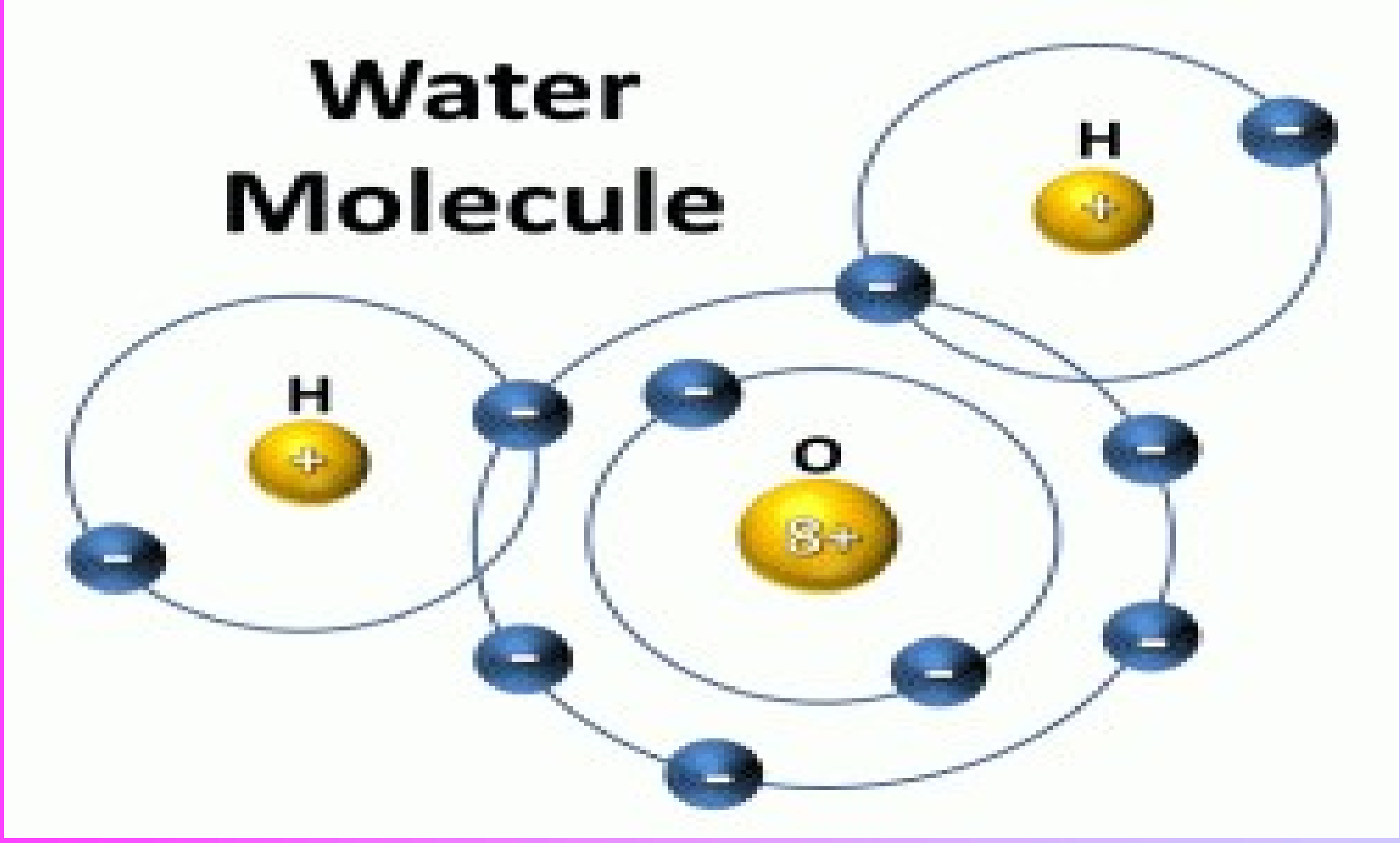
The important parameters in water chemistry

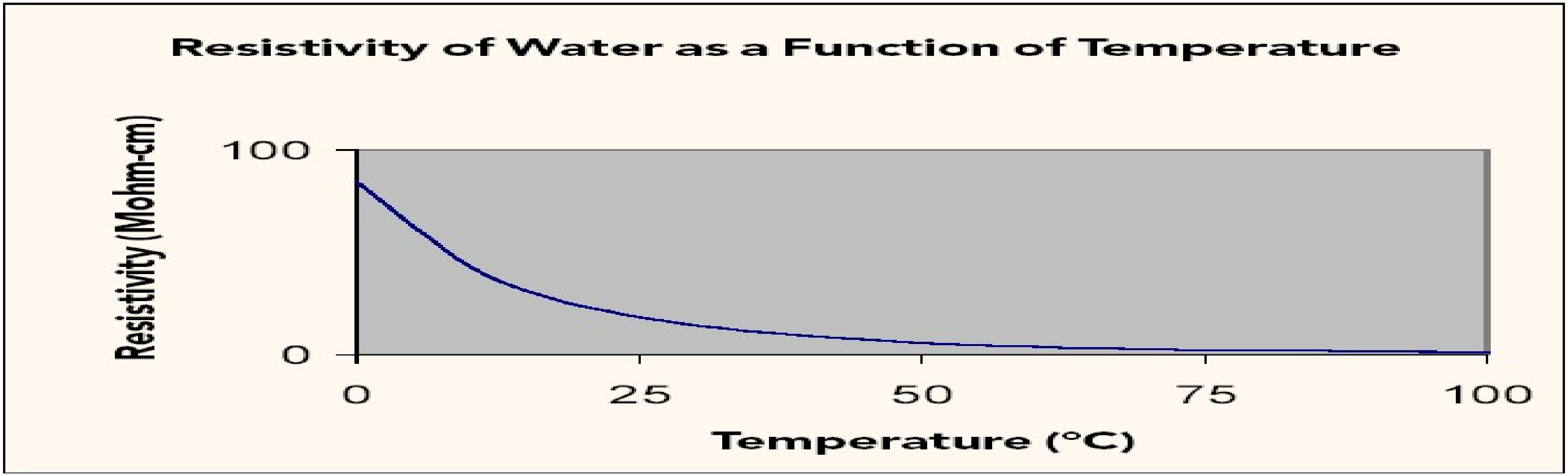
Water Molecule

- **O: 6 Electrons and Needs 2**
- **H: 1 Electron and Needs 1**
- **Bent Shape Due Electrical Repulsion → Polar Molecule**



Conductivity:

- Ability of a substance to transfer electrons.
- Solid: Copper wire: decreases as the temperature increases.
- Liquid: Increases as the temperature increase.
- (More Ions Mobility + More Water Dissociate)
- Liquid: Ions from • Impurities • water
- Different Ions → Different Conductivity



Conductivity Depends on:

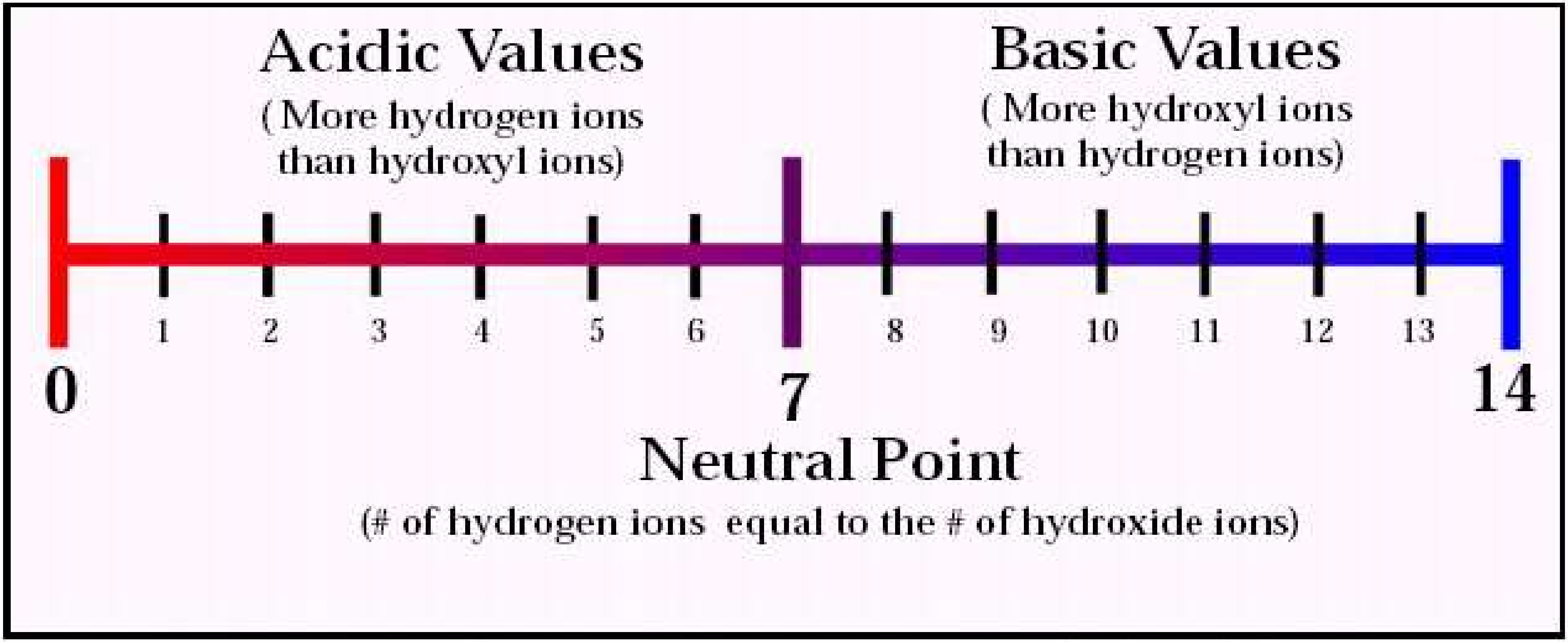
- a) Charge
- b) Quantity
- c) Mobility
- Dissolved in solution: no ions → no conductivity:
- Examples: O_2, Glycol, Sugar, Ethyl-alcohol, N_2, or H_2.

- 20 μS/cm (Ice melt water)
- 70,000 μS/cm seawater.

pH:

The pH unit measures the degree of acidity or basicity of a solution

- **Acidic: (H) > (OH)**
- **Caustic: (OH) > (H)**
- **Neutral pH=7**



pH

Every aqueous solution can be measured to determine its pH value.

This value ranges from 0 to 14 pH.

Values below 7 pH exhibit acidic properties & values above 7 pH exhibit basic properties.

Since 7 pH is the center of the measurement scale, it is neither acidic nor basic and is, therefore, called “neutral”.

Effect of pH on R.O. Performance

Lowering the feed water pH with acid results lower LSI (Langlier Saturation Index) value, which reduces the scaling potential of calcium carbonate.

Feed water and reject water pH can also affect the solubility and fouling potential of silica, aluminum, organics and oil.

Alkalinity

Alkalinity is comprised primarily of carbon dioxide, bicarbonate, carbonate and hydroxides.

Alkalinity is usually expressed as equivalent concentration of CaCO3.

Bicarbonate (HCO3)

A monovalent anion.

The solubility of calcium bicarbonate is low and cause a RO scaling problem in the back end of a RO.

Bicarbonate is one component of alkalinity.

Bicarbonate concentration is in balance with carbon dioxide between pH 4.4-8.2 and is in balance with carbonate between pH 8.2-9.6

Bicarbonate (HCO3)

Calcium bicarbonate solubility is measured using LSI for brackish water or the Stiff-Davis Index for sea waters.

Calcium bicarbonate solubility lowers with increasing temperature and increasing pH.

Carbonate (CO3)

A divalent anion.

The solubility of calcium carbonate is low and cause a RO scaling problem in the back end of a RO.

Carbonate is one component of alkalinity.

Carbonate concentration is in balance with bicarbonate between the pH 8.2-9.6.

At a pH of 9.6 and higher there is no carbon dioxide or bicarbonate, with all the alkalinity being in the carbonate form.

Carbonate (CO_3)

Calcium carbonate solubility is measured using LSI for brackish water or the Stiff-Davis Index for sea waters.

Calcium carbonate solubility lowers with increasing temperature and increasing pH.

Carbon Dioxide (CO_2)

Carbon Dioxide is a gas.

When dissolved in water reacts with the water to form weak carbonic acid.

$$H_2O + CO_2 = H_2CO_3$$

Water **Carbon Dioxide** **Carbonic Acid**

If pure water is completely saturated with Carbon Dioxide, its concentration would be about 1600 ppm and the pH would be about 4.0.

Carbon Dioxide (CO2)

Carbon dioxide being a gas, is not rejected or concentrated by RO membranes, there fore its concentration will be the same in feed, concentrate and product water.

Conductivity

Conductivity is the measurement of the ability of water to transmit electricity due to the presence of dissolve ions.

This ability depends on the presence of ions, their total concentration, mobility, valence, relative concentration, and temperature.

Conductivity

Solutions of most inorganic acids, bases and salts are relatively good conductors.

Molecules of organic compounds that do not dissociate in aqueous solutions have very poor conductivity.

Conductivity is measured by conductivity meter and is reported as micromhos/cm.

Total Dissolved Solids (TDS)

TDS, in water treatment, is the residue left after the filtration of colloidal and suspended solids and then the evaporation of known volume of water

TDS is reported as ppm or mg/lit.

Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) comprises of inorganic salts (principle calcium, magnesium, potassium, sodium, bicarbonate, chlorides, sulfate and nitrates) and some small amount of organic matter that are dissolved in water.

In general, the total dissolved solids concentration is then sum of the cations (positively charged) and anions (negatively charged) ions in the water.

Total Dissolved Solids (TDS)

Total dissolved solids test provides an qualitative measure of the amount of dissolved ions., but does not tell us the nature or ion relationships.

Total Dissolved Solids (TDS)

In addition TDS test does not provide us insight into the specific water quality issues, such as, Elevated Hardness, Salty Test, or Corrosive ness.

Following table can be used as generalization of the relationship of TDS to water quality problem.

Total Dissolved Solids (TDS)

Cations combined with Carbonates $CaCO_3$, $MgCO_3$ etc.	Associated with hardness, scale formation, bitter test.
Cations combined with chloride. NaCl, KCl, etc.	Salty or brackish test, increase corrosivity.

Cations

Cations are ions with positive valence state.

They are willing to accept electrons.

Anions

Anions are ions with negative valence state.

They have extra electrons to share.

Cations &Anions

The sharing of electrons between cations and anions creates electronuttrality.

Ca++ + 2Cl- = CaCl2

Divalent Cation of Calcium + two monovalent anions of chloride = One molecule of Calcium Chloride

Color

Color is a non specific test that measures the relative level of organic compounds in water, based on their contribution to adding color.

TURBIDITY

Definition

A measure of the degree to which light is scattered by suspended particulate material and soluble color compound in the water.

Turbidity is measured by a Nephelometer in Nephelometric Turbidity Units (NTU).

TURBIDITY

Turbidity provides an estimate of the muddiness or cloudiness in the water due to clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton, and microscopic organisms.

Typical RO membrane element warranties list a maximum of 1.0 NTU for feed water.

Visible turbidity is found at greater than 5 NTU.

The limit of turbidity in drinking water is 0.5-1.0 NTU.

Silt Density Index (SDI)

Suspended solids and colloidal material in feed water are one of the biggest problems in reverse osmosis system, in spite of having pretreatment systems including 5 micron pre-filters.

In order to have some measure of the degree of fouling by suspended solids and colloidal matter, a concept called "Silt Density Index" is used.

Hear a 0.45 micron filter is exposed to the feed water under pressure and filtration rates are calculated.

Silt Density Index (SDI)

An SDI of less than 5 is considered acceptable for the reverse osmosis system.

There are exceptions when lower SDI (less than 3) is desirable due to nature of the suspended solids in the feed water.

At this SDI membrane should foul at a very low rate.

Silt Density Index (SDI)

SDI of < 3.0 : No pre-filtration is necessary.

SDI of 3-6 : A media (sand type) filter is required.

SDI of > 6.0 : A two stage media filtration is necessary, possibly with the aid of coagulants or settling tanks.

Is SDI same as Turbidity?

They are not the same and there is no direct correlation between the two.

However the membrane show very little fouling @ feed water turbidity < 1.0 NTU.

&

Correspondingly the membrane shows very low fouling at a feed SDI of < 5.0.

SDI & Turbidity

SDI	Turbidity
SDI is a measurement of the fouling potential of suspended solids.	Turbidity is a measurement of the amount of suspended solids.

Total Organic Carbon (TOC)

Total Organic Carbon is a non specific test that measures amount of carbon bound in organic material and is reported in units of "ppm as carbon".

The alert level for potential organic fouling in natural water sources for TOC is 3.0 ppm.

Biological Oxygen Demand (BOD)

BOD is a non specific test that measures the quantity of “biologically-degradable” organic matter and is reported as “ppm as oxygen”.

The alert level for potential organic fouling in natural water sources for BOD is 5.0 ppm.

Biological Oxygen Demand (BOD)

BOD test measures the quantity of oxygen depletion resulting from the ability of common bacteria to digest organic matter during 5 day incubation period at 20 deg C.

Chemical Oxygen Demand (COD)

COD is a non specific test that measures the quantity of both "bio-degradable and non-biodegradable" organic matter and is reported as "ppm as oxygen".

The alert level for potential organic fouling in natural water sources for COD is 8.0 ppm.

Hydrogen Sulfide (H2S)

Hydrogen sulfide is a gas that causes noticeable "rotten egg" smell in feed waters.

It is readily oxidized to elemental sulfur by oxidants like chlorine.

Sulfur acts as a colloidal foulant and is not easily removed by conventional multimedia filtration.

The preferred RO system design suggests leaving the hydrogen sulfide in gaseous form, let it pass through the membranes in to the permeate, and then treat the permeate for its removal.

TEMPERATURE

Temperature is one of the most important parameter as far as performance of a Reverse Osmosis system is concern.

Feed temperature has significant effect on:

Feed pump required pressure.

Permeate flow.

As a rough rule of thumb, every 10-degree Fahrenheit decrease in feed temperature increases the feed pump pressure requirements by 15%.

TEMPERATURE

Feed temperature has significant effect on:

The amount of permeate produced by each stage(Hydraulic Flux balance).

When feed water temperature increases the element located at front end of the system produce more permeate which results in reduced permeate flow by the elements located at the rear end of the system.

TEMPERATURE

Feed temperature has significant effect on:

Salt Passage:

At warmer temperatures, salt passage increases due to the increased mobility of the ions through the membranes.

Solubility of inorganic salts:

Warmer temperature decreases the solubility of calcium carbonate.

Colder temperature decreases the solubility of calcium sulfate, barium sulfate, strontium sulfate, and silica.

Calcium (Ca)

A divalent cation.

Calcium is a major component of hardness in brackish water.

The solubility of calcium sulfate (CaSO4) is typically limited to 230% with the use of antiscalant.

The solubility of calcium carbonate is limited to LSI value of 1.8 to 2.6.

Magnesium (Mg)

A divalent cation.

Magnesium can account for about third of the hardness in a brackish water.

However the solubility of magnesium salts is high and does not cause a scaling problem in RO system.

Sodium (Na)

A monovalent cation.

The solubility of sodium salts is high and does not cause a RO scaling problem.

Sodium is the cation used to automatically balance a RO feed water analysis.

Potassium (K)

A monovalent cation.

It is typically found at much lower concentration than sodium.

The solubility of sodium salts is high and does not cause a RO scaling problem.

Barium (Ba)

A divalent cation.

Solubility of barium sulfate ($BaSO_4$) is low and causes problem in backend of RO.

Barium sulfate solubility is lower with increasing sulfate levels and decreasing temperatures.

Strontium (Sr)

A divalent cation.

Solubility of strontium sulfate ($SrSO_4$) is low and causes problem in backend of RO.

Strontium sulfate solubility is lower with increasing sulfate levels and decreasing temperatures.

Iron (Fe)

Iron is one of the most dangerous foulants for the Reverse Osmosis Membranes. Iron as a water contaminant exists in two major forms.

Water soluble form	Water insoluble form
Ferrous state (Fe^{++})	Ferric State (Fe^{+++})
With aeration can be converted in to Fe^{+++}	Colloidal in nature.
Most probably will foul rear end of the RO system.	Will foul the front end of the RO system.
Can be removed by, iron filters, Softeners, lime softening.	Can be removed by, iron filters, and removed with limits by, Softeners, lime softening, ultrafiltration,

Iron (Fe)

Iron as foulant will quickly increase RO feed pressure requirements and increase permeate TDS.

In some cases iron reducing bacteria can create a biofouling due to formation of a slimy biofilm that can plug the RO feed path.

A Combined (Soluble and insoluble) iron level of 0.05 mg/lit is recommended for RO feed water.

Manganese (Mn)

Present in both well and surface waters, with levels up to 3.0 ppm.

An alert level for potential manganese fouling in RO feed water is 0.05 ppm.

Aluminum (Al)

Not found in any significant concentrations in well or surface waters.

Aluminum, when present in an RO feed water is typically colloidal in nature.

Carryover from pretreatment.

Alert level in RO feed water 0.1 – 1.0 ppm.

Least soluble in pH range of 5.5-7.5

Ammonium (NH_4)

A monovalent Cation.

Ammonium salts are very soluble and do not cause a RO scaling problem.

Chloride (Cl)

A monovalent anion.

Solubility of chloride is high and does not create a RO scaling problem.

The recommended upper limit for chloride in potable water by WHO is 250 ppm based on test issues.

Sulfate (SO4)

A divalent anion.

The solubility of calcium, barium and strontium sulfate is low and can cause a RO scaling problem in the back end of the RO.

Sulfate (SO_4)

Solubility of $CaSO_4$, $BaSO_4$ & $SrSO_4$ is lower with decreasing temperature.

The recommended upper limit for sulfate in potable water is 250 ppm based on test issues.

Nitrate (NO3)

A monovalent anion.

Nitrate salts are highly soluble and does not create a RO scaling problem.

The recommended upper limit for nitrate in potable water is 44.3 ppm as nitrate or 10.0 ppm as nitrogen.

Fluoride (F)

A monovalent anion.

The rejection of fluoride by a RO membrane is pH dependent.

In basic pH range fluoride is in salt form hence the rejection is > 99%

In acidic pH range fluoride being in acid form rejection drops below 50%.

Silica (SiO_2)

Silica is one of the most difficult to handle inorganics in the reverse osmosis process.

Silica in water supplies is present in three different forms.

- **Reactive**
- **Unreactive (Colloidal)**
- **Suspended Particles**

Reactive silica is the form of silica to be used in RO projection programs.

Silica solubility increases with increasing pH

pH	Mg/lit SiO2 @ 25 deg C
6.0 – 8.0	120
9.0	138
9.5	180
10.0	310.0
10.6	876.0

Reactive silica solubility increases with increasing temperature and decreases in the presence of iron.