Waughter

AKTION CONSULTANCY

Volume 1 : Edition 7 – Desalting-RO & Fouling With Special pre-treatment *July 31, 2021*

Dear Water Warriors,

The HCl & NaOH too beautiful chemicals as they look have the Safety issues associated with them and were always a concern in De-mineralization to produce low conductivity water for Boiler feed. Reverse of Osmosis, provided first time a cost-effective alternative to remove majority of TDS from water, thus limiting use of regenerants to polishing steps (Mixed bed).

With time, Electro Deionization shall completely eliminate chemicals.

'**Waughter**', is the name for recycled waste water and I am happy to welcome International Desalination Expert Mr Kourosh Mokhtri as our guest Editor.

Nidhi Jain
Editor Waughter

Mr Kourosh Mokhtri has a degree in mechanical engineering (2001) and a post-Degree certificate in MBA (2009). He has over 16 years' experience in desalination industry, both at technical designer and management level. His main area of expertise is SWRO, BWRO, pre-treatment, post treatment, membrane cleaning (CIP) and pump station designing.

In 2001, he joined to National Iranian Gas company (petroleum ministry) and gained a lot of experience in operating and maintenance of gas turbines. In 2004, he joined to Noor Vizhe Company.

He played an active role in the design, installation and commissioning of all NVCO desalination projects. Since 2008, as a designer for various Iranian and foreign companies, he has designed more than 100 RO units in different capacities.

He has also served as a consultant on dozens of projects aimed at RO troubleshooting, system modification and plant re-engineering.

Nano filtration element or Brackish RO Membrane?

Contrary to popular belief, Nano-membranes are not based on nanotechnology and it does not have higher technology than RO.

Nano-membrane is the same as RO membranes with larger pores, Ro membrane pores are about 1 angstrom, Hence the relation between a Nano meter and an angstrom is that one Nano meter is equal to ten times of an angstrom as a result, more salts pass through the Nano filter than RO membranes.

In desalination units, especially in waters where the major elements are composed of nitrate, Sulphate, calcium, magnesium, silicate, and sodium chloride have a lower share, the use of Nano filters is more economical.

RO membranes are more available than Nano-filters, and Nano-filters are not as easy to obtain as RO membranes in the market, but the use of Nano-filters has advantages over RO membranes, which justifies the difficulty of providing them. The use of Nano filters for brackish waters (surface water), whose main constituents (soluble elements) are polyvalent salts, is a better option than RO membranes.

To prove this claim, for the treatment of a water sample with the following specifications, we design two desalination plants by using RO membranes and Nano filtration elements and compare the results with each other.

Cations

Symbol	mg/L	ppm $CaCO_3$	meq/L
NH_4	0.000	0.000	0.000
K	10.000	12.799	0.256
Na	25.000	54.419	1.087
Mg	120.000	494.156	9.875
Ca	100.000	249.731	4.990
Sr	0.000	0.000	0.000
Ba	0.000	0.000	0.000
Total Cations:	**255.000**		**16.208**

Anions

Symbol	mg/L	ppm $CaCO_3$	meq/L
CO_3	0.150	0.250	0.005
HCO_3	120.942	99.191	1.982
NO_3	30.000	24.213	0.484
Cl	70.000	98.809	1.974
F	0.000	0.000	0.000
SO_4	564.978	588.642	11.763
Br	0.000	0.000	0.000
PO_4	0.000	0.000	0.000
Total Anions:	**786.070**		**16.208**

Estimated Conductivity: 1,741.40 µS/cm

Sample Water Specification

As you can see in the picture, the main elements of the sample are sulphate, calcium, and magnesium, and monovalent elements such as sodium and chloride are very low.

The results of designing two desalination units with a capacity of 2400 m^3/d with two types of Nano filtration element and RO membranes are as follows:

As you can see in Figure 1, by selecting RO membranes, and based on 70% recovery, a high-pressure pump with a minimum pressure of 11.2 bar is required, which, considering temperature decreasing in cold seasons, should be at least 20 % more.

A suitable high-pressure pump with the following specifications is required:

Flow: 150 m^3/h (approximately) Head: 14 bar (140 m) (at least)

Electricity consumption will average 0.55 kW/h.m^3 of permeate

High-pressure pipe, fittings, and valves must be stainless steel (due to corrosion problems and pressure resistance0)

Now, if we use nano membranes to desalinate this sample, the results of Figure will be obtained.

#	Description	Flow (m^3/h)	TDS (mg/L)	Pressure (bar)
1	Raw Feed to RO System	142.9	1,041	0.0
2	Net Feed to Pass 1	142.8	1,042	11.2
4	Total Concentrate from Pass 1	42.9	3,448	7.0
6	Net Product from RO System	100.0	9.18	0.0

RO Flow Table (Stage Level) - Pass 1

Stage	Elements	#PV	#Els per PV	Feed: Feed Flow (m^3/h)	Feed: Recirc Flow (m^3/h)	Feed: Feed Press (bar)	Feed: Boost Press (bar)	Concentrate: Conc Flow (m^3/h)	Concentrate: Conc Press (bar)	Concentrate: Press Drop (bar)	Permeate: Perm Flow (m^3/h)	Permeate: Avg Flux (LMH)	Permeate: Perm Press (bar)	Permeate: Perm TDS (mg/L)
1	BW30-400	12	6	142.8	0.00	10.8	0.0	70.2	9.1	1.8	72.6	27.1	0.0	6.97
2	BW30-400	6	6	70.2	0.0	8.9	0.0	42.9	7.0	1.9	27.4	20.5	0.0	15.10

Average NDP	(bar)	8.4
Specific Energy	(kWh/m^3)	0.55

BW30 - 400

As you can see in the picture, the working pressure is 4.6 bar and in the worst case, considering the decrease in temperature, it will be less than 6 bars.

This means for this unit, a pump with a 150 m^3 flow (similar to RO membrane) and a maximum pressure of 6 bars (60 m) will suffice.

Electricity consumption per m^3 of permeate will be 0.23 kW (approximately 40% of RO membrane)

Due to the low working pressure, PVC pipes, fittings, and valves can be used, which are both cheaper than stainless steel and easier to install, repair and maintenance.

Of course, permeate TDS with Nano-filtration will be close to 50 mg / l, but for RO membranes, less than 10 ppm.

And if very high purity of permeate is not required (for some industrial uses very low purity water is required) a Nano filter is a more suitable option for desalination of the evaluated water sample.

In addition to reducing the cost of construction (pump, pipe, and fittings), during one year of operation, 481,800 kWh of electricity will be consumed for RO membranes and 201,480 kWh for nan- membranes.

And with an average cost of 13.2 cents of US dollar per kilowatt-hour, using a Nano-membrane would save 37,000 $ annually in electricity costs.

So, let's not forget that choosing RO membranes is not necessarily the best choice for any type of brackish water.

Accurate analysis of water-soluble elements, and consultation with a person specializing in desalination unit design, can significantly reduce operating costs.

Mr Kourosh Mokhtri
Guest Chief Editor – Waughter Vol 1 Edi 7

Back to Basics... in Reverse Osmosis?

Recall from Waughter Volume 1 Edition 1.

Look at the table below:

Molecule	Molecular Weight	Size
H_2O	18	~ 2.75 ANGSTROM
Na	23	Ionic Radius 154 pm
Na^+	23	Ionic Radius 102 pm
F^-	35.5	Ionic Radius 133 pm

pm IS peta meter 1 x 10^{-15}

Wonder why the water is filleted across a composite polyamide membrane RO membrane with distributed pore size in the range of 3 – 10 Å, but Na^+ or F^- which is at-least 1000 times smaller in size cannot?

The answer lies in understanding hydration.

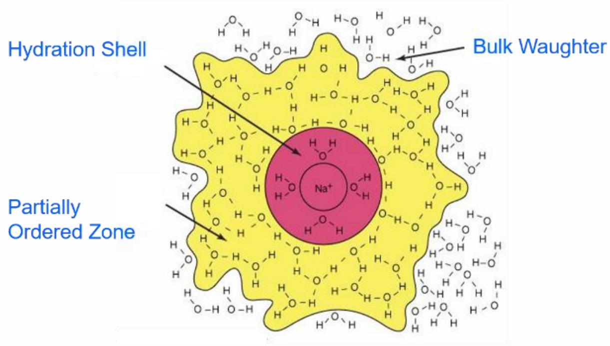

Image 1.3 : Hydration of Na^+ in H2O

The ions that are hydrated cannot move alone; they must take the hydration shell fully as well as little bit of partially ordered zone when they move.

Furthermore, a single Na^+ can not pass alone even if opportunity exists, as we cannot have *Charge* transferring across membrane. Counter charge e.g. Cl^- shall also have the mood to go with Na^+, this is very improbable and thus bulk of NaCl is rejected across RO membrane.

So, refresh Salt, Solvent, Solution, Diffusion, Surface Tension, Hydrogen Bonding, Hydration, Intermolecular space, Gravity Filtration, etc. and enjoy this issue.

Driving water sustainability with advanced UF products.

Customers around the globe depend on the ZeeWeed* 1500 PVDF ultrafiltration membrane for their drinking water treatment, wastewater tertiary filtration, pre-treatment for brackish and seawater desalination.

9000+ MLD
installed capacity.

PROVEN PERFORMANCE

Decades of research and operational experience.From packaged plants offering quick delivery and rapid installation, to custom solutions engineered to strict specifications.

PROVEN RESULTS

Turbidity	< 0.1 NTU[1]
Bacteria	> 4-log removal
Giardia	> 4-log removal
Cryptosporidium	> 4-log removal
Iron	< 0.05 mg/L[2]
Manganese	< 0.02 mg/L[2]
TSS	< 1 mg/L
TOC	50 - 90% removal [2,3]
Arsenic	< 5 µg/L[2]
Color	< 5 PCU [2,3]

1. 95% of the time
2. Pre-treatment required
3. Removal dependent on raw water quality

PROVEN ADVANTAGE

Simple, automated, easy to operate and requires less frequent and less aggressive cleaning. It also has high solid tolerance and demonstrated performance on a variety of water sources.

PURE WATER

suez

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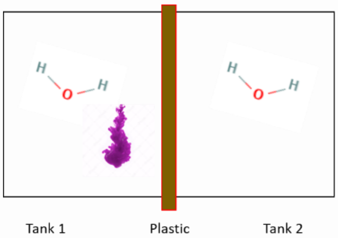
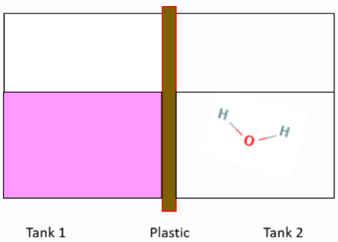
Imagine 2 tanks separated by a <u>Plastic sheet</u> in between that are filled with water as shown below:

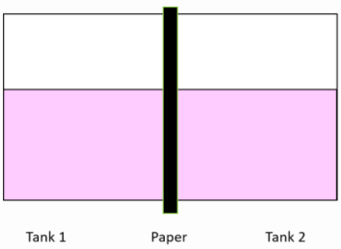


If we spread ink or salt as shown, it will diffuse in inter molecular space of H_2O. Remember, H_2O is not moving, it's the salt that moves. After some time, the salt will be well spread in $Tank_1$. <u>Why salt did not go to $Tank_2$?</u>



If your answer is small pore size, you are partially right. The right answer is Plastic is hydrophobic and does not produce capillary action, that can suck the water. Hence neither water nor salt will pass to $Tank_2$.

Next figure explains, if we replace paper with plastic, salt and water are now free to move.

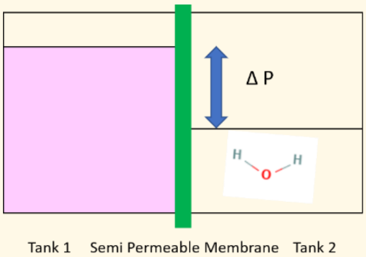


And the Salt will spread in $Tank_2$ as water would be sucked due to capillary action while salt shall diffuse through the thickness of paper and reach $Tank_2$.

If we replace paper with a Semi permeable material, the pore size defined in a way that allows water molecule to pass but <u>Hydration Cell plus salt</u> not to pass, the system is uncomfortable.

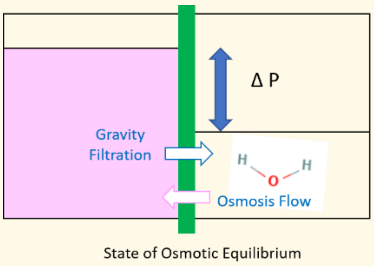
H_2O is willing to fill it's Inter Molecular Space with salt but salt can not move. This is the first opportunity where water changes it's nature and starts travelling towards salt from pure water side ($Tank_2$ to $Tank_1$).

This flow of water is Osmosis Flow.

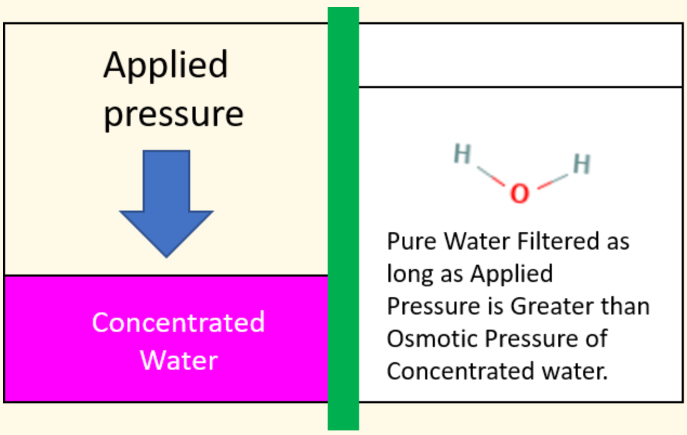


The next picture explains the state of osmotic Equilibrium where Osmosis flow = Gravity Flow,

the natural flow of water from higher Altitude to low altitude under the influence of gravity.



If we mechanically assist Gravity Flow by pushing-pumping water to $Tank_1$ (Applied Pressure), we can achieve Higher Flow (Gravity Filtration) <u>*over and above the potential Osmosis flow*</u>, resulting in net flow of pure water from concentrated side to lean water side. And the world know this as "Reverse Osmosis". See Below:



Reverse Osmosis

Once you understand this page very well, read *Suck Back Tank* need in SWRO designs. Hint.. Osmosis Flow

Factor Affecting Reverse Osmosis

Pressure

With increasing effective feed pressure, the permeate TDS will decrease while the permeate flux will increase.

Temperature

If the temperature increases and all other parameters are kept constant, the permeate flux and the salt passage will increase due to higher diffusion of water and salt through membrane.

Recovery

Recovery is the ratio of permeate flow to feed flow. In the case of increasing recovery, the permeate flux will decrease and stop if the salt concentration reaches a value where the osmotic pressure of the concentrate is as high as the applied feed pressure. The salt rejection will drop with increasing recovery.

Feed water Salt Concentration

Increase in feed water salt concentration will decrease the permeate flux. The ideal reverse osmosis membrane has a very high-water permeability and a zero-salt permeability. As a general rule, membranes with a high-water permeability (low feed pressure) also have a higher salt permeability compared to membranes with lower water permeability.

The permeability of solutes decreases (the rejection increases) with an increase in the Degree of dissociation weak acids, for example lactic acid, are rejected much better at higher pH when the dissociation is high
Ionic charge e.g. divalent ions are better rejected than monovalent ions.

Molecular weight

Higher molecular weight species are better rejected.

Non-polarity

Less polar substances are rejected better.

Degree of hydration

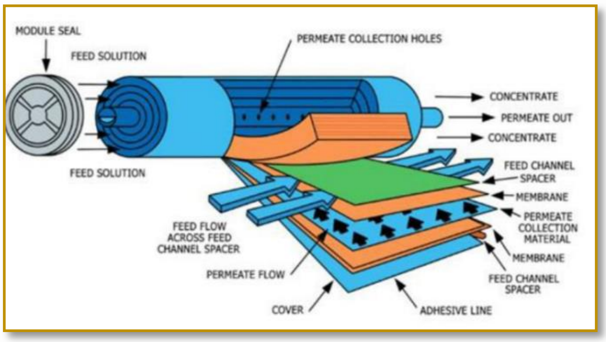
highly hydrated species, e.g. chloride, are better rejected than less hydrated ones, e.g. nitrate.

Degree of molecular branching

e.g. iso-propanol is better rejected than n-propanol.

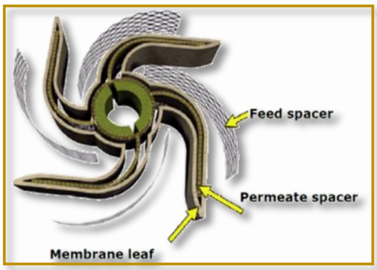
RO Membrane design

RO membranes are thin film composite membranes packed in a spiral wound configuration. Spiral wound designs offer many advantages compared to other module designs, such as tubular, plate and frame and hollow fiber module design like membrane area, smallest footprint, robust design which prevents membrane breakage and has relatively low capital and operating costs.



Spiral-wound elements consist of membranes, feed spacers, permeate spacers, and a permeate tube. First, a membrane is laid out and folded in half with the membrane facing inward. The feed spacer is placed between the folded membranes, forming a membrane sandwich. The purpose of the feed spacer is to provide space for water to flow between the membrane surfaces, and to allow for uniform flow between the membrane leaves.

Next, the permeate spacer is attached to the permeate tube, and the membrane sandwich prepared earlier is attached to the permeate spacer using glue.

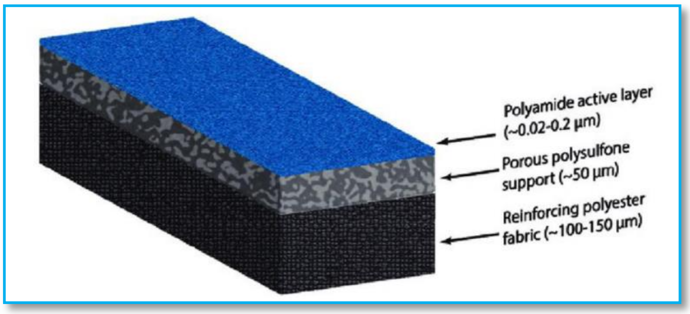


The next permeate layer is laid down and sealed with glue, and the whole process is repeated until all of the required permeate spacers have been attached to the membranes.

The finished membrane layers then are wrapped around the tube creating the spiral shape.

Cont…

Thin film composite membrane consists of 3 layers: Polyester support web, microporous polysulfone interlayer and an ultrathin polyamide barrier layer on top surface.



Feed water limiting conditions

The quality of feed water is defined in terms of concentration of suspended particles and saturation levels of sparingly soluble salts. The common indicators of suspended particles used in the RO industry are turbidity and Silt Density Index.

The maximum limits are: Turbidity of 1 NTU and SDI of 4. Indicators of saturation levels of sparingly soluble salts in the concentrate stream are the Langelier Saturation Index (LSI).

Negative values show that the water is aggressive and it will have a tendency to dissolve calcium carbonate. Positive value shows that calcium carbonate will precipitate.

The membrane shows some resistance to short-term attack by chlorine (hypochlorite). The free chlorine tolerance of the membrane is < 0.1 ppm. Continuous exposure, however, may damage the membrane and should be avoided.

Under certain conditions, the presence of free chlorine and other oxidizing agents will cause premature membrane failure.

Since oxidation damage is not covered under warranty, it is recommended to remove residual free chlorine by pre-treatment prior to membrane exposure. Refer below Table 1.

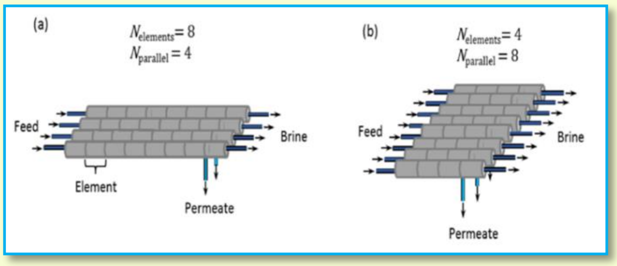
Table 1: Recommended water quality

#	Parameter	RO feed	After RO	PW	WFI
1	Hardness (PPM CaCO3)	≤ feed water	< 1	< 1	< 1
2	TOC (ppb)	≤ feed water	< 500	< 500 (online)	< 500 (online)
3	Endotoxin (EU/ml)	NA	NA	NA	< 0,25
4	Microbial total count (cfu/ml)	< 500	< 200	< 100	< 10 cfu/100 ml
5	Free Chlorine (ppm)	< 0,05	< 0,05	< 0,05	< 0,05
6	Pseudomonas (cfu/100 ml)	< 1	< 1	< 1	< 1
7	E. coli (cfu/100 ml)	< 1	< 1	< 1	< 1
8	Total coliforms, Fungus, (cfu/100 ml)	< 1	< 1	< 1	< 1
9	Conductivity (μS/cm)	Like feed water	< 10	< 1,3 (online)	< 1,3 (online)

Conductivity shall be measured uncompensated at 25 °C according to USP.

Reverse Osmosis

A module consists of a pressure vessel with up to eight membrane elements, which are connected in series. The concentrate of the first element becomes the feed to the second, and so on. The product tubes of all elements are coupled and connected to the module permeate port. The permeate port may be located on the feed end or on the concentrate end of the module.



Feed water enters the system through the feed valve and flows through the cartridge filter to the high-pressure pump.

From the high-pressure pump, the feed water flows to the feed inlet connection of the module. The product stream should leave the module at no more than 5 psi (0.3 bar) over atmospheric pressure.

However, higher permeate pressure is sometimes required, e.g., to feed the post-treatment section or to distribute the product without further pumping.

Then the feed pressure must be increased by the required value of the permeate pressure, but the specified maximum feed pressure must be observed.

The concentrate leaves the concentrate outlet connection at essentially the feed pressure.

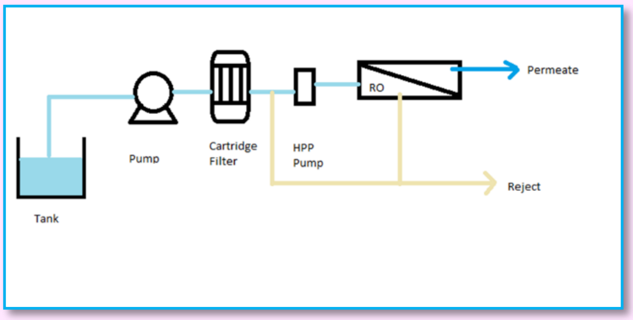
Cont…

Pressure drop will usually amount to 5–30 psi (0.3–2 bar) from feed inlet to concentrate outlet, depending on the number of membrane elements, the feed flow velocity and the temperature.

The concentrate flow rate is controlled by the concentrate flow control valve. In single-module systems, concentrate recycling is usually required to comply with the guidelines for element recovery.

To achieve system recovery of more than 50%, a part of the concentrate leaving the module goes to drain, while the other part is recycled and added to the suction side of the high-pressure pump, thus increasing the feed flow to the module. A high fraction of the concentrate being recycled helps reduce element recovery and thus the risk of fouling.

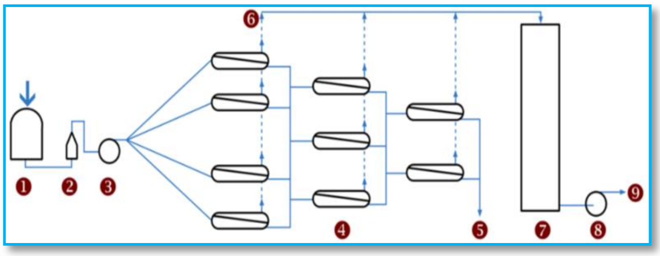
Single-stage RO



In a single-stage system, two or more modules are arranged in parallel. Feed, product and concentrate lines are connected to manifolds. Other aspects of the system are the same as in a single-module system. Single-stage systems are typically used where the system recovery is less than 50%, e.g., in seawater desalination.

Multi-stage RO

Systems with more than one stage are used for higher system recoveries without exceeding the single element recovery limits. Usually two stages will suffice for recovery up to 75%, and three must be used for higher recovery. To compensate for the permeate that is removed and to maintain a uniform feed flow to each stage, the number of pressure vessels per stage decreases in the direction of feed flow.



Steps to design RO system:

Step 1: Consider feed source, feed quality, feed/product flow, and required product quality
Step 2: Select the flow configuration and number of passes
Step 3: Select membrane element type
Step 4: Select average membrane flux
Step 5: Calculate the number of elements needed
Step 6: Calculate number of pressure vessels needed
Step 7: Select number of stages
Step 8: Select the staging ratio
Step 9: Balance the permeate flow rate
Step 10: Analyse and optimize the membrane system

System Components:

1. High Pressure Pump
2. Pressure Vessel (RO skids)
3. Shutdown switches
4. Valves
5. Control instruments
6. Tanks (Permeate, feed, CIP, dosing)

Pretreatment before RO

To increase the efficiency and life of reverse osmosis systems, effective pretreatment of the feed water is required. Selection of the proper pretreatment will maximize efficiency and membrane life by minimizing:

- Fouling
- Scaling
- Membrane degradation

Fouling is the accumulation of foreign materials that may be present in the feed water on the active membrane surface and/or on the feed spacer to such a level that it is causing operational problems.

Cont..

Examples of such salts are calcium carbonate, barium sulfate, calcium sulfate, strontium sulfate, and calcium fluoride.

The type and extent of a pretreatment system will depend to a large extent on feed water source (i.e., well water, surface water, and municipal wastewater). In general, well water is a consistent feed source that has a low fouling potential. Well water typically requires a very simple pretreatment scheme such as acidification and/or antiscalant dosing and a 5-µm cartridge filter.

Pretreatment for surface water (microbiological & colloidal) is more elaborate than pretreatment for well water. Depending on the raw water quality, the pretreatment process may consist of the following steps:

- Removal of particles using coarse strainer
- Disinfecting water with chlorine, UV or ozone
- Clarification with or without flocculation
- Hardness removal using lime treatment
- Media Filtration
- Addition of scale inhibitor
- Reduction of alkalinity by pH adjustment
- Reduction of free chlorine
- Final removal of suspended particles using cartridge filter

Industrial and municipal wastewaters have a wide variety of organic and inorganic constituents. Some types of organic components may adversely affect RO/NF membranes, inducing severe flow loss and/or membrane degradation (organic fouling). Thus, a well-designed pretreatment scheme is imperative.

Scaling in RO

Scaling of RO/NF membranes may occur when sparingly soluble salts are concentrated within the element beyond their solubility limit.

For example, if a reverse osmosis plant is operated at 50% recovery, the concentration in the concentrate stream will be almost double the concentration in the feed stream. As the recovery of a plant is increased, so is the risk of scaling.

The following design practices can be used to prevent scaling of a membrane.

1. Acid addition
2. Scale inhibitor addition (up to LSI +2.4)
3. Softening with a SAC Resin
4. DE alkalization with WAC Resin
5. Lime Softening
6. Preventive cleaning

Silica Scale Prevention

Dissolved silica (SiO_2) is naturally present in most feed waters in the range of 1–100 mg/l. The prevailing forms of silica are meta silicic acids as $(H_2SiO_3)n$ with low n numbers.

Since silicic acid is a weak acid, it is mostly in the undissociated form at or below a neutral pH.

Supersaturated silicic acid can further polymerize to form insoluble colloidal silica or silica gel, which can cause membrane scaling. The maximum allowable SiO_2 concentration in the concentrate stream is based on the solubility of SiO_2.

As the pH exceeds neutral, silicic acid dissociates into the silicate anion $(SiO_3^{--})n$. This can react with calcium, magnesium, iron, manganese or aluminum to form insoluble silicates.

Scale inhibitors such as high molecular weight polyacrylates can also be used to increase the solubility of silica (upto 300 mg/l in Brine/Reject).

Cont..

Colloid Fouling Potential

Colloidal fouling of RO elements can seriously impair performance by lowering productivity and sometimes salt rejection.

An early sign of colloidal fouling is often an increased pressure differential across the system.

The source of silt or colloids in reverse osmosis feed waters often includes bacteria, clay, colloidal silica, and iron corrosion products.

Pretreatment chemicals used in a clarifier such as aluminum sulfate, ferric chloride, or cationic polyelectrolytes are materials that can be used to combine these fine particle size colloids resulting in an agglomeration or large particles that then can be removed more easily by either media or cartridge filtration.

Such agglomeration, consequently, can reduce the performance criteria of media filtration or the pore size of cartridge filtration where these colloids are present in the feed water.

It is important, however, that these pretreatment chemicals become incorporated into the agglomerates themselves since they could also become a source of fouling if not removed.

In addition, cationic polymers may coprecipitate with negatively charged antiscalants and foul the membrane.

Several methods or indices have been proposed to predict a colloidal fouling potential of feed waters, including turbidity, Silt Density Index (SDI) and Modified Fouling Index (MFI).

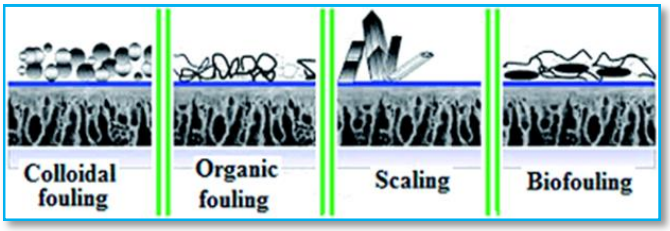
Methods to prevent colloidal fouling are:
1. Media filtration
2. Oxidation Filtration
3. In-line Filtration
4. Coagulation/Flocculation
5. Microfiltration/Ultrafiltration
6. Cartridge Filtration
7. Lime Softening

Biological Fouling:

All raw waters contain microorganisms such as bacteria, algae, fungi, viruses, and higher organisms. The typical size of bacteria is about 1 µm.

Microorganisms can be regarded as colloidal matter and removed during pretreatment as discussed in colloidal fouling. The difference between microorganisms and non-living particles, however, is the ability of microorganisms to reproduce and form a biofilm under favorable conditions.

Methods to prevent colloidal fouling are:
1. Chlorination
2. Microfiltration/Ultrafiltration
3. Ozonation
4. UV Radiation
5. Biofiltration
6. Copper Sulfate



The feed must be dechlorinated to prevent oxidation of the membrane, so dosing of SMBS is to be done. Under alkaline pH conditions, chlorine attack is faster than at neutral or acidic pH. The absence of chlorine should be monitored using an oxidation-reduction potential (ORP) electrode downstream of the mixing line.

Organic Fouling:

Adsorption of organic substances on the membrane surface causes flux loss, which is irreversible in serious cases. The adsorption process is favored with high molecular mass compounds when these compounds are hydrophobic or positively charged. A high pH value helps to prevent fouling, because both the membrane and many organic substances assume a negative charge at pH > 9. Organics present as an emulsion may form an organic film on the membrane surface, and must therefore be removed in the pretreatment.

Cont..

Organics occurring in natural waters are usually humic substances in concentrations between 0.5 and 20 mg/l TOC.

Pretreatment should be considered when TOC exceeds 3 mg/l. Humic substances can be removed by a coagulation process with hydroxide flocs, by ultrafiltration, or adsorption on activated carbon.

Coagulation or activated carbon must also be applied when oils (hydrocarbons or silicone-based) and greases contaminate the RO feed water at levels above 0.1 mg/l.

These substances are readily adsorbed onto the membrane surface. They can be cleaned off, however, with alkaline cleaning agents if the flux has not declined by more than 15%.

What if H_2S is in your feed?

The presence of H_2S in feed water exposed to oxidants (e.g., oxygen in air, chlorine) can result in the precipitation of elemental sulfur or metallic sulfides.

The deposits clogs filter cartridges and coats the feedwater piping. Not only will these precipitated solids cause a higher than normal filter cartridge replacement but, because the particle size for metallic sulfides and colloidal sulfur is in the sub-micron range, a significant quantity of precipitants will pass through the typical 5 micron (µm) rated filter cartridge.

These suspended solids will accumulate in the feed/concentrate channel spacer of the RO or NF membrane elements, increasing the operating differential pressure. Further accumulation of sulfur and metallic sulfides on the membrane's surface will cause an increase in salt passage and a decrease in flux reducing the system efficiency.

Colloidal sulfur may be difficult to remove. A solution of sodium hydroxide (NaOH) with a chelating agent such as EDTA is an appropriate cleaner. H_2S gas passes through the membrane barrier layer and, under certain conditions, will precipitate as elemental sulfur in the membrane microporous polysulfone substrate, polyester supporting web and permeate channel spacer.

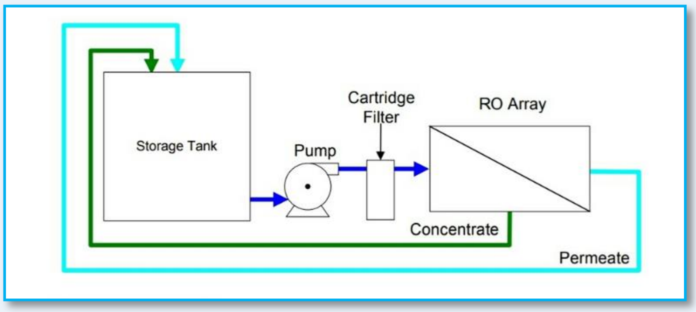
An ivory to yellowish precipitate is formed on the "backside" on the membrane composite when H_2S is exposed to an oxidizing environment, such as on shutdown where air enters the permeate side of the system.

Cleaning Requirements

Cleaning is the removal of foulants and scalants from the membrane element to restore membrane flux and rejection as far as possible elements should be cleaned whenever the normalized permeate flow drops by ≥10%, or the normalized salt passage increases by ≥10%, or the normalized differential pressure (feed pressure minus concentrate pressure) increases by ≥15% from the reference condition established during the first 48 h of operation.

Differential pressure (ΔP) should be measured and recorded across each stage of the array of pressure vessels. If the feed spacer within the element becomes plugged, the ΔP will increase.

It should be noted that the permeate flux will drop if feed water temperature decreases. This is normal and does not indicate membrane fouling.



Seven steps for cleaning membrane:

1. Make-up cleaning solution
2. Introduction of cleaning solution
3. Recycle
4. Soak
5. High-flow pumping
6. Flush out
7. Restart

Acids being low pH cleaners are used first to remove precipitated salts or mineral scale.

Cont..

Phosphoric acid is the least aggressive (not recommended for ceramic membranes). It also has its own detergent action because of the phosphate groups.

Nitric acid is very corrosive but effective. Citric acid is very effective for iron foulants. It combines acidity with detergent properties and chelating ability.

Sulphuric acid and hydrochloric acid are not recommended when there are stainless steel components.

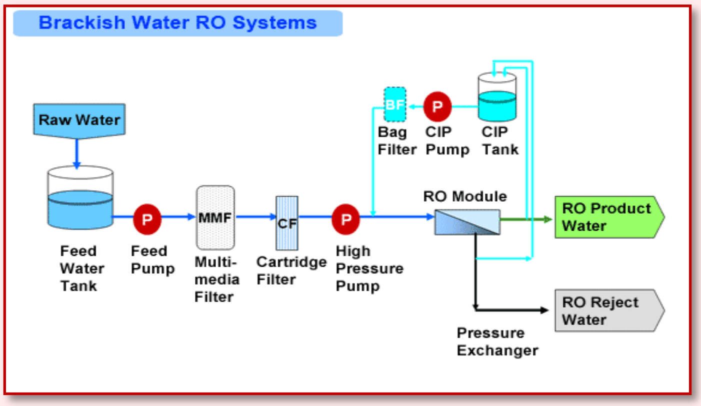
Alkalis being high pH cleaners are used for removing organics and proteins; they act by solubilizing them.

Polyphosphates are added to help solubilize carbonates and emulsify fats. Caustic solutions act by breaking the bonds between the membrane surface and the foulant.

Membrane Sanitization

Membrane systems are sanitized in order to keep the number of living microorganisms at an acceptably low level. There are two main reasons why sanitization is required: Smooth Operation & Permeate water quality. Hydrogen peroxide or a mixture of hydrogen peroxide and peracetic acid has been used successfully for treating biologically contaminated reverse osmosis

BWRO



Brackish water typically contains TDS in concentration ranging from 1000 mg/l to 10000 mg/l.

The normal way of operating brackish water RO and NF membrane plants is to keep the flows and thus the recovery constant at the design values.

Any change in the membrane flux, e.g. by temperature or fouling, are compensated by adjusting the feed pressure. However, the maximum specified feed pressure must not be exceeded, nor should too much fouling be tolerated.

The most common situation is that the permeate capacity of the plant has to be adjusted to the needs. Normally, the capacity is designed to meet the peak needs.

Operating with overcapacity is generally not recommended. Thus, adjustment means lowering the design permeate output.

The easiest way is to shut the plant down when no permeate is needed. A high start/stop frequency, however, can lower the performance and the lifetime of the membranes.

A permeate buffer tank may be used to allow a more constant operation. Reducing the feed pressure is another way to reduce the permeate flow.

Preferably, this is done by using a speed-controlled pump in order to save energy.

Normally, the system recovery is kept constant when the permeate flow is reduced.

Desalination, is a vast subject and we have just covered the tip of the iceberg? With time Waughter shall cover more on SWRO desalination.

Waughter

AKTION CONSULTANCY

Volume 1 : Edition 7 – Desalting-RO & Fouling With Special pre-treatment *July 31, 2021*

Is RO different than a Boiler?

No Not at all.

You are already an Expert on Reverse Osmosis if your Fundamentals on Boiler are correct.

The driving force in Boiler is Heat Energy & phase transfer, where Impurities can not leave Boiler drum and need to be blown down. H_2O molecule goes in gas phase and if you condense that you get the pure water, termed as distilled water and process is distillation.

In RO, we do not have phase transfer and H_2O molecule travels across as semipermeable membrane. It's a simple Push of H_2O and is :

Homogenous Solution Diffusion Model

Water and Solute Flux

$$F_W = K_W (\Delta P - \Delta\pi)$$

Fw = solvent flux, gallons per square foot per day (gfd)
K_w = solvent mass transfer coefficient, gfd/psi (A value)
ΔP = transmembrane pressure differential, psi
$\Delta\pi$ = osmotic pressure differential, psi

$$F_s = K_s (\Delta C)$$

F_s = solute flux, pounds per square foot per day
K_s = solute mass transfer coefficient, gfd (B value)
ΔC = transmembrane concentration differential, lb/gal

$F_w = K_w (\Delta P - \Delta\pi)$

Water Flux (Production) is governed by Applied Pressure – Osmotic pressure.

Where the mass transport of Salt is governed by

$F_s = K_s \Delta C$, thus Pressure has no role in quality of the permeate, which mainly depends upon the Pore Size of membrane and the concentration differential across a semi permeable membrane.

Since salt can not concentrate beyond a point in RO either, it's must to Reject a stream that flushes salts out of RO.

All mass balance equations are same.

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Our world is Waughter

The technical knowledge share attempt of Aktion Consultancy and the contents in the magazine shall be qualified by Sanjeev Srivastava our Technology Lead. Our next edition focuses on: MF UF & MBR and associated engineering.

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