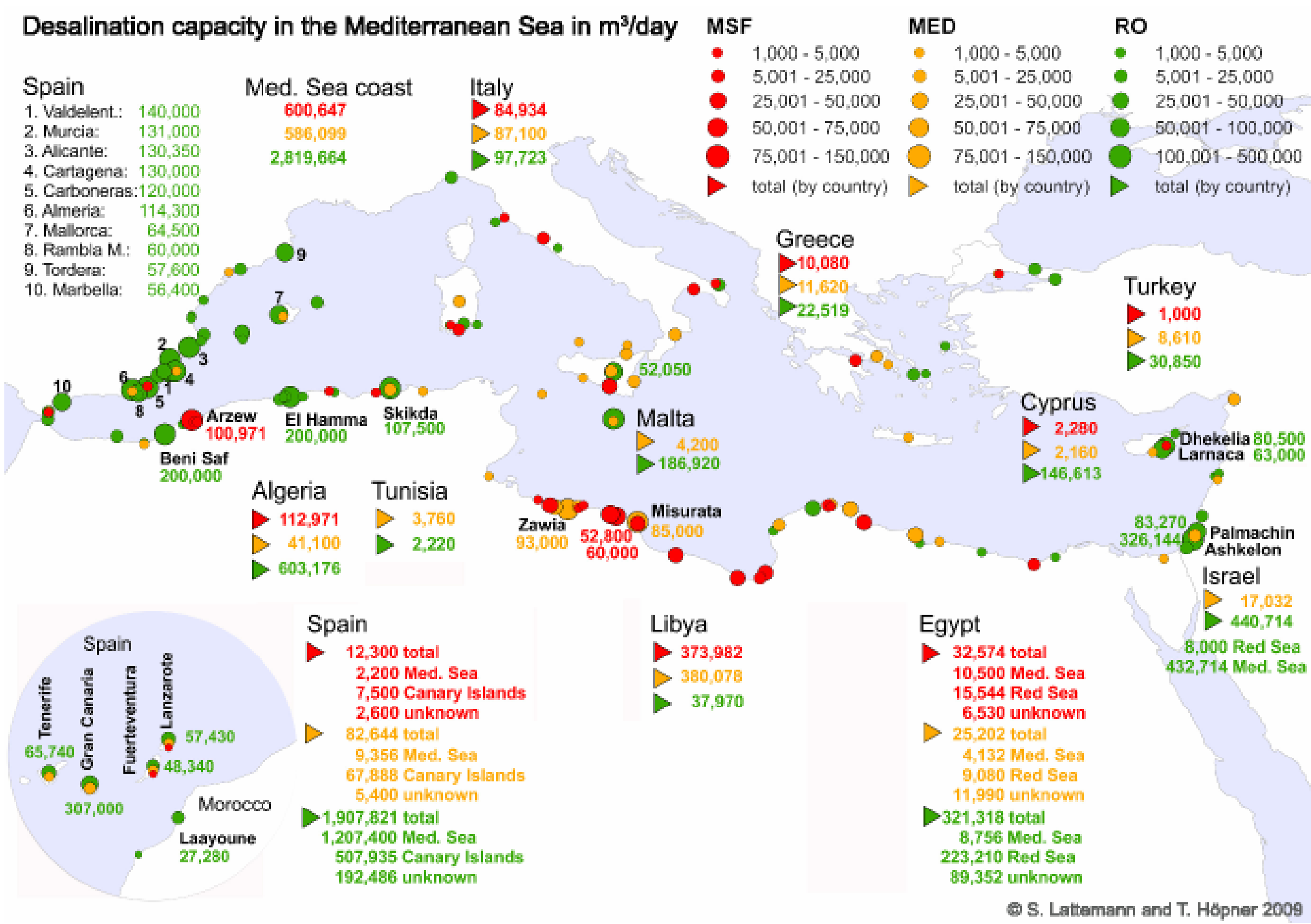
Red Sea Coast



# Environmental Issues

## Plant location

Medtteranean Sea



## Brine Disposal Effects

Since the reject contains mostly the salts of the seawater with minor amounts of other chemicals used during the process of pre-treatment, post-treatment and chemical cleaning of membranes or scale and corrosion control with proper disposal and dilution, no pollution or contamination problems are expected.

The problems faced for disposal of the brine to the sea are mainly the disturbance of the seabed during construction and the dilution of the salt concentration as follows:

### Direct impacts

- **Water intake issues**
- **Discharge issues**
- **Plant siting and construction issues**.

### Indirect impacts

- **Energy use effects**
- **Downstream effects**

## Brine Disposal Quality

The water quality of the concentrate stream depends on:

- Feed water quality
- Pretreatment chemicals (polymer additives, acids, chlorination, corrosion inhibitors, de-chlorination)
- Water recovery
- Temperature
- Post-treatment
- Cleaning chemicals
- Amount of concentrate blending

Feed water is typically pretreated with chemicals to control scaling, fouling, and corrosion of internal equipment, These chemicals are present in relatively low levels - typically less than 10 mg/l, and, therefore, the constituents in the feed water primarily define the concentrate stream.

Unlike most industrial processes, the concentrate stream produced from the desalting process is not characterized by process-enhanced chemicals.

Instead, the concentrate stream reflects the characteristics of the feed water and is primarily only the feed water at a more concentrated level.

*Source: Bureau of Reclamation, USA*

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## Brine Disposal Salinity

The easiest method to consider the impact of the concentrate is to consider the extent of concentration (concentration factor) in the desalination process. The definition of concentration factor is:

$$CF = 1/(1-R)$$

A plant, for example, with a 30% recovery would result in a concentration factor of 1.43, which means that the concentrate is 43% higher in salinity than the feed water. This high-salinity concentration can be reduced by blending water with other lower saline wastewaters in the proximity of the desalination plant

The reverse osmosis (RO) process results in significantly higher concentrations of salts in their concentrate, compared to thermal processes, due to the higher recoveries practiced in the membrane processes (typical salinities of 60,000-85,000 mg /l).

Though brackish water RO results in the highest concentration factor (2.5 to 6.7), keep in mind that this is relative to the feed water quality and is still less than seawater in salt content, even at the higher recoveries.

Thermal processes usually blend their concentrate streams with cooling water prior to discharge, which causes the concentration factors to be lower, compared with the other processes. However, this may also increase the discharge temperature. The concentrate streams are generally less than 15% above feed water concentration.

## Brine Disposal Temperature

Usually, the **mixture brine-cooling water** discharged by thermal plants is between **5 to 15 °C warmer** than ambient seawater, whereas the **temperature** of the **RO concentrate is similar to ambient** values.

It's recommended a **maximum allowable increase** in the temperature **of 3°C** **in the mixing area**, defined as the circular zone with a distance of 100 m from the disposal point.

## Brine Disposal Density

The density of the waste is **influenced by** both the **salinity** and the **temperature** of the brine:

- the high salt content makes higher the density of reject streams with respect to the ambient seawater;
- high temperatures (relative to thermal processes) lower the density of the brine.

# Desalination processes and characteristics of their concentrate streams

| Process | Brackish RO | Seawater RO | Multi-stage flash (MSF) | Multiple-effect distillation (MED) |
|---|---|---|---|---|
| Feed water | Brackish | Seawater | Seawater | Seawater |
| Recovery, percent | 60 to 85 percent | 30 to 60 percent | 30 percent | 20 percent |
| Concentrate temperature | Ambient | Ambient | 5.5 to 15.5 °C above ambient | 5.5 to 15.5 °C above ambient |
| Concentrate blending | Possible, not typical | Not typical, but becoming more common | With cooling water discharge | With cooling water discharge |
| Final concentration factor | 2.5 to 6.7 | 1.4 to 2.5 | < 1.15 | < 1.15 |

*Source: Mickley, 1995*

# Pretreatment Process (1)

Some pretreatment of the feed water for a desalting plant is generally always required.

Pretreatment ensures that constituents that are present in the raw water supply do not result in a loss of performance or a reduction in the output of the facility during normal operation of the plant.

Each desalting technology has different requirements for the quality and condition of water entering the process.

**For distillation processes**, the concerns are:

- Scaling of the heat exchanger tube surfaces
- Corrosion of the plant components
- Erosion by suspended solids
- Effect of other constituents

**For membrane processes,** the major concerns are:

- Membrane fouling and scaling
- Suspended solids plugging
- Biological fouling or attack
- Membrane degradation by oxidation or other means

## Pretreatment Process (2)

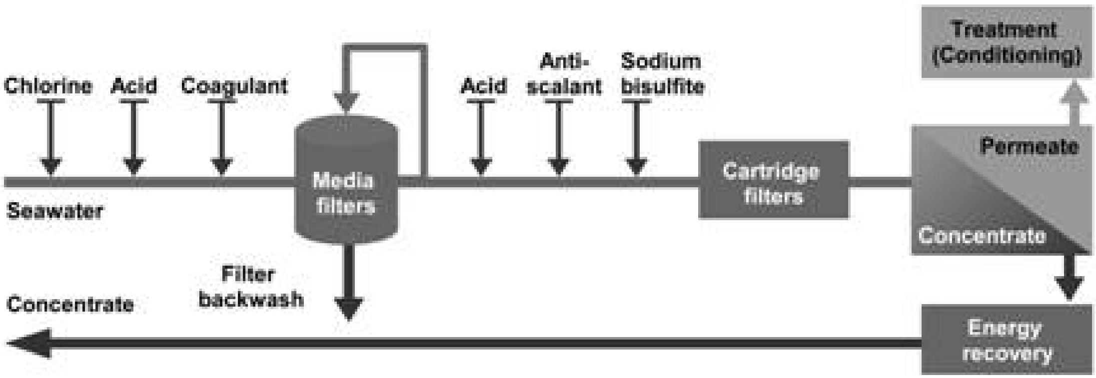
Pretreatment may include processes such as chlorination, dechlorination, coagulation, acidification, and degasification used on the feed water to minimize algae growth, scaling, and corrosion.
The pretreatment chemical agents are important to consider because they remain in the concentrate before disposal.

*Pretreatment*

- Somewhat similar schemes may be used in all processes
- Chlorination where biological growth may be present (more for surface waters)
- Polymer additives used for scale control
- Acid sometimes used in addition to additives (particularly for RO)
- Corrosion inhibitors used in thermal processes
- Dechlorination for some membrane processes where chlorination is used

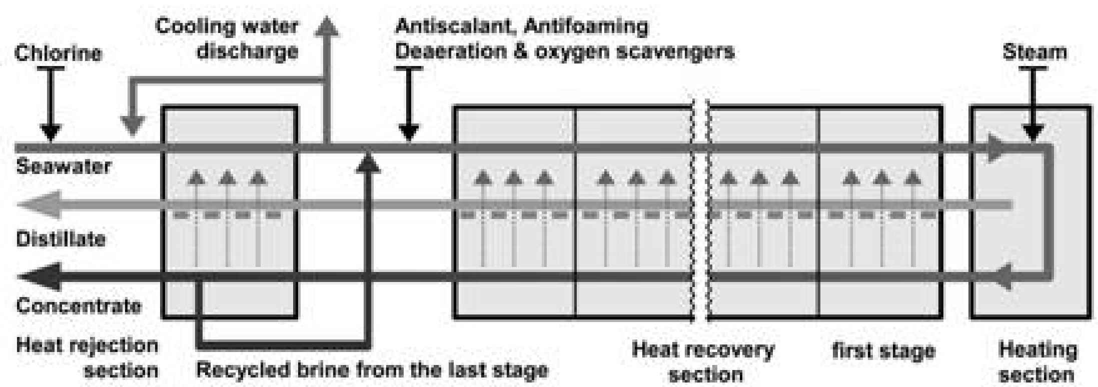
*Source:WWF*

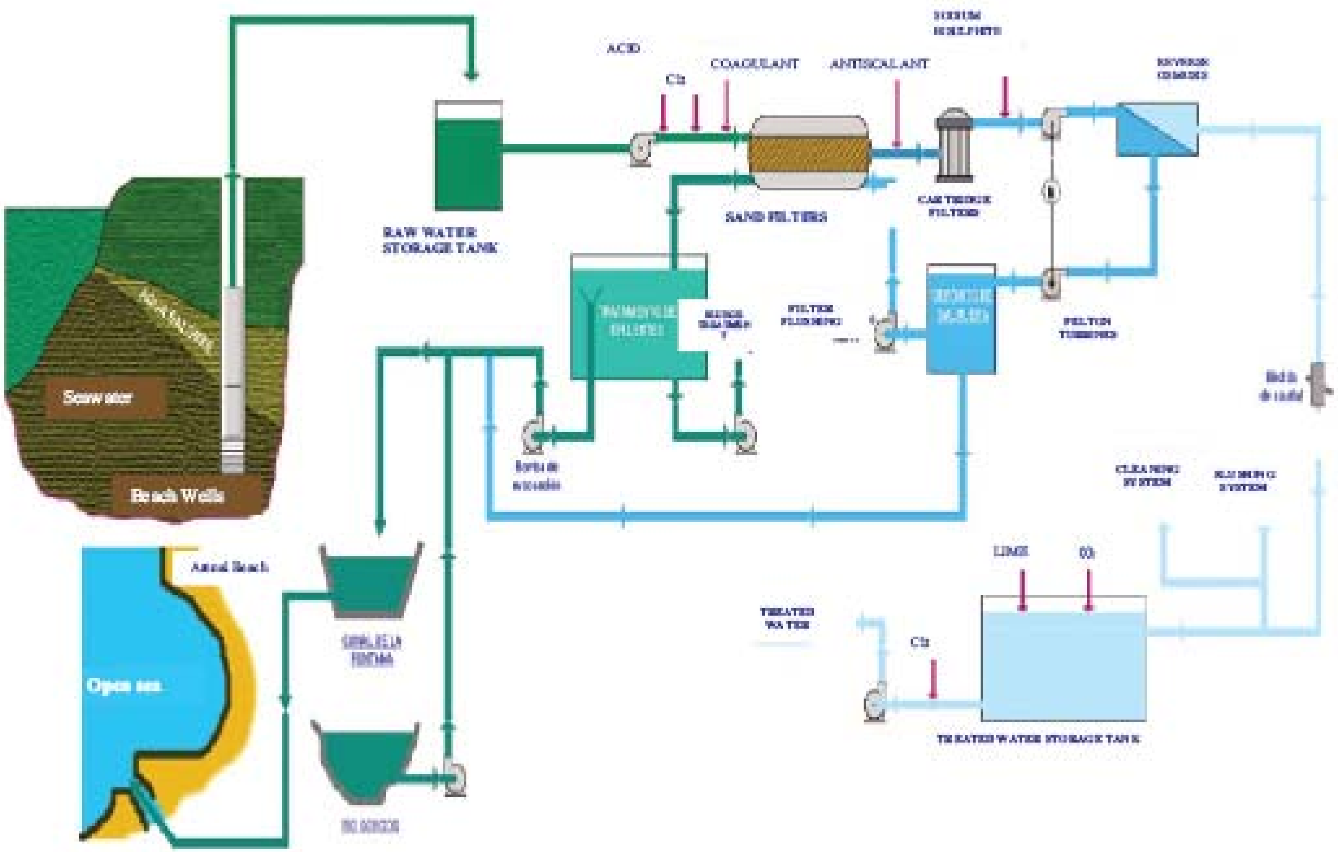
## Reject streams




Flow-chart of an SWRO system showing the conventional pretreatment and chemical addition steps

Flow-chart of an MSF system showing the conventional pretreatment and chemical addition steps






*Source:Malfeido J, 2005*

## Post-treatment Process

Product water from desalination plants normally require to be treated prior to storage and transmission to consumers. This is necessary as the product can be very aggressive and cause serious corrosion problems in the pipe transmission.

The mineral content (dissolved solids in the product water) from desalting processes is quite low. Product water from distillation processes typically ranges between 0.5 and 50 mg/l TDS. Product water from membrane processes can range from 25 to 500 mg/l TDS, depending on the application. Therefore, product water must be treated either to reintroduce minerals or to add corrosion inhibitors to render it benign.

Adding calcium and bicarbonate, along with a change in pH, will result in a water supply that will not corrode piping, storage tanks, and other components in the distribution system, including the end user's plumbing system.

Regardless of what other post-treatment steps are employed, disinfection and maintenance of a chlorine residual in the water distribution system are required for all municipal drinking water systems.

Post- treatment process includes:

- Stabilization (i.e. addition of Caustic soda, NaOH; Sodium bicarbonate, NaHCO3; Soda ash)
- Sterilization
- Enrichment
- Degasification

**Desalination Cleaning Processes**

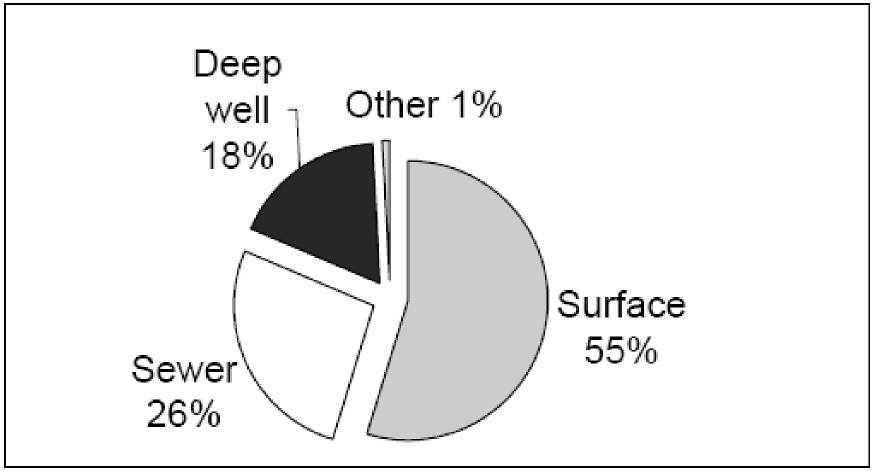
Also, during the cleaning procedure of a distillation or a membrane plant several chemicals are used.

The cleaning procedure may takes place every 3 to 6 months.

# Options for Brine Disposal Rejection

Effluent disposal options for concentrate disposal that have been used include:

- Surface water discharge
- Disposal to the front end of a sewage treatment plant for processing
- Deep well injection
- Land application
- Evaporation ponds/salt processing ponds
- Concentrate concentrators for zero discharge facilities




Comparison of concentrate disposal methods for all brackish water processing facilities in the U.S. (Mickley, 2001)

# More Info

# Environmental Issues

## Reject streams

**Chemicals for the control of biofouling.** Chlorine is usually added to the feed to prevent biofouling; its concentration quickly decrease, due to the **oxidant demand** of different organic compounds present in the intake.

**Chlorination and dechlorination in RO plants**. Because off chlorine can compromise the chemical stability of the membranes used in RO processes, it has to be removed before feeding the RO modules. This aim is typically achieved adding **sodium bisulfite as a dechlorination agent**. Then, the discharged brine of a RO plant **doesn't contains chorine** in appreciable concentration.

**Chlorine emissions in thermal desalination plants**. In thermal desalination plants, doses of between **0.4 and 4.0 mg/l** and resulting levels of between **0.1 and 0.5 mg/l at the point of discharge** have been reported. European laws recommend that the average daily value of free residual oxidant emissions should be ≤ **0.2 mg/l at the outlet**, for continuous seawater chlorination.

**Toxicity of chlorine**. Despite the fact that residual chlorine levels are quickly decreased following discharge (due to the oxidation demand of the receiving body), the potential for toxic effects still exists in the mixing zone of the plume. It causes the **mortality of a portion of the entrained planktonic organisms**, depending on species sensitivity, life stage and the thermal regime involved.

## Environmental Issues

### Reject streams

**Chemicals for the control of scaling.** **Calcium carbonate** is the main scaling compound formed in desalination plants. In thermal desalination plants, **magnesium hydroxide and sulphate** scales are also formed due to high operating temperatures.

Scale formation is usually controlled either by the addition of **sulphuric or hydrochloric acid** ( 20-100 mg/l), the addition of a special **scale inhibitor** (“antiscalant”), or a combination thereof.

**Effects on the pH of the receiving body**. Due to the acid treatments the pH value of the discharged brine has values in the range **6 ÷ 7,** lower if compared to a natural seawater pH of about 8.3.
However the lowering pH effect is usually **buffered** by the receiving body (seawater), which will **neutralize surplus acidity quickly** following disposal.

## Effect of corrosion on reject streams

**Copper-nickel** alloys are common heat exchanger materials in distillation plants. Corrosion of these materials typically causes contamination of reject streams with copper and nickel. **Copper concentrations** in reject streams **of 15-100 µg/l** have been reported.

The presence of copper does not necessarily mean that it will adversely affect the environment. **Natural concentrations** of copper range from an oceanic background level of **0.1 µg/l to 100 µg/l** in estuaries.

It is therefore difficult to distinguish between natural copper levels and anthropogenic effects, e.g. caused by industrial outfalls or oil pollution.

The discharge levels of **thermal plants**, however, are within a range that **could affect natural copper concentrations**.

## Effects of cleaning on reject streams

**Alkaline and acidic cleaning in RO plants.** In RO plants, alkaline solutions (pH 11-12) are typically used to remove silt deposits and biofilms from membranes, while acidic solutions (pH 2-3) are applied to dissolve metal oxides or scales.

**Chemicals used.** These solutions often contain additional chemicals to improve the cleaning process, such as detergents (e.g. dodecylsulfate, dodecylbenzene sulfonate) or oxidants (e.g. sodium perborate, sodium hypochlorite).

**Disinfection.** After cleaning, or prior to storage, membranes are typically disinfected with either oxidizing (such as chlorine and hydrogen peroxide) or non-oxidizing (such as formaldehyde) compounds.

**Cleaning in thermal processes.** The cleaning of distillation plants is comparatively easier: the plants are usually washed with warm acidic seawater, to which corrosion inhibitors (e.g. benzotriazole derivates) may be added, to remove alkaline scales from heat exchanger surfaces.

**Disposal of cleaning water.** In many cases, the residual cleaning solution and also the first rinse, which contains most of the constituents from cleaning, are neutralized and discharged to a sanitary sewer to be treated.

# Brine outfalls systems

Brines from desalination units can either be:

-**buoyant** (lighter than the receiving body);

-**neutral** (same density as the receiving body);

-**sinking** (denser than the receiving body);

usually from Thermal Processes

usually from Reverse Osmosis

**Brine dilution** strategies can be adopted to **reduce** the environmental impact

For cogeneration plants (thermal process):

Blending the brine with much larger flow rates of cooling seawater allows the discharge of a very diluted brine, warmer and, usually, lighter than the receiving seawater

For stand alone systems (often RO):

Use of a multi-port diffuser allow the dilution of discharged brine (usually denser than seawater) by mixing with the receiving seawater before the impingement on the sea floor

# WHO guidelines for potable water

- **Chlorine** is used as a disinfectant. Its concentration in potable water must be below 1 mg/l;
- The maximum allowable concentration of **chlorides** is 250 mg/l; higher values makes the water unpalatable and inhibit the deposition of lime to protect the tubes;
- The **hardness** is a parameter taking in account the concentration of ions $Ca^{2+}$ and $Mg^{2+}$; potable water must have hardness in the range 60-200 mg/l of calcium (equivalent to 15-50°f );
- **pH** of potable water has to be in the range 6.5-9.5;
- **Sodium** ions concentrations has to be below 200 mg/l. Higher values aren't unhealthy, but compromise the organoleptic features of potable water;
- **Sulphates** concentration must be below 250 mg/l. They can inhibit the kinetics of deposition of lime;
- The higher allowable concentration of **Total Dissolved Solids (TDS)** has to be below 1000 mg/l;
- The presence of **ions $Fe^{3+}$** is due to the aggressive behavior of water and corrosion of pipelines giving rise to the phenomenon called "**red water**";

## Atmospheric pollution in co-generation plants

Chimneys of the power station in the Shuweihat plant (UAE)

Chimneys of the power station in the JebelAli plant (UAE)

# Intake and outfall structures

Intake of the Shuweihat plant (UAE)

Intake of the JebelAli plant (UAE)

## Intake and outfall structures

Intake and outfall of the RO plant in the Isola del Giglio (Italy)

## Brine outfall

Source:WWF, 2007