

## COMPOSITION OF DESALINATED WATER

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### Summary

The determining factors for the composition of the drinking water produced by brackish water or seawater desalination plants are not only the nature and extent of the measures for potabilization and post-treatment, but also the type of desalination processes employed. When considering the product quality of the treatment process itself, a basic distinction has to be made between:

- The composition of the permeate from reverse osmosis plants;
- Dialysate composition of electro dialysis (ed or edr systems);
- The distillate composition from thermal water desalination processes (msf and med).

In the case of the two thermal processes, the desalinated product quality is virtually identical.

Due to the very low salt content of evaporator distillate, but also the similar low values of calcium and bicarbonate ions in evaporator product as well as reverse osmosis permeate, in the presence of quite small amounts of carbon dioxide, desalinated water from these processes reacts aggressively towards materials of distribution networks and domestic installations. In view of - under organoleptic considerations - the unbalanced ratio of monovalent to bivalent ions and low salt content, product water from

desalination processes should not be supplied as drinking water without being potabilized or remineralized.

## 1. Distillate

### 1.1. Ionogenic Composition

The distillate produced by evaporation plants contains salts and dissolved gases (carbon dioxide, oxygen and nitrogen) in very low concentrations.

The total dissolved solids (TDS) content in the distillate mixture from the stages of a thermal desalination plant is normally in the range of 20-30 ppm, but this can increase to 50 ppm or more due to leaks as the plant ages or is influenced by operating and equipment conditions. The ionogenic composition of the distillate corresponds approximately to the distribution of ions in the raw water. For practical purposes, the contents of alkalinity and carbon dioxide in the distillate are negligible.

Distillate normally has a pH of 6.0-6.3 and a CO<sub>2</sub> content of less than 1 ppm (Table 1).

Parameter	Unit	RO <sup>a</sup>		MSF/ MED	Hybrid <sup>b</sup>
		1st stage	2nd stage		MSF-RO
Sodium	mg l <sup>-1</sup>	72.8	1.6	7.1	34.9
Potassium	mg l <sup>-1</sup>	4.8	0.2		1.9
Calcium	mg l <sup>-1</sup>	1.0	-	0.4	0.7
Product composition					
Magnesium	mg l <sup>-1</sup>	3.8	0.1		1.6
Chloride	mg l <sup>-1</sup>	122.7	2.6	11.0	58.2
Sulfate	mg l <sup>-1</sup>	7.4	0.1	-	3.1
Nitrate	mg l <sup>-1</sup>	1.1	0.1	-	0.5
Alkalinity	mg l <sup>-1</sup>	1.4	-	0.7	0.9
	HCO <sub>3</sub>				
Silica	mg l <sup>-1</sup>	0.2	-	-	0.1
Carbon dioxide	mg l <sup>-1</sup>	20	20.0	0.5	8.7
TDS	mg l <sup>-1</sup>	215.2	4.7	19.2	110.6

<sup>a</sup> Recovery rate 40%, Temperature 28°C

<sup>b</sup> RO capacity = 1.00      MSF capacity = 1.37

Table 1. Product composition of different seawater desalination processes (seawater salinity 32 g l<sup>-1</sup>).

### Design and operational influences on ionogenic distillate composition

The main influences of the equipment and operating conditions on the salt content of distillate from thermal desalination processes are:

- Purity of steam at its place of formation, i.e. Proper design and geometry features of heat transfer surfaces and flash chambers as well as their equipment (spray nozzles, orifices, brine distribution systems);
- Demister design and maintenance;
- Prevention of leakage at all equipment parts where feed water and brine could contact vapor and distillate.

As the demister design and its condition have a predominant influence on distillate purity, the efficiency of this salt transfer barrier must be kept high through proper maintenance by rinsing and acid cleaning it during outage periods. High vapor purity is a prerequisite for keeping the entrainment at the demisters low, supporting their droplet removal efficiency and reducing fouling, and thus lengthening intervals between maintenance.

The prerequisite for high vapor purity even during periods of fluctuating or low feed water temperature is a favorable geometric design and an even distribution of mass flow through the evaporator stages.

As the operating period of the equipment increases, there is a greater probability of leakage influencing distillate purity. Preventive maintenance measures must be intensified to keep distillate quality at an acceptable level

## **1.2. Trace Substances**

The sources of pollution of distillate by trace substances like metals, other inorganic compounds and organics could be:

- Materials of the evaporators and their associated equipment;
- Raw water pollutants or pollutants formed during pretreatment (chlorination), which pass the evaporative barrier together with the vapor;
- Raw or feed water pollutants which reach the distillate in side streams from raw water to distillate/product, bypassing the evaporative barrier;
- Pollution from maintenance and repair activities.

### **1.2.1. Metals**

Evaporator equipment comprises a large number of metal components like shells, condensers, heat exchangers, water boxes, pumps, pipework etc. Depending on the nature of the raw water to be treated and with the appropriate pretreatment and conditioning measures, the proper choice of metallic materials is not only of great importance to minimize corrosion and consequently enhance reliability and extend plant lifetime, but in the interests of a low heavy metals in the distillate.

For seawater desalination, experience with a broad range of materials of high corrosion resistance is available, especially copper/nickel alloys and stainless steel. Also aluminum bronzes and metals with a lesser degree of corrosion resistance, but with surface coatings or linings of rubber or plastics, are applied.

However, the main materials to be considered as a source of trace metals in the distillate are the copper/nickel alloys and stainless steel. Depending on the alloying constituents of these compounds, the metals involved are mainly copper and nickel, but also chromium, molybdenum and iron.

For modern evaporation plants, designed, operated and maintained in accordance with the state of the art, the copper content in the distillate is in the range of less than 0.01-0.1 ppm. Usually the copper content is below 0.035 ppm (Oldfield and Todd 1996).

Specific corrosion phenomena like vapor side corrosion in copper/nickel tubed hot reject stages of MSF systems could raise the copper content in the common distillate of such a system to 0.18 ppm (McGregor and Karim 1995). Also of influence is the choice of tubing material (Cu/Ni alloys, stainless steel or titanium, as well as type and composition of the materials) and the manner and mode of operation of conditioning (antiscalant or acid dosing, hybrid conditioning). Especially with acid dosing, care must be taken to avoid excessively acidic and corrosive conditions of the evaporator feed, arising from accidental acid overdosing.

In the distillate of evaporator systems tubed and clad with copper/nickel material the nickel content is even lower than the copper content.

Stainless steel materials, which could be used for tubing, cladding, pumps and piping of evaporators in addition to copper and nickel, could release other metals into the distillate like chromium and molybdenum. For molybdenum, analytical data are not available for distillate originating directly from evaporation. Chromium was below the level of detection in product water from Saudi Arabian MSF plants (Mayan et al. 1995).

Calculations for stainless steel of 316L type material based on passive current considerations for an MSF system with certain stainless steel material equipment, showed very low trace metal release to distillate and extremely low heavy metal trace concentrations (Table 2) (Oldfield and Todd 1996).

Element	Heavy metal level in product water ( $\mu\text{g l}^{-1}$ )		
	Average passive current ( $\mu\text{A cm}^{-2}$ )		
	1	0.1	0.01
Iron Fe	10.0	1.00	0.100
Chromium Cr	3.0	0.30	0.030
Nickel Ni	2.0	0.20	0.020
Molybdenum Mo	0.3	0.03	0.003

Table 2. Predicted levels of alloy elements leaching into product water of MSF via the stainless steel passive current from SS type 316 L (Oldfield and Todd 1996).

Raw water to be treated by desalination processes also contains heavy metals. Ground water and brackish water out of wells often exhibit relatively high contents of iron and manganese. Before treatment in desalination plants, the content of these metals must be reduced in pretreatment systems, in brackish water desalination often combined with measures for prevention of scaling.

Surface water generally contains a broad range of heavy metals, normally present, however, only in trace concentrations. Nevertheless, industrial and domestic wastewater discharges can lead to increased metal contents in river water and seawater.

Thermal desalination processes, as investigations for arsenic, cadmium, chromium and lead in Saudi Arabian MSF plants have been shown to very effectively reduce common heavy metal concentrations of seawater. Only for mercury, do thermal processes show diminished separation capabilities due to the volatile properties of this element and some of its compounds (Table 3) (Mayan et al. 1995).

Element	Heavy metals concentration ( $\mu\text{g l}^{-1}$ ) in				
	Seawater			Product water of MSF plants	
	Min.	Max.	Mean	Min.	Max.
Arsenic As	ND-1.2	5.6-7.2	2.6-3.3	ND	0.77-1.8
Cadmium Cd	ND-0.03	1.3-1.5	0.08-1.0	ND	1.0-1.3
Chromium Cr	ND	ND	ND	ND	ND
Mercury Hg	ND-0.04	0.1-1.8	0.04-0.17	ND	0.3-2.8
Lead Pb	ND	ND	ND	ND	ND
Selenium Se	ND	0.75-0.96	0.20-0.33	ND	0.52-0.67

Table 3. Heavy metal concentrations in Arabian Gulf water and in the distillate of MSF plants at various Saudi Arabian dual purpose installations 1992-1994 (Mayankutty et al. 1995).

### 1.2.2. Organics

During thermal desalination, organic compounds found in raw water are normally very effectively prevented (to more than 95 per cent) from passing into the distillate. However specific organic pollutants, e.g. from industrial oil, chemicals discharges or spillages, comprise vapor volatile constituents which are set free during vapor flashing and can dissolve in the condensing distillate. These compounds are mainly low boiling point aliphatic and aromatic hydrocarbons like methane, ethane, propane derivatives and aromatic compounds like benzenes, xylenes and phenols. During seawater chlorination and chlorine generation by seawater electrolysis, however, higher molecular weight and less volatile substances are formed due to oxygenative cracking and are halogenated. Chlorinated and bromated hydrocarbons like chloro- and bromo- methanes, ethanes and halogenated aromatics, which develop from these reactions, are of a similar highly volatile nature. Also these substances, if present in the feed of thermal processes, can reach the distillate via stripping and dissolving in distillate during the vapor condensing process. However the concentration of these substances in the feed to thermal processes is normally already near the values stipulated for drinking water. Due to their already quite efficient removal in the deaerator and the fact that most are released from the water phase to the venting partial stream of the evaporators, the content of organic impurities in the distillate from thermal desalination systems is at concentrations posing virtually no risk to consumers (Mayankutty et al. 1991).

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