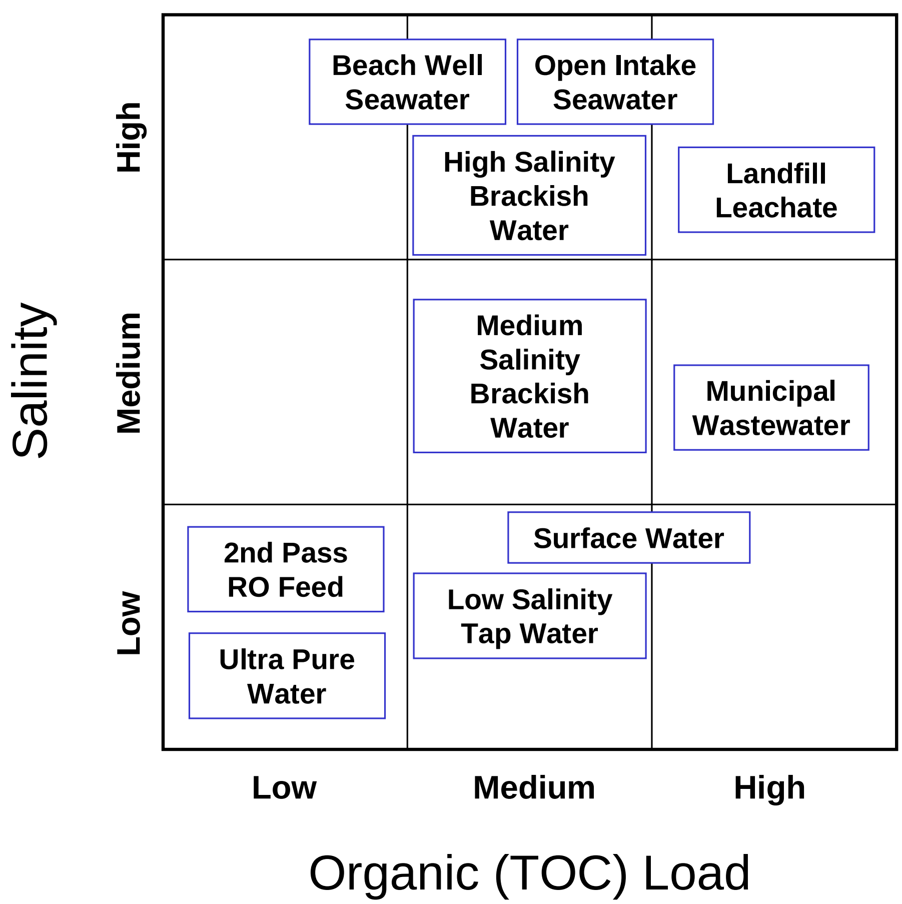
FILMTEC Membranes
Water Chemistry and Pretreatment: Feedwater Type and Analysis

Feedwater Type and Analysis

The major water types being treated by RO/NF can be roughly characterized from the total dissolved solids (TDS) content and the organic load (total organic carbon, TOC), see Figure 2.1.

- Very-low-salinity, high-purity waters (HPW) coming from the first RO systems (double-pass RO system) or the polishing stage in ultrapure water (UPW) systems with TDS up to 50 mg/L.
- Low-salinity tap waters with TDS up to 500 mg/L.
- Medium-salinity groundwater with high natural organic matter (NOM) and TDS up to 5,000 mg/L.
- Medium-salinity brackish waters with TDS up to 5,000 mg/L.
- Medium-salinity tertiary effluent with high TOC and biological oxygen demand (BOD) levels and TDS up to 5,000 mg/L.
- High-salinity brackish waters with TDS in the range of 5,000–15,000 mg/L. Seawater with TDS in the range of 35,000 mg/L.

Figure 2.1 Major water types being treated by RO and NF



* Trademark of The Dow Chemical Company

Seawater

Seawater with TDS of 35,000 mg/L is considered standard seawater constituting, by far, the largest amount of water worldwide. The composition is nearly the same all over the world. The actual TDS content may, however, vary within wide limits from the Baltic Sea with 7,000 mg/L to the Red Sea and Arabian Gulf with up to 45,000 mg/L. The actual compositions can be proportionally estimated from the standard seawater composition (Table 2.1). The water from seashore wells, however, depending on the soil, influx from inland, etc., can often have salinity and composition quite different from water taken from the sea itself.

Table 2.1 Standard seawater composition

Ion	Concentration (mg/L)
Calcium	410
Magnesium	1,310
Sodium	10,900
Potassium	390
Barium	0.05
Strontium	13
Iron	<0.02
Manganese	<0.01
Silica	0.04 - 8
Chloride	19,700
Sulfate	2,740
Fluoride	1.4
Bromide	65
Nitrate	<0.7
Bicarbonate	152
Boron	4 - 5
Other	
TDS	35,000 mg/L
pH	8.1

In Table 2.2 and Table 2.3, some chemical and physical characteristics of seawaters with different salinity are shown.

Table 2.2 Inorganic composition of seawater with different salinity

Water	K (ppm)	Na (ppm)	Mg (ppm)	Ca (ppm)	HCO_3 (ppm)	Cl (ppm)	SO_4 (ppm)	SiO_2 (ppm)
Standard seawater - 32,000 ppm	354	9,854	1,182	385	130	17,742	2,477	0.9
Standard seawater - 35,000 ppm	387	10,778	1,293	421	142	19,406	2,710	1.0
Standard seawater - 36,000 ppm	398	11,086	1,330	433	146	19,960	2,787	1.0
Standard seawater - 38,000 ppm	419	11,663	1,399	456	154	20,999	2,932	1.0
Standard seawater - 40,000 ppm	441	12,278	1,473	480	162	22,105	3,086	1.1
Standard seawater - 45,000 ppm	496	13,812	1,657	539	182	24,868	3,472	1.2
Standard seawater - 50,000 ppm	551	15,347	1,841	599	202	27,633	3,858	1.4

Table 2.3 Salinity and conductivity of seawaters

Location	Salinity TDS ppm	Conductivity K µS/cm	Factor K/TDS µS/(cm·ppm)
South Pacific	<36,000	<51,660	1.43 - 1.44
Gran Canaria (Atlantic Ocean)	37,600	53,280	1.42
Sardinia (Mediterranean Sea)	40,800	57,240	1.40
Bahrain	42,500	59,350	1.40
Egypt (Red Sea)	44,000	62,990	1.38

Seawater (cont.)

The characteristic features of seawater have to be considered in the design and operation of the pretreatment and the reverse osmosis process. As a consequence of the high salinity of seawater involving a high osmotic pressure, the recovery of the system is limited to typically 40 to 50% in order to not exceed the physical pressure limits of the membrane element, or to limit the energy consumption associated with higher feed pressures at higher recoveries, or to limit the salinity and/or the boron concentration in the product water. Seawaters from open intakes may cause biofouling of the RO membranes if no biofouling prevention measures are in place (see *Biological Fouling Prevention, Section 2.6.1*).

Brackish Water

The composition of brackish waters is of extremely wide variation, and a water analysis is a must for a good process design. Several examples of brackish water analyses are given in Table 2.4.

In brackish water treatment, the factor limiting recovery is mainly of a chemical nature (i.e., precipitation and scale formation by compounds such as calcium carbonate or calcium sulfate). The potential for biofouling is also another limiting factor in brackish water treatment. A number of methods are available to assess the biological fouling potential (see *Assessment of the Biological Fouling Potential, Section 2.6.2*). In industrial and municipal wastewater treatment, a wide variety of organic and inorganic constituents may be present. Thus, the limiting factors are sometimes governed by additional characteristics of feed waters, for example the organic matter or the phosphate scaling potential.

Table 2.4 Examples of brackish water composition

Parameter	Unit	Well water[a]	Well water[b]	Lake water[c]	Surface water[d]	Pretreated tertiary effluent[e]
Calcium	mg/L	84	113	54	102	40 - 64
Magnesium	mg/L	6	2.7	23	11	—
Sodium	mg/L	36	23	87	20	150 - 200
Potassium	mg/L	3.3	2	6.6	4	—
Iron	mg/L	<0.05	0.2	0.05	ND-015	0.02 - 0.09
Manganese	mg/L	0.01	0.1	<0.01	<0.01	<0.05
Barium	mg/L	0.07	0.1	0.09	—	0.01 - 0.1
Strontium	mg/L	0.7	1	1	—	0.2 - 1
Ammonium	mg/L	<0.05	—	—	0.3	22 - 66
Aluminum	mg/L	0.02	—	0.02	ND-0.15	0.03
Chloride	mg/L	45	52	67	33	150 - 500
Bicarbonate	mg/L	265	325	134	287	48.8 - 97.6
Sulfate	mg/L	24	8	201	56	120 - 160
Nitrate	mg/L	4.3	4	<1.0	15	40 - 60
Fluoride	mg/L	0.14	0.7	—	0.25	0.7 - 0.7
Phosphate	mg/L	<0.05	0.6	0.01	1.2	6.1 - 12.2
Silica	mg/L	9	11	3.1	7 - 17	6 - 10
Hydrogen Sulfide	mg/L	—	1.5	—	—	ND
TDS	mg/L	478	377	573	400	500 - 1,300
TOC	mg/L	1.5	10	3.6	2.4	20 - 30 (COD)
Color	Pt	<5	40	—	<5	13 (Hazen)
Turbidity	NTU	—	—	—	2 - 130	0.4 - 1.7
pH	—	7.5	7.4	8.2	8	6.6 - 7.4
Conductivity	µS/cm	590	—	879	400 - 700	700 - 2,200
Temperature	°C	12	23 - 28	—	3 - 25	25 - 35

a. Well water: Germany
b. Well water: The Turnpike Aquifer in Florida (design of the Boynton Beach, FL Membrane Softening Water Treatment, Proc. AWWA Annual Conference, Eng. And Op., 139 (1992))
c. Lake Mead, Nevada (2000)
d. River Oise, France
e. Tertiary effluent: industrial water in Jurong Island, Singapore (Water Reclamation – The Jurong Island Experience – SUT Seraya using Fouling Resistant RO Membrane to Reclaim Wastewater, IDA, Bahrain (2002))

Brackish Water
(cont.)

With such wide variation in feed water quality, the first step is to know the water characteristics. Before a projection of an RO or NF system design can be run, a complete and accurate water analysis must be provided. A water analysis form (Table 2.5) must be completed and balanced to electroneutrality (i.e., anion and cation concentrations must be identical when stated in terms of the calcium carbonate equivalent). If the water analysis is not balanced, the addition of either Na^+ or Cl^- to achieve electroneutrality is recommended.

Table 2.5 Water analysis for RO/NF

Sample identification: ....

Feed source: ....

Conductivity: .... pH: .... Temperature (°C): ....

Feed water analysis:				
Please give units (mg/L as ion	NH_4^+	....	CO_2	....
or ppm as $CaCO_3$ or meq/L)	K^+	....	CO_3^{2-}	....
	Na^+	....	HCO_3^-	....
	Mg^{2+}	....	NO_3^-	....
	Ca^{2+}	....	Cl^-	....
	Ba^{2+}	....	F^-	....
	Sr^{2+}	....	SO_4^{2-}	....
	Fe^{2+}	....	PO_4^{2-}	....
	Fe (tot)	....	S^{2-}	....
	Mn^{2+}	....	SiO_2 (colloidal)	....
	Boron	....	SiO_2 (soluble)	....
	Al^{3+}	....		

Other ions: ....

TDS (by method): ....

TOC: ....

BOD: ....

COD: ....

AOC: ....

BDOC: ....

Total alkalinity (m-value): ....

Carbonate alkalinity (p-value): ....

Total hardness: ....

Turbidity (NTU): ....

Silt density index (SDI): ....

Bacteria (count/ml): ....

Free chlorine: ....

Remarks: ....

(odor, smell, color, biological activity, etc.) ....

....

....

Analysis by: ....

Date: ....

Brackish Water
(cont.)

Ba^{2+} and Sr^{2+} must be analyzed at the 1 µg/L (ppb) and 1 mg/L (ppm) level of detection, respectively. It is also important that the temperature be given as a range rather than an absolute value. Temperature variation can impact the scaling potential of an RO system, especially when silica and bicarbonate levels in the feed water are high.

After the membrane system is in service, the feed water should be analyzed on a regular basis so that the pretreatment and the plant operation can be adjusted accordingly. Many standards are available for water analysis techniques. It is recommended to use the standards of ASTM International (www.astm.org) or the latest edition of *"Standard Methods for the Examination of Water and Wastewater"*/1/.

A guide for water analysis for reverse osmosis applications is given in ASTM D 4195 /2/; this can be applied to nanofiltration as well. A listing of the relevant ASTM procedures and Standard Methods for the Examination of Water and Wastewater are given in Table 2.6.

Table 2.6 Standard procedures relevant to water analysis for RO/NF applications

	ASTM	Standard Methods /1/
Calcium and magnesium	D 511	3500-Ca, Mg
Chloride	D 512	4500-Chloride
Carbon dioxide, bicarbonate, carbonate	D 513	4500-Carbon dioxide, 2320
Phosphorus	D 515	4500-P
Sulfate	D 516	4500-Sulfate
Aluminum	D 857	3500-Al
Manganese	D 858	3500-Mn
Silica	D 859	4500-Silica
Dissolved oxygen	D 888	4500-O
Iron	D 1068	3500-Fe
Fluoride	D 1179	4500-Fluoride
COD	D 1252, D 6697	5220
Residual chlorine	D 1253	4500-Cl
pH	D 1293	4500-pH value
Lithium, potassium, sodium	D 1428, D 3561	3500-Li, Na, K
Ammonia nitrogen	D 1426	45---NH_3
Particulate and dissolved matter	D 1888	2560
Turbidity	D 1889	2130
Total organic carbon (TOC)	D 2579, D 4129, D 4839, D 5904	5310
Arsenic	D 2972	3500-As
Boron	D 3082	4500-B
Strontium	D 3352	3500-Sr
Practices for sampling water	D 3370	1060
Nitrite - nitrate	D 3867	4500-Nitrogen
Silt density index	D 4189	—
Barium	D 4382	3500-Ba
Microbiological contaminants in water	F 60	—
Oxidation-reduction potential (ORP)	D 1498	2580
BOD	—	5210
AOC	—	9217

FILMTEC™ Membranes
For more information about FILMTEC membranes, call the Dow Liquid Separations business:
North America: 1-800-447-4369
Latin America: (+55) 11-5188-9222
Europe: (+32) 3-450-2240
Pacific (ex. China): +800-7776-7776
China: +10-800-600-0015
http://www.filmtec.com