

# Technical Support Manual

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# Introduction

While dealing with water management, one often finds that the source and the point of application are miles apart. Therefore, transporting water from one location to another plays a critical role in any industry. Water in its various forms (like raw water, treated water, sea water, wastewater, polluted water and sludge), along with various chemicals (like acid, alkali, lime, alum, polyelectrolyte, chlorine solution and salt solution) needs to be handled carefully while transportation.

Rapid industrialization, unplanned resource utilization and poor environment management have affected environmental resources resulting in deterioration of the quality of water. With the ever increasing TDS content in raw water and treated effluent, Reverse Osmosis (RO) has been emerged as most economical technology not only for the desalination of water containing salts, but also for eliminating heavy metals, pesticides etc.

# How Reverse Osmosis Works

The phenomenon of osmosis occurs when pure water flows from a dilute saline solution through a membrane into a higher concentrated saline solution.

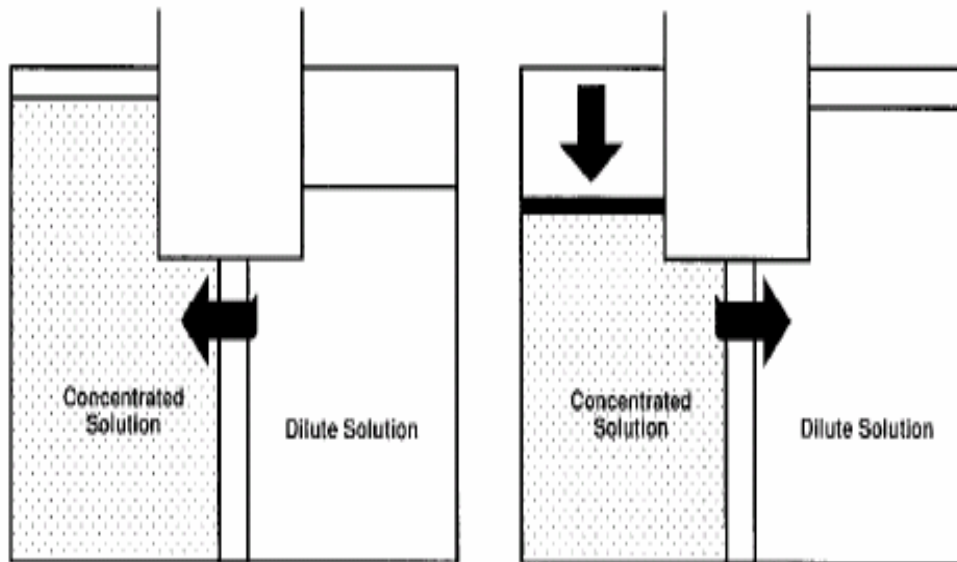
The phenomenon of osmosis is illustrated in Figure 1. A semi permeable membrane is placed between two compartments. “Semi permeable” means that the membrane is permeable to some species, and not permeable to others. Assume that this membrane is permeable to water, but not to salt. Then, place a salt solution in one compartment and pure water in the other compartment. The membrane will allow water to permeate through it to either side. But salt cannot pass through the membrane.

As a fundamental rule of nature, this system will try to reach equilibrium. That is, will try to reach the same concentration on both sides of the membrane. The only possible way to reach equilibrium is for water to pass from the pure water compartment to the salt-containing compartment, to dilute the salt solution.

Figure 1 also shows that osmosis can cause a rise in the height of the salt solution. This height will increase until the pressure of the column of water (salt solution) is so high that the force of this water column stops the water flow. The equilibrium point of this water column height in terms of water pressure against the membrane is called osmotic pressure.

If a force is applied to this column of water, the direction of water flow through the membrane can be reversed. This is the basis of the term reverse osmosis. Note that this reversed flow produces pure water from the salt solution, since the membrane is not permeable to salt.

Figure 1.4 Overview of osmosis



#### Osmosis

Water diffuses through a semi-permeable membrane toward region of higher concentration to equalize solution strength. Ultimate height difference between columns is "osmotic" pressure.

#### Reverse Osmosis

Applied pressure in excess of osmotic pressure reverses water flow direction. Hence the term "reverse osmosis".

# Understanding Total Dissolved Solids

Total Dissolved Solids (TDS) consist mainly of carbonates, bicarbonates, chlorides, sulphates, phosphates, nitrates, calcium, magnesium, sodium, potassium, iron, manganese, and a few others. They do not include gases, colloids, or sediment. The TDS can be estimated by measuring the specific conductance of the water. Dissolved solids in natural water range from less than 10 mg/L for rain to more than 100,000 mg/L for brines. Since TDS is the sum of all materials dissolved in the water, it has many different mineral sources. The chart below indicates the TDS from various sources.

## **Total Dissolved Solid (Mg/Ltr)**

Distilled Water (0)

Two-column Deionizer Water(8)

Rain and Snow(10)

Ganges River Water(upto 10 km from start-30)

Average rivers in the U.S.(210)

Missouri River(360)

Pecos River(2600)

Oceans(35000)

Brine Well (125000)

Dead Sea(250000)

Yamuna River-Delhi(350)

High levels of total dissolved solids can adversely affect industrial applications requiring the use of water such as cooling tower operations, boiler feed water, food and beverage industries, and electronics manufacturers. High levels of chloride and sulphate will accelerate corrosion of metals. The US EPA has a suggested level of 500 mg/l listed in the Secondary Drinking Water Standards.

# Understanding of RO Membrane Maintenance and Cleaning

Following gives you a clear understanding of Membrane working and effectiveness of maintenance and cleaning. If practice is adopted and seriousness is developed membrane can give you consistent flow of required specified quality water apart from longer life.

One RO design feature that is commonly over looked in reducing RO cleaning frequency is the use of RO permeate water for flushing foul ants from the system. Soaking the RO elements during standby with permeate can help dissolve scale and loosen precipitates, reducing the frequency of chemical cleaning.

Eventually the day comes when your RO system will require cleaning. Cleaning is recommended when your RO shows evidence of fouling, just prior to a long-term shutdown, or as a matter of scheduled routine maintenance. Fouling characteristics that signal that you need to clean are- a 10-15% decrease in normalized permeate flow, a 10-15% decrease in normalized permeate quality, or a 10-15% increase in normalized pressure drop as measured between the feed and concentrate headers.

RO cleaning frequency due to fouling will vary by site. A rough rule of thumb as to an acceptable cleaning frequency is once every 3 to 12 months. If you have to clean more than once a month, you should be able to justify further capital expenditures for improved RO pre-treatment or a re-design of the RO operation. If cleaning frequency is every one to three months, you may want to focus on improving the operation of your existing equipment but further capital expenditure may be harder to justify.

What you clean for can vary site depending on the foulant. Complicating the situation frequently is that one more than one foulant can be present. Typical foul ants are:

- Calcium carbonate scale
- Sulphate scale of calcium, barium or strontium
- Metal oxides of iron, manganese, aluminum, etc.
- Silica scale
- Colloidal deposits (inorganic or mixed inorganic/organic)
- Organic material of natural origin or man-made origin
- Biological (bios lime, mold, or fungi)

There are a number of factors involved in the selection of a suitable cleaning chemical (or chemicals) and proper cleaning protocol. The first time you have to perform a cleaning, it is recommended to contact the manufacturer of the equipment, the RO element manufacturer, or a RO specialty chemical supplier. Once the suspected foulant(s) are identified, one or more cleaning chemicals will be recommended. These chemical(s) can be generic and available from a number of suppliers or can be private-labeled proprietary cleaning solutions. The proprietary solutions can be more expensive but may be easier to use and you cannot rule out the advantage of the intellectual knowledge supplied by these companies. An invaluable service offered some service companies is that they will determine the proper cleaning chemicals and protocol by testing at their facility an element from your system.

It is not unusual to have to use a number of different cleaning chemicals in a specific sequence to achieve the optimum cleaning. There are times that a low pH cleaning is used first to remove foulants like mineral scale, followed by a high pH cleaning. Some cleaning solutions have detergents added to aid in the removal of heavy biological and organic debris, while others have a chelating agent like EDTA added to aid in the removal of colloidal material, organic and biological material, and sulphate scale. An important thing to remember is that the improper selection of a cleaning chemical or the sequence of chemical introduction can make the foulant worse.

There are a number of precautions in cleaning chemical selection and usage for a composite polyamide membrane:

- Follow the manufacture's recommended chemical list, dosage, pH, temperature and contact time guidelines.
- Use the least harshest chemical cleaning to get the job done. This will optimize the useful life
- Be prudent in the adjustment of pH at the low and high pH range to extend the useful life of the membrane. A "gentle" pH range is 4 to 10, while the harshest is 2 to 12.
- Don't mix acids with caustics. Thoroughly rinse the 1<sup>st</sup> cleaning solution from the system before introducing the next solution.
- Flush out detergents with high pH permeates.
- Verify that proper disposal requirements for the cleaning solution are followed.

If your system has been fouled biologically, you may want to consider the extra step of introducing a sanitizing biocide chemical after a successful cleaning. Biocides can be introduced immediately after cleaning. Biocides can be introduced immediately after cleaning, periodically (e.g. once a week), or continuously during service. You must be sure however that the biocide is compatible with the membrane, does not create any healthy risks, is effective in controlling biological activity, and is not cost prohibitive.

The successful cleaning of RO on-site requires a well-designed RO cleaning skid. Normally this skid is not hard piped to the RO skid and uses temporary hosing for connections. It is recommended to clean a multi-stage RO one stage at a time to optimize cross flow cleaning velocity. The source water for chemical solution and rinsing should be RO permeate, DI water or at least soft water. Components must be corrosion proof. Major cleaning system components are:

- RO Cleaning Tank: This tank needs to be sized properly to accommodate the displacement of water in the hose, piping, and pressure vessels. The tank should be designed to allow 100% drainage, easy access for chemical introduction and mixing, a recirculation line from the RO Cleaning Pump, proper venting, overflow, and a return line located near the bottom to minimize foam formation when using a surfactant.
- RO Cleaning Pump: This pump needs to be sized to develop the proper cross flow velocity to scrub the membrane clean. The cleaning rate for a 8-inch diameter vessel is 30 to 40 gpm and for a 4-inch diameter vessel is 8 to 10 gpm. The maximum recommended pressure is 60 psi to minimize the production of permeate during cleaning and reduce the convective redeposition of foulant back on to the membrane surface.
- RO Cleaning Cartridge Filter: Normally 5 to 10-micron and is designed to remove foulants that have been displaced from the cleaning process.
- RO Tank Heater or Cooler: The optimal temperature for cleaning is 35 to 45° C. One cannot forget that heat is generated and imparted by the RO Cleaning Pump during recirculation.
- RO Tank Mixer: This is recommended to get optimal mixing of chemical, though some designers rely solely on the slow introduction of chemical while maintaining a recirculation through the RO Cleaning Pump back to the tank.
- Instrumentation: Cleaning system instrumentation should be included to monitor flow, temperature, pressure, and tank level.
- Sample Points: Sample valves should be located to allow pH and TDS measurements off the RO Cleaning Pump discharge and the concentrate side recirculation return line.

- Permeate Return Line: A small amount of the cleaning solution can permeate through the membranes and so, a permeate side return line is recommended.

RO Cleaning procedures may vary dependent on the situation. The time required to clean a stage can take from 4 to 8 hours. The basic steps of cleaning are:

1. Perform a low pressure flush with feed or permeate water to remove service concentrate and foulants.
2. Make the cleaning solution as per the manufacturer's instructions.
3. Introduce the cleaning solution to the first stage for 60 minutes. You may want to throttle the flow up slowly to minimize the plugging of the feed path with dislodged foulant. Send the displaced water and up to 20% of the fouled cleaning solution to drain before returning the cleaning solution back to the RO Cleaning Tank. Readjust the pH to the target when it changes more than 0.5 pH units.
4. An optional soak and recirculation sequence can be used. The soak time can be from 1 hour to overnight depending on the manufacturer's recommendations, but the cautions that the proper temperature and pH be maintained and that this does increase the chemical exposure time of the membrane.
5. A low pressure Cleaning Rinse with permeate water is required to remove all traces of chemical from the Cleaning Skid and the RO Skid.
6. Once all the stages of a train are cleaned, the RO can be placed back into service. It is not unusual for it to take from a few hours to a few days for the RO permeate quality to stabilize, especially after high pH cleanings.

It is exciting to have a successful cleaning and watch your pressures and permeate quality improve. On the flip side it is frustrating to have an unsuccessful cleaning. If the cleaning did not provide the results you were hoping for, you may want to consider talking to those suppliers who offer off-site services rather than proceed with a trial-and-error approach on site. Pull one or two elements from the front or back end and send them to a service company. A service company can determine the optimal cleaning procedure and also report how effective the cleaning was in restoring flow and salt rejection.

# Understanding Reverse Osmosis

## Semi permeable Membranes are the Heart of RO Systems

The process of reverse osmosis (RO) represents the finest level of liquid filtration available today. While ordinary liquid filters use a screen to separate particles from water streams, an RO system employs a semi permeable membrane that separates an extremely high percentage of unwanted molecules. For example, the membrane may be permeable to water molecules, but not to molecules of dissolved salt. If this membrane is placed between two compartments in a container as shown in Figure 1, and a salt solution is placed in one half of the container and pure water in the other, water passes through the membrane while the salt cannot.

Figure 1.

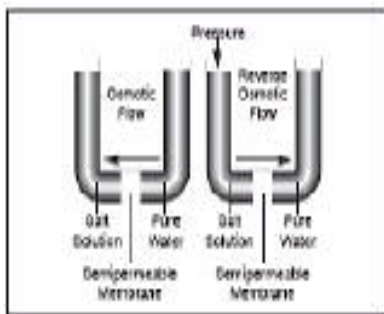
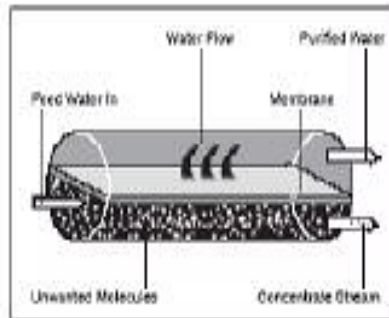


Figure 2.



## Pressure is applied to Reverse Natural Osmotic Flow

Now a fundamental scientific principle comes into play. That is, dissimilar liquid systems will try to reach the same concentration of materials on both sides of the membrane. The only way for this to happen in our example, is for pure water to pass through the membrane to the salt-water side in an attempt to dilute the salt solution. This attempt to reach equilibrium is called osmosis. But if the goal in our example water purification system is to remove the salt from water, it is necessary to reverse the natural osmotic flow by forcing the salt water through the membrane in the reverse direction. This can be accomplished by applying pressure to the salt water as it's fed into the system, creating a condition known as "reverse osmosis." (See Figure 1).

### **Cross-flow Filtration Permits Long-term Performance**

While the principals of reverse osmosis are simple, in practical terms, the RO process cannot go on indefinitely unless steps are taken to ensure that the membrane doesn't become clogged by precipitated salts and other impurities forced against it by the pressurized stream of feed water. To significantly reduce the rate of membrane fouling, RO systems employ cross-flow filtration (shown in Figure 2), which allows water to pass through the membrane while the separate flow of concentrate sweeps rejected salts away from the membrane surface.

# How to Use Reverse Osmosis In Practice

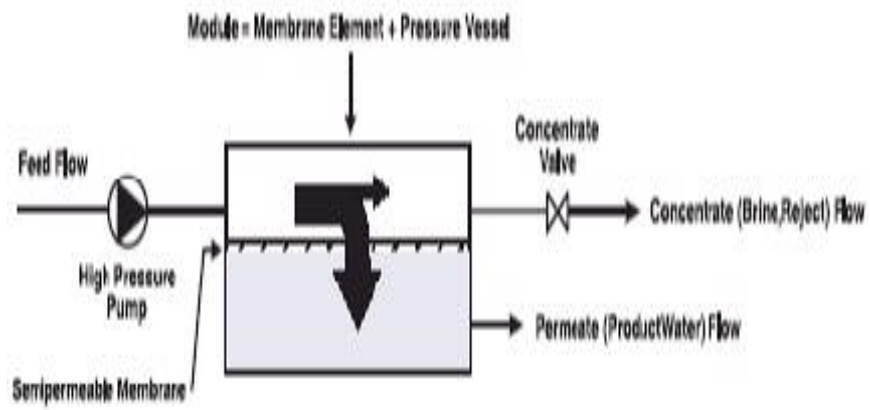
The simplified reverse osmosis process is shown in Figure 2.

With a high-pressure pump, pressurized saline feed water is continuously pumped to the ro system. In the system, consisting of a pressure vessel (housing) and a membrane element, the feed water will be split into a low saline product, called permeate and a high saline brine, called concentrate or reject. A flow-regulating valve, called concentrate valve, controls the percentage of feed water that is going to the concentrate stream and the permeated which will be obtained from the feed.

In the case of a spiral wound module consisting of a pressure vessel and several spiral wound elements, pressurized water flows into the vessel and through the channels between the spiral windings of the element. Up to seven elements are connected together within a pressure vessel. The feed water becomes more and more concentrated and will enter the next element, and at last exists from the last element to the concentrate valve where the applied pressure will be released. The permeate of each element will be collected in the common permeate tube installed in the center of each spiral wound element and flows to a permeate collecting pipe outside of the pressure vessel.

## Figure 2 : Reverse Osmosis Process

Figure 1.5 Reverse osmosis process



## Pretreatment required for RO

Typical pretreatment consists of:

- Coarse filtration (~80 micron) to remove large materials
- Hypochloride addition to reduce biofouling potential
- Fine filtration using multimedia filters or clarification
- Bisulphide addition to reduce residual free chlorine
- Cartridge filter upstream of the feed pump and membranes

Additional pretreatment considerations: Waters with higher particle contents, measured by silt density index (SDI), require a higher degree of pretreatment to achieve acceptable quality. Systems using groundwater as the feed source frequently operate without hypochloride and bisulphide addition. Waters with high hardness may require softening and / or acid addition. Activated carbon may be needed for water with high organic content. The in-line addition of antiscalants may be required for waters with high scaling potential.

## **Pore Size recommended for Filter Cartridge in an RO**

- Most commonly a filter with a micron rating of 5 micron absolute.
- With high levels of colloidal silica, lower micro-ratings are advisable.

## **Reverse Osmosis Module Designs**

Four basic types of RO module designs are in commercial use: tubular, plate-and-frame, spiral wound, and hollow fibre modules.

The tubular and the plate-and-frame devices date back to the early days of RO membrane technology. Both of these designs involve a high initial capital cost and a low membrane packing density (very low for the tubular design). However, these designs can operate on highly fouling feed waters. Thus, these designs find use in the food industry (examples: milk concentration for cheese manufacture, tomato juice concentration), and in concentration/treatment of wastewaters. They seldom compete with spirals and hollow fibre modules in desalination and water purification applications.

The design of spiral wound elements contains two layers of membrane glued back-to-back onto a permeate collector fabric (permeate channel spacer). This membrane envelope is wrapped around a perforated tube into which the permeate empties from the permeate channel spacer. Plastic netting is wound into the device, and maintains the feed-stream channel spacing. It also promotes mixing of the feed stream to minimize concentration polarization.

## Comparisons of Reverse Osmosis System Types

System Costs: Tubular, plate & frame >> hollow fiber, spiral
Flexibility in Design: Spiral >> hollow fiber > plate & frame > tubular
Cleaning Behavior: Plate & frame > tubular > spiral > hollow fiber
System Space Requirements: Tubular > plate & frame > spiral > hollow fiber
Susceptibility to Fouling: Hollow fiber >> spiral > plate & frame > tubular
Energy Requirement: Tubular > plate & frame > hollow fiber > spiral

The design of a hollow fiber permeator can package a tremendous amount of membrane area into a small volume. The difficulty in this approach, however, is that these fibers act almost like a string filter. This design requires a high level of feed water pretreatment to minimize the fouling potential of the feedwater. And when they are fouled, they are very difficult to regenerate by cleaning methods. Another aspect of hollow fiber permeators is that abrasion through fiber-fiber contact or via fiber contact with trapped particles appears to occur during RO operation. This results in gradual fall-off of salt rejection with time.

Above is a set of comparisons between the four basic module designs. Comparing their susceptibility to fouling for example, hollow fiber devices are much worse than spiral wound devices, which in turn are much worse than tubular devices and plate-and-frame devices.

Referring to system costs, spiral wound and hollow fiber systems are relatively equal on well water sources. For surface water sources, pretreatment costs tend to be higher for hollow fiber systems because of their fouling potential. Tubular and plate-and-frame systems are far more expensive than hollow fiber and spiral wound devices, and are relatively cost competitive to each other. As

for system space requirements, tubular modules require the most space, hollow fiber and spiral modules require the least space.

One specific advantage of spiral wound units is that they can be linked together into series of two to seven elements within a single pressure vessel. Thus, up to seven times the flow of product water can be handled with only a single set of plumbing connections for feed, concentrate and permeate to a pressure vessel. In the case of hollow fiber modules, each hollow fiber unit requires installation of one feedwater inlet, one concentrate outlet, and one permeate outlet. For large modular systems for field application, a significant percentage of the system cost will be in the plumbing connections.



# Factors Affecting RO Membrane Performance

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Reverse osmosis (RO) technology can be a complicated subject, particularly without an understanding of the specific terminology that describes various aspects of RO system operation and the relationships between these operating variables.

This bulletin defines some of these key terms and provides a brief overview of the factors that affect the performance of RO membranes, including pressure, temperature, feed water salt concentration, permeate recovery, and system pH.

## Definitions

**Recovery** - the percentage of membrane system feedwater that emerges from the system as product water or “permeate”. Membrane system design is based on expected feedwater quality and recovery is fixed through initial adjustment of valves on the concentrate stream. Recovery is often fixed at the highest level that maximizes permeate flow while preventing precipitation of super-saturated salts within the membrane system.

**Rejection** - the percentage of solids concentration removed from system feedwater by the membrane.

**Passage** - the opposite of “rejection”, passage is the percentage of dissolved constituents (contaminants) in the feedwater allowed to pass through the membrane.

**Permeate** - the purified product water produced by a membrane system.

**Flow** – Feed flow is the rate of feedwater introduced to the membrane element, usually measured in gallons per minute (gpm). Concentrate flow is the rate of flow of non-permeated feedwater that exists the membrane element. This concentrate contains most of the dissolved constituents originally carried into the element from the feed source. It is usually measures in gallons per minute (gpm).

**Flux** - the rate of permeate transported per unit of membrane area, usually measured in gallons per square foot per day (gfd).

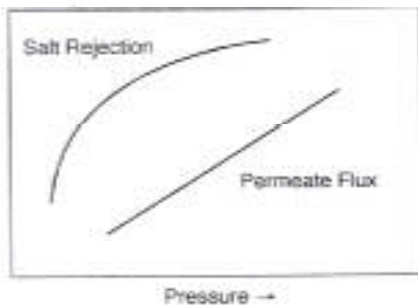
**Dilute solution** - purified water solution, RO system product water.

**Concentrated solution** – brackish water solution such as RO system feedwater.

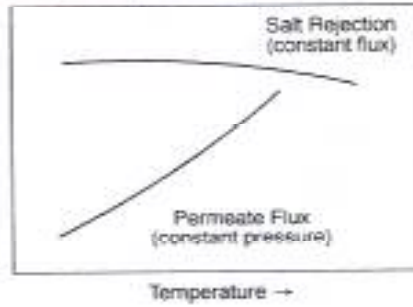
### **Effect of pressure**

Feedwater pressure affects both the water flux and salt rejection of RO membranes. Osmosis is the flow of water across a membrane from the dilute side toward the concentrated solution side. Reverse osmosis technology involves application of pressure to the feedwater stream to overcome the natural osmotic pressure. Pressure in excess of the osmotic pressure is applied to the concentrated solution and the flow of water is reversed. A portion of the feedwater (concentrated solution) is forced through the membrane to emerge as purified product water of the dilute solution side

**Figure 2. Effect of Feedwater Pressure on Flux and Salt Rejection**



**Figure 3. Effect of Feedwater Temperature on Flux and Salt Rejection**



As shown in Figure 2, water flux across the membrane increases in direct relationship to increases in feedwater pressure. Increased feedwater pressure also results in increased salt rejection but, as Figure 2 demonstrates, the relationship is less direct than for water flux.

Because RO membranes are imperfect barriers to dissolved salts in feedwater, there is always some salt passage through the membrane. As feedwater pressure is increased, this salt passage is increasingly overcome as water is pushed through the membrane at a faster rate than salt can be transported.

However, there is an upper limit to the amount of salt that can be excluded via increasing feedwater pressure. As the plateau in the salt rejective curve (Figure 2) indicates, above a certain pressure level, salt rejection no longer increases and some salt flow remains coupled with water flowing through the membrane.

**Effect of temperature** As figure 3 demonstrates, membrane productivity is very sensitive to changes in feedwater temperature. As water temperature increases, water flux increases almost linearly, due primarily to the higher diffusion rate of water through the membrane.

Increased feedwater temperature also results in lower salt rejection or higher salt passage. This is due to a higher diffusion rate for salt through the membrane.

The ability of a membrane to tolerate elevated temperatures increases operating latitude and is also important during cleaning operations because it permits use of stronger, faster cleaning processes.

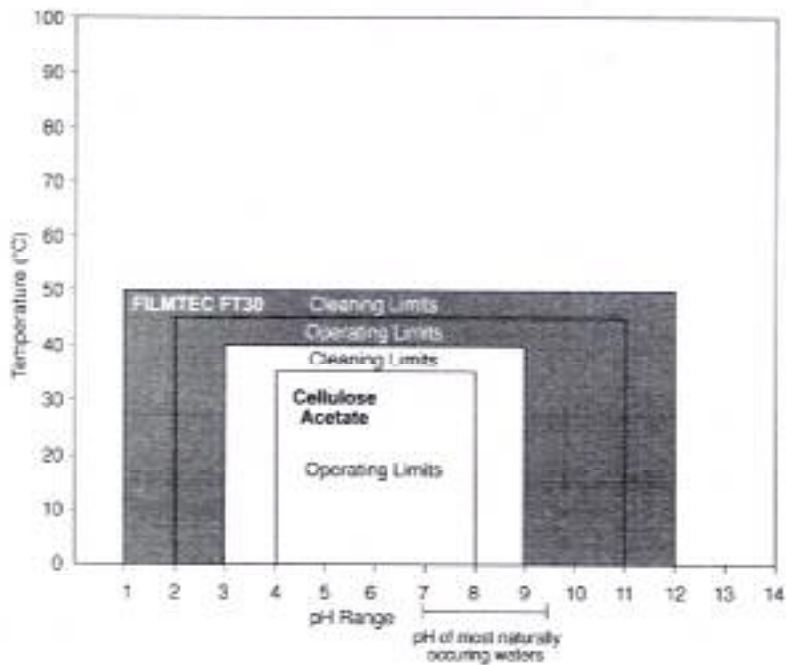
**Effect of salt concentration** Osmotic pressure is a function of the type and concentration of salts or organics contained in feedwater. As salt concentration increases, so does osmotic pressure. The amount of feedwater driving pressure necessary to reverse the natural direction of osmotic flow is, therefore, largely determined by the level of salts in the feedwater.

Figure 5 demonstrates that, if feed pressure remains constant, higher salt concentration results in lower membrane water flux. The increasing osmotic pressure offsets the feedwater driving pressure. Also illustrated in Figure 5 is the increase in salt passage through the membrane (decrease in rejection) as the water flux declines.

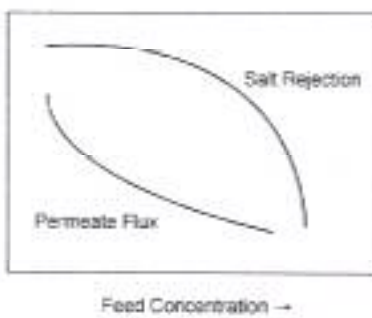
**Effect of recovery** As shown in Figure 1, reverse osmosis occurs when the natural osmotic flow between a dilute solution and a concentrated solution is reversed through application of feedwater pressure. If percentage recovery is increased (and feedwater pressure remains constant), the salts in the residual feed become more concentrated and the natural osmotic pressure will increase until it is as high as the applied feed pressure. This can negate the driving effect of feed pressure, slowing or halting the reverse osmosis process and causing permeate flux and salt rejection to decrease and even stop (please see Figure 6).

The maximum percent recovery possible in any RO system usually depends not on a limiting osmotic pressure, but on the concentration of salts present in the feedwater and their tendency to precipitate on the membrane surface as mineral scale. The most common sparingly soluble salts are calcium carbonate (limestone), calcium sulphate (gypsum), and silica. Chemical treatment of feedwater can be used to inhibit mineral scaling.

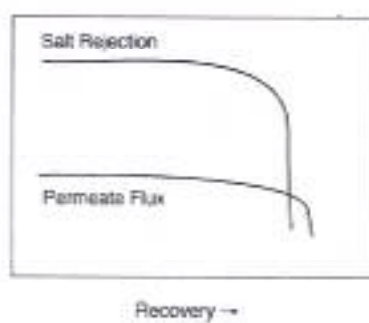
**Figure 4. Comparison of Operating and Cleaning Parameters for FT30 Thin-Film Composite Membrane and a CA Membrane**



**Figure 5. Effect of Increasing Salt Concentration on Flux and Salt Rejection**

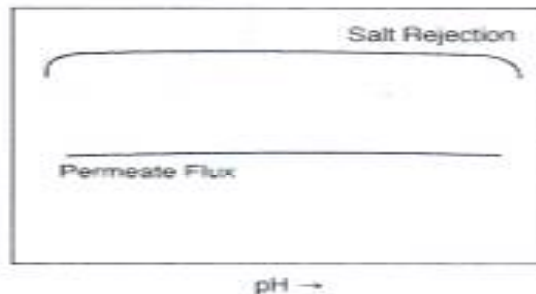


**Figure 6. Effect of Increased Recovery on Flux and Salt Rejection**



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**Figure 7. Effect of Feedwater pH on Water Flux and Salt Rejection**



## Effect of pH

The pH tolerance of various types of RO membranes can vary widely. Thin-film composite membranes are typically stable over a broader pH range than cellulose acetate (CA) membranes and, therefore, offer greater operating latitude (please see Figure 4).

Membrane salt rejection performance depends on pH. Water flux may also be affected. Figure 7 shows that water flux and salt rejection of a good membrane are essentially stable over a broad pH range.

As illustrated in Figure 4, the stability of membrane over a broad pH range permits stronger, faster, and more effective cleaning procedures to be used compared to CA membranes.

# Factors Influencing Reverse Osmosis Performance

Permeate Flux and salt rejections are the key performance parameters of a reverse osmosis process. They are mainly influenced by variable parameters, which are as follows:

- Pressure
- Temperature
- Recovery
- Feed water salt concentration

The following graphs show the impact of each of those parameters when the other three parameters are kept constant. In practice, there is normally an overlap of two or more effects.

Not to be neglected are several main factors which cannot be seen directly in membrane performance. These are maintenance and operation of the plant as well as proper pretreatment design. Consideration of these three 'parameters', which have very strong impact on the performance of a reverse osmosis system, is a must for each OEM (original equipment manufacturer) and end user of such a system.

## **Pressure**

With increasing effective feed pressure, the permeate TDS will decrease while the permeate flux will increase as shown in Figure 3.

## **Temperature**

If the temperature increases and all other parameters are kept constant, the permeate flux and the salt passage will increase (see Figure 4).

## Recovery

The recovery is the ratio of permeates 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 recover (see Figure 5).

## Feedwater Salt Concentration

Figure 6 shows the impact of the feedwater salt concentration on the permeate flux and the salt rejection. Table 1 shows a summary of the impacts influencing reverse osmosis plant performance.

Figure 1.6 Performance vs. pressure

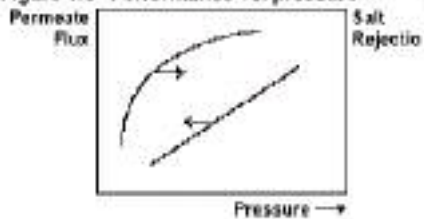


Figure 1.7 Performance vs. temperature

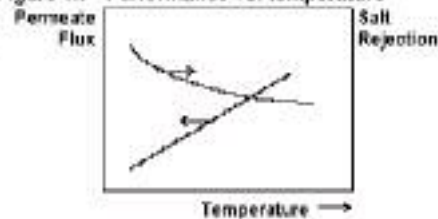


Figure 1.8 Performance vs. recovery

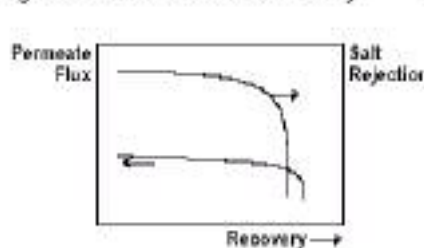
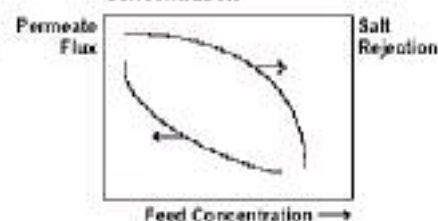


Figure 1.9 Performance vs. feedwater salt concentration



# Handling and Preservation

**Preservation** Some new elements are sent in a standard preservation solution containing 1% sodium bisulphide. , Soaked in the mentioned solution for one hour, drained and bagged into a double plastic bag. The inner bag is made out of an oxygen barrier material.

Bisulphite provides protection from biological growth.

Some types of elements are also available as dry elements. Those elements have been dry vacuum tested, but not tested with saline water. They are bagged into a single plastic bag. They do not require any preservation solution, but they should be kept in their sealed bag until they are used.

Any element that has been used and removed from the pressure vessel for storage or shipping must be preserved in a preservation solution. Use a mixture of 1% (by weight) of sodium bisulfite - food grade, not cobalt activated – and water. Soak the element for one hour in the solution, allow dripping out and sealing it into an oxygen barrier plastic bag. Do not fill the plastic bag with the preservation solution – the moisture in the element is sufficient, and leaking bags might create a problem during transport. Identify the element and the preservation solution on the outside of the bag.

**Rewetting of Dried Out Elements** Elements that have dried out after use may irreversibly lose water permeability. Rewetting might be successful with one of the following methods:

- Soak in 50/50% ethanol/water or propanol/water for 25 min.
- Pressurize the element at 10 bar (150 psi) and close the permeate port for 30 min. Take care that the permeate port is reopened before the feed pressure is released.
- Soak the element in 1% HCl or 4% HNO<sub>3</sub> for 11-30 hours.

**Storage** The following are guidelines for storage of elements :

- Store cool inside a building or warehouse and not in direct sunlight.
- Temperature limits:  $-4^{\circ}\text{C}$  to  $+35^{\circ}\text{C}$  ( $22^{\circ}\text{F}$  to  $95^{\circ}\text{F}$ ). New, dry elements will not be affected by temperatures below  $-4^{\circ}\text{C}$  ( $22^{\circ}\text{F}$ ).

Elements stored in 1% sodium bisulphide will freeze below  $-4^{\circ}\text{C}$  ( $22^{\circ}\text{F}$ ),  
Keep new elements in their original packaging.

## Basics of RO and NF: Element Construction

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 for most of the reverse osmosis applications in water treatment. Typically, a spiral wound configuration offers significantly lower replacement costs, simpler plumbing systems, easier maintenance and greater design freedom than other configurations, making it the industry's standard for reverse osmosis and nanofiltration(NF) membranes in water treatment.

The construction of a spiral wound membrane element as well as its installation in a pressure vessel is schematically shown in Figure 1.13. A element contains from one, to more than 30 membrane leaves, depending on the element diameter and element type. Each leaf is made of two membrane sheets glued together back-to-back with a permeate spacer in-between them. The consistent glue lines about 1.5 in (4 cm) wide that seal the inner (permeate) side of the leaf against the outer (feed/concentrate) side. There is a side glue line at the feed end and at the concentrate end of the element, and a closing glue line at the outer diameter of the element. The open side of the leaf is connected to and sealed against the perforated central part of the product water tube, which collects the permeate from all leaves. The leaves are rolled up with a sheet of feed spacer between each of them, which provides the channel for the feed and concentrate flow. In operation, the feed water enters the face of the element through the feed spacer channels and exists on the opposite end as concentrate. A part of the feed water – typically 10-20% - permeates through the membrane into the leaves and exists the permeate water tube.

When elements are used for high permeate production rates, the pressure drop of the permeate flow inside the leaves reduces the efficiency of the element.

In membrane systems the elements are placed in series inside of a pressure vessel. The concentrate of the first element becomes the feed to the second element and so on. The permeate tubes are connected with interconnectors

(also called couplers), and the combined total permeate exits the pressure vessel at one side (sometimes at both sides) of the vessel.

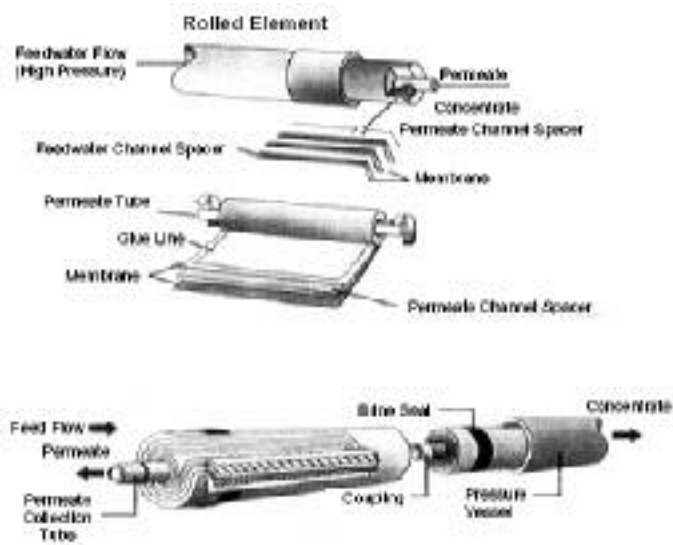


Figure 1.14 Cross-section of a permeate water tube through the side glue lines of the leaves (arrows indicate even spacing of leaves)



## **Degasifier use for RO**

Many people ask questions regarding degasification. Typically degasification is not necessary. However, for specific needs, the use of a degasifier depends upon quality requirement needed and the composition of the feed water. Reasons to need a degasifier may be that a reduction of the CO<sub>2</sub> or the H<sub>2</sub>S content is necessary. The use of a vacuum degasifier is preferable when H<sub>2</sub>S is present in the water or when airborne contaminations are present in the environment.

## RO Maintenance

Understanding and reacting to the performance of a reverse osmosis (RO) system is necessary for continued successful operation. It is this interaction that allows us to quickly and correctly identify and correct issues that may arise. The following discussion is intended to explain the importance of RO maintenance.

First, we must understand why maintenance is needed. The following question will answer some of these needs.

- Have you ever had a problem with a RO unit?
- Have you ever had the same problem occur more than once?
- Has anyone ever asked about the performance before the problem occurred?
- Did anyone have documentation illustrating past performance?

Understanding and performing routine RO maintenance can prevent most problems before they occur. RO maintenance is more than repairing and replacing parts. It means taking steps to reduce or replacing parts. It means taking steps to reduce or prevent problems from occurring and being aware that a problem may be coming before it happens. Ensuring the RO is properly applied to the project and that feed water pretreatment (and the feed water itself) is checked on a regular basis also are instrumental. You also must check that normal scheduled maintenance occurs. If the system is large enough, daily log sheets are to be filled out. Maintenance is a combination of all these.

## **RO Care**

An RO unit is only as good as the application allows. The first step in preventative care is to ensure the feed water is of satisfactory condition. Customers just don't want to pay for that all-important feed water analysis, yet it cannot be stressed strongly enough. The larger the system, the greater the importance. Be aware of your feed water source. Surface water can produce needs that groundwater does not and vice versa. If your community mixes the two, it can be a "double whammy." The point is to understand your feed water and install the proper pretreatment.

Understand both the amount of water and how the water will be used. Try to avoid traps such as knowing it needs to be 3,000 gallons per day and not knowing the day is eight hours. Make sure the unit is properly applied to the application and that any post treatment will allow proper flow and pressure.

Know the correct operating flows of the unit. Be sure to stay within manufacturer guidelines of pressure, product flow and recovery. Changes in feedwater temperature and total dissolved solids will change with the seasons. Expect these changes to cause minor adjustments to the unit.

## Preventative Care

On initial installation, main plumbing lines are flushed and any pretreatment is properly working before you run water into the RO. Double check for the lack of carbon fines and water hardness. Carbon fines from improperly rinsed carbon beds or cartridges will cause premature failure of the 5-micron pre filter used for particle protection just prior to the RO. Hardness leakage may lead to fouling of the membranes. Once installed be certain to set the unit flows to those recommended by the RO manufacturer and put these settings on a start-up sheet. Instruct the operating personnel on the importance of proper operation. Ensure it is understood to keep a watch on any pretreatment and check it on a regular basis. For instance, if carbon filters are used, periodically test for chlorine.

Water softeners should be tested for hardness and/or iron leakage. Don't test just the treated water; also test the incoming water. Remember the best time to test a water softener is just before it regenerates. Testing a freshly regenerated water softener (when regenerating properly) is of little use. Cities that have multiple sources of water will have varying amounts of constituents. The pretreatment must be capable of performing in the worst conditions. When checking pretreatment, be sure to check any regenerates such as salt in the brine tank. Do not let the brine tank run low or become empty. Salt on a skid next to a brine tank can cause problems.

## Routine Maintenance

Regardless of system size certain tasks need to be performed on a regular basis. The most frequent maintenance is changing cartridge pre filters. These usually are nominally rated as 5 micron and are used to protect the RO membrane from particle fouling. Run length or time before changing is based on pressure drop. As these filters trap particles from the water supply, a reduction in pressure to the RO will occur. Most RO units include a low-pressure switch that prevents the RO from running if feed pressure drops too low. Check with your filter supplier to determine the allowable pressure drop across the cartridge and compare this to the incoming feed pressure. Applications with low feed pressure may not allow full use of these filters, requiring more frequent changes.

Carbon filters are commonly used for chlorine removal. Small systems may use carbon cartridges, while larger units may have backwashing carbon as well as other filter units. The time for carbon filter replacement is dependent on each application. Carbon cartridges should be replaced at least (if not before) every three months and backwashing filters should be changed annually if not before. Regardless of which type may exist, the change frequency is dependent on the application, size and type of cartridge and carbon as well as feed water make-up. Make certain the cartridges and any backwashing filters are well rinsed before sending any water to the RO. Backwashing filters should have an overnight presoak prior to use. It also is important to note that the use of some carbons is well-rinsed prior to placement online.

Check any RO pretreatment for correct operation. Check RO product water quality, system flows and pressure. Pressures include pre and post filters, RO pump discharge and waste and product water pressure. Keep a log sheet on this information and compare old data with new. Check the unit carefully for any leaks. Listen for any unusual noises. Pumps will exhibit a problem usually associated with a noise or leak prior to failure. Depending on size, the RO pump may be coupled to the motor and include an oil bowl reservoir. Be sure to check its level. Check to ensure that pressure switches and / or level controls are properly functioning.

Do not rush in and out. It is important to check the complete system both pre and post treatment. Make note of any deficiencies and take corrective action. Cleaning of the membranes usually is needed when the product flow rate falls 10 to 15 percent. When checking, it is necessary to ensure the loss of production is not caused by low feed water pressure, dirty pre filters or low feed water pressure. As a general rule, hardness scaling causes both a loss of water quality and flow rate. Biological fouling causes a loss of flow rate. If you are uncertain but believe a problem exists check with your RO supplier.

## **Data Log**

Data log sheets are used to represent the past and present performance of an RO system. These sheets provide a window into expected future performance. Not all RO units need or have data logs. Some units are small enough that these sheets just do not make sense. You'll know if your RO is large enough to need one of these. Just check the unit manual. If it needs one you will find it there. Typically, log sheets include all available operating data such as date, time, run time in hours, pre and post filter pressures, feed, concentrate and permeate pressures, feed water quality, permeate water quality, SDI, feed water hardness (ppm), chlorine, pH and others. The size and options selected will affect the data required for logging.

Use of these sheets allows the operator to spot trouble ahead of time. Through filling out these sheets, the operator will see patterns developing indicating normal or abnormal operation. Abnormal operation will indicate the type of problem that is occurring, allowing corrective action to take place. For example, if pressure drop rises, product water decreases and quality is falling, the need for cleaning is indicated. In this example, the need for an acid cleaning is indicated. In this example, the need for an acid cleaning to remove hardness scale is indicated. This is merely one example. A hardness fouling condition is described above for two reasons. The first one is that it indicates a problem is coming and how to correct it. The other is to illustrate that you now can go one step further. Hardness fouling indicates a possible failure in pretreatment or a change in raw water hardness level. This allows a correction of the problem and correction of the cause.

## **When to Clean an RO Plant**

Generally it is recommended to clean an RO plant when a 10% decrease in normalized flux is observed. For orientation, cleaning frequency can be in the range of 4 year with an SDI of less than 3. With an SSDI of 5, the cleaning frequency could double. However, cleaning frequency will depend on the specific situation.

# Reversing Problems in Reverse Osmosis

The useful life of reverse osmosis (RO) membrane elements is reduced by scaling, fouling and chemical attack. By preventing these processes from occurring, you can maximize membrane life.

**Scaling** results from the precipitation of certain feed water dissolved substances within an RO unit due to the concentration of feed water within the unit. The two most common scalants are calcium carbonate (limestone) and calcium sulphate (gypsum).

Scaling reduces permeate flow and increases permeate conductivity. Sharply pointed scale crystals may come into contact and cut the membrane, causing irreversible damage. Scalants other than polymerized silica generally will effectively be removed by chemically cleaning the affected elements with hydrochloric acid (muriatic acid) or citric acid. The pH of the cleaning solution should be no lower than the minimum pH allowed by the membrane manufacturer.

Polymerized silica scales are generally removed with a high pH cleaning solution. Caustic (sodium hydroxide) at the maximum pH allowed by the membrane manufacturer will remove polymerized silica scales. However, it will take many hours to remove a silica scale.

Most scaling can be eliminated by installing an upstream sodium-cycle ion exchange unit, commonly called sodium zeolite softeners. Silica scaling is less common, but more difficult to treat cost-effectively. An upstream dolomitic lime softener or the injection of a silica scale inhibitor will be required.

**Fouling** results when feedwater suspended particles are deposited within an RO unit. The most common fouling particles are bacteria, followed by aluminium, iron and silica.

Fouling reduces permeate flow rate. Bacterial fouling usually does not cause the permeate conductivity to increase until the system is extremely plugged. Other particles may cause the permeate conductivity to gradually increase. Sharp particles may cut the membrane and cause irreversible damage.

Most biological and particulate silica foulants can be removed by a high-pH detergent solution. The maximum pH is established by the membrane manufacturer. Appropriate and inappropriate detergents are specified by the membrane manufacturers. Aluminum and iron foulants are generally removed by scale-removing cleaning solutions.

Many vendors sell cleaning chemicals that are effective in cleaning RO membrane elements that can be used in place of the cleaning solutions described above or those recommended by the membrane manufacturers.

If biofouling is a problem, pretreatment may have little impact on RO unit fouling. For example, installing a UV (ultraviolet) unit upstream may have little effect on RO unit fouling. While the UV unit will kill or deactivate 90 to 100 percent of the feedwater bacteria, the same number of fouling particles (living and dead) enters the RO unit. The living bacteria can use the decomposing dead bacteria as food to promote swift re growth.

The action of chlorine, ozone, or other oxidizing compounds breaks down essential bacterial molecules, killing the bacteria or making it unable to reproduce. Additionally, these oxidizing compounds break down relatively large feedwater organic molecules that bacteria can't eat, turning them into smaller, easily digested food molecules. The regrowth after chlorination/dechlorination or after ozonation/deozonation may be very high.

Biofouling is usually more effectively handled by periodically cleaning and sanitizing the RO units and upstream equipment and piping that is not continuously chlorinated. Fouling by non-living particles is usually handled by installing sediment filters or cartridge filters with a nominal filtration rating of five micron or less.

# When to Clean

Residential / commercial RO units typically are too small to justify the costs of installing instrumentation to determine when to chemically clean them. For a larger, industrial RO unit the following instruments are the minimum required to adequately monitor performance:

## \* Feedwater

Temperature, Conductivity, Pressure

## \* Interstage

Pressure

## \* Permeate

Conductivity, Flow, Pressure

## \* Concentrate

Conductivity, Flow, Pressure

Based upon the daily readings, graphs are generated that track normalized permeate flow (NPF), differential pressure (DP), and percent salt rejection (%SR). NPF tracks the pressures, conductivities, and temperature and determines if the amount of permeate produced is appropriate given the current conditions or whether too much pressure is required, which indicates whether scaling and /or fouling is present.

DPs are a measurement of the resistance to flow rate. A higher DP across one or more RO elements indicates the presence of a scalant and / or foulant.

Percent salt rejection measures the membrane's ability to reject dissolved substances. Scaling and membrane damage cause the %SR to drop.

By monitoring the performance of an RO unit, the need for chemical cleaning becomes apparent. When the NPF drops by 10 to 15 percent, or if the DP across any stage increases by 10 to 25 percent, it is time to clean.

Cleaning at an early stage can remove most scalants and foulants. By waiting too long, however, the elements can become so plugged that channeling occurs. Small channels of high flow will develop in the elements. Cleaning solution will then go through the same channel as during normal service, but the plugged areas will remain plugged.

Again, for small residential / commercial units, instruments generally aren't required to monitor performance. If you wait until the customer complains about taste, odor, and /or low – flow problems, the elements may be plugged significantly and a chemical cleaning may be ineffective or may take many hours to get the elements back to its almost – original performance. Periodic cleanings on a preventive maintenance contract may be worthwhile for certain customers.

# Chemical Attack

Chlorine is the most common agent to chemically attack and destroy frequently used polyamide thin-film membranes. Activated carbon blocks are generally used upstream on smaller RO units to remove the chlorine. For larger units, dechlorination is accomplished either by an upstream granular AC (activated carbon) bed or by injecting a sulfite generating ( $\text{SO}_3^{2-}$ ) compound.

Active chlorine-consuming sites on the activated carbon material are depleted over time. Eventually dechlorination will diminish and finally quit, damaging downstream chlorine – sensitive membranes.

Activated Carbon blocks, or Activated Carbon beds, must be replaced as frequently as Activated Carbon manufacturers specify. However, if you periodically sanitize the Activated Carbon units with a chlorine solution or hydrogen peroxide (or other oxidant) solution, you'll exhaust the Activated Carbon unit quicker than the design. Also, if the chlorine compound concentration in the feedwater increases, this will reduce the useful life of the Activated Carbon units. For example, it is common today for municipal drinking water treatment systems to periodically super-chlorinate the distribution system.

During most of the year, both gaseous chlorine and ammonia are commonly injected into municipal drinking water in order to provide microbiological control without creating excessive amounts of trihalomethane compounds. Since chloramines (chlorine plus ammonia) compounds are not as biocidal as free chlorine compounds, periodic super-chlorination with free chlorine residual is required to maintain microbiological control. If the expected useful life of an AC unit is based upon the usually low chloramines levels and doesn't take into account a month or two per year of higher free chlorine residual, the AC unit may exhaust prematurely and cause downstream membrane damage.

# Changing Reverse Osmosis Membranes

To open a PVC pressure vessel, first remove any pins holding one end plug in place. (Note: many fiberglass pressure vessels use a snap ring to hold the plug in place. Properly – sized snap ring pliers should be used to safely remove the snap ring). Next, remove the fittings from the plug.

Thread a nipple and tee into the feed or concentrate port long enough to extend past the end of the pressure vessel. Apply a coating of glycerin to the inside and rime of the pressure vessel from the plug to the end so the plug will slide out more easily. Pry off the plug using a pry bar. We either use a ball joint separator, also called a “pickle fork,” which is an automotive tool, or a slide hammer. Remove the fittings used to remove the plug.

Next, remove the membrane from the pressure vessel, noting which side the brine seal is on. Insert the new membrane with the brine seal on the feed side of the pressure vessel. Replace any damaged O-rings. Lubricate the plug with glycerin. Tap the plug securely into place using a piece of wood and a rubber mallet. Replace any pins to hold the plug in place. Reattach the fittings to the pin.

With a new membrane, flush all permeate and concentrate to drain for 30 minutes at low pressure to flush out the preservative.

# Common Impurities in Water and Methods to Remove It

Impurities	Effect	Method of Removal
Turbidity Suspended Silica	Can clog pipelines and equipments can choke Ion exchange resin and RO membranes	Coagulation, setting and filtration
Color	Indication of organic, iron, etc. and can be harmful to the unit operation ahead.	Coagulation, setting filtration, followed by activated carbon filter.
Organic matter	Can foul Ion exchange resins membranes and may be detrimental to process.	Coagulation, setting, filtration, followed by activated carbon filtration.
Bacteria	Will depend upon the type of bacteria, can induce corrosion and also harmful to RO membrane.	Coagulation, filtration, setting and super chlorination, UV, ozonation
Iron	Red water, corrosion, deposit, interferes with dyeing, bleaching, etc.	Aeration, coagulation, filtration, filtration through Manganese Zeolite
PH	High pH or low pH can both induce corrosion.	Ion exchange, addition of acid or alkali.
Calcium, Magnesium (Hardness)	Scaling, cruds with soap interfere with dyeing and also harmful to other process.	Ion exchange Lime Soda
Sodium	Unharmful when low in concentration, increase TDS, high concentration can induce corrosion	Ion Exchange through cation H + resin. Reverse Osmosis

Bicarbonates, Carbonates, Alkalinity, Hydroxide (Alkalinity)	Corrosion, foaming and carry over.	<ul style="list-style-type: none"> <li>• Acid addition.</li> <li>• Ion Exchange by weak acid cation</li> <li>• Split stream by hydrogen cation resin</li> <li>• Degasification</li> </ul>
Sulphate	Scaling if associated with Calcium, harmful in construction water.	<ul style="list-style-type: none"> <li>• Ion Exchange</li> <li>• Reverse Osmosis</li> <li>• Evaporation</li> <li>• Electrolysis.</li> </ul>
Chloride	Corrosion	<ul style="list-style-type: none"> <li>• Ion Exchange</li> <li>• Reverse Osmosis</li> <li>• Evaporation</li> <li>• Electro dialysis</li> </ul>
Nitrate	Normally not found in raw water. Harmful in food processes (especially baby food).	<ul style="list-style-type: none"> <li>• Ion Exchange</li> <li>• Reverse Osmosis</li> </ul>
Silica	Scaling and deposition on equipment.	Ion Exchange
Carbon Dioxide	Corrosion	Open aeration, Degasification, and Vacuum deaeration.
Hydrogen Sulphide	Corrosion	Aeration, filtration thorough Manganese Zeolite, aeration plus chlorination.

Oxygen	Corrosion	<ul style="list-style-type: none"> <li>• Deaeration</li> <li>• Addition of chemicals like sodium sulphite or hydrazine.</li> <li>• Anion exchanger</li> </ul>
Ammonia	Corrosing especially of Copper and Zinc	<ul style="list-style-type: none"> <li>• Aeration</li> <li>• Hydrogenations Exchange if ammonia is present in Ionic form.</li> </ul>
Free Chlorine	Corrosion	<ul style="list-style-type: none"> <li>• By adding chemicals</li> <li>• Activated Carbon</li> </ul>

# Water Analysis Conversion Table for Units Employed: Equivalents

Water Analysis Conversion Table	Parts per million (ppm)	Milligrams per litre Mgm/l	Grams per Litre gms/L	Parts per hundred thousand pts/100000	Grains per U.S. gallons grs/U.Sgal	Grains per british Imp gallon Grm/Impgal	Kilograins per cubic foot Kgr/cu.ft
1 Part per million (1 ppm)	1	1	.001	.1	.0583	.07	.0004
1 milligram per litre (1mg/litre)	1	1	.001	.1	.0583	.07	.0004
1 gram per litre (1 m/litre)	1000	1000	1	100	58.3	70	.435
1 Parts per hundred thousand (1pt/100000)	10	10	.01	1	.583	.7	.00436
1 Grain per U.S. gallon (1 gr/U.S gal)	17.1	17.1	.017	1.71	1	1.2	.0075
1 Grain per british Imp gallon (1 gr/Imp gal)	14.3	14.3	.014	1.43	.833	1	.0052
1 Kilograin per cubic foot (1 Kgr/cu.ft)	2294	2294	2.294	229.4	134	161	1

### Conversion (Continued)

Conversion Table	Parts CaCO <sub>3</sub> per million (ppm)	Parts CaCO <sub>3</sub> per hundred thousand (ft/100 000)	Grains CaCO <sub>3</sub> per U.S. gal gpg	English Degrees or CLARK	French Degrees French	German Degrees German	Milli equivalents per litre or equivalents per million
1 Parts per million (1 ppm)	1	0.1	.0583	.07	.1	.0560	.020
1 Part per hundred thousand (1pt/10000 0)	10	1	0.583	0.7	1	0.560	.20
1 Grain per Us gallon (1 gpg)	17.1	1.71	1	1.2	1.71	0.958	.343
1 English or Clark degree	14.3	1.43	.833	1	1.43	0.800	.286
1 French Degrees (1.French)	10	1	.583	.7	1	0.560	20
1 German Degrees (1 German)	17.9	1.79	1.04	1.24	1.79	1	.357
1 Milli equivalent / litre or 1 equivalent per million	50	5	2.92	2.50		2.80	1

## **Indian standard grade form the commonly used regeneration chemicals**

Hydrochloric Acid	:	IS 265
Sulphuric Acid	:	IS 266
Sodium Hydroxide	:	IS 252 (Tech/Rayon Grade 46% lys) IS 1021 (Pure Grade – Flakes)
Sodium Carbonate	:	IS 251 (Tech Grade)
Sodium Suphite	:	IS 247 (Tech Grade)
Sodium Chloride	:	IS 297 (Tech Grade)
Alum	:	IS 260 (Tech Grade)

## Conversion Factors for conversion to Calcium Carbonate (CaCO<sub>3</sub>)

Ions	Symbol	Ionic weight	Equivalent Weight	To convert to CaCO <sub>3</sub> multiply by
<b>CATIONS</b>				
Aluminium	Al <sup>+++</sup>	27.0	9.0	5.56
Ammonium	NH <sub>4</sub> <sup>+</sup>	18.0	18.0	2.78
Barium	Ba <sup>++</sup>	137.4	68.7	.728
Calcium	Ca <sup>+</sup>	40.1	20.0	2.49
Copper	Cu <sup>++</sup>	63.6	31.8	1.57
Hydrogen	H <sup>+</sup>	1.0	1.0	50.0
Iron (Ferrous)	Fe <sup>++</sup>	55.85	27.8	1.80
Iron (Ferric)	Fe <sup>++</sup>	55.85	18.6	2.69
Magnesium	Mg <sup>++</sup>	24.3	12.2	4.10
Manganese	Mn <sup>++</sup>	54.9	27.5	1.82
Potassium	K <sup>+</sup>	39.1	39.1	1.28
Sodium	Na <sup>+</sup>	23.0	23.0	2.17
<b>ANIONS</b>				
Bicarbonate	HCO <sub>3</sub> <sup>-</sup>	61.0	61.0	0.82
Bisulphate	HSO <sub>4</sub> <sup>-</sup>	97.1	97.1	0.515

Bisulphite	HSO <sub>3</sub> <sup>-</sup>	81.1	81.1	0.617
Carbonate	CO <sub>3</sub> <sup>-</sup>	60.0	30.0	1.67
Chloride	Cl <sup>-</sup>	35.5	35.5	1.41
Fluoride	F <sup>-</sup>	19.0	19.0	2.63
Hydroxide	OH <sup>-</sup>	17.0	17.0	2.94
Nitrate	NO <sub>3</sub> <sup>-</sup>	62.0	62.0	0.807
Phosphate (monovalent)	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	97.0	97.0	0.516
Phosphate (divalent)	HPO <sub>4</sub> <sup>-</sup>	96.0	48.0	1.04
Phosphate (trivalent)	PO <sub>4</sub> <sup>-</sup>	95.0	31.7	1.58
Sulphate	SO <sub>4</sub> <sup>-</sup>	96.1	48.0	1.04
Sulphide	S <sup>-</sup>	32.1	16.0	3.12
Sulphite	SO <sub>3</sub> <sup>-</sup>	80.1	40.0	1.25

# Filter Operation

Basic Operation of Filter : Basic operation of Pressure Filter, Dual Media Filter and Activated Carbon is as follows :

Mode of Operation : All units operate in down flow mode, where the water enters from the top, percolates through the media and treated water is collected from the bottom.

Sequence of Operation :

- (1) Service : The water to be filtered enters from the top of the shell, percolates downward through the media and is drawn off from the bottom.
- (2) Backwash : The water enters from the bottom of the vessel, passes through the media and is drained from the top. This is called BACKWASH and it is done to carry the dirt accumulated on the top. Generally back washing is done once in every 24 hrs or when the pressure drop exceeds 8 psi. (0.5 kg/cm<sup>2</sup>)
- (3) Rinse : The water enters from the top passed through the media and is drained off from the bottom.

# Thumb rules for designing a filter

Calculate areas of vessel by required volumetric flow rate and the velocity as mentioned in the following table :

$$\text{Area (m}^2\text{)} = \frac{\text{Volumetric Flow Rate (m}^3\text{/hr)}}{\text{Velocity (m/hr)}}$$

$$\text{Velocity (m/hr)}$$

Based on above calculated area calculate dia of the vessel by the following formulae :

$$\text{Dia (m)} = \sqrt{\frac{\text{Area (m}^2\text{)}}{0.7856}}$$

Parameters	Sand Filters	Dual Media Filters	Activated Carbon
Velocity (m <sup>3</sup> /m <sup>2</sup> /hr)	7.5-12	12.20	15.20
Effective size of Media (mm)	0.45-0.6 (fine sand)	0.65-0.76 (Anthracite)	0.35-0.5
Uniform coefficient	1.6 max	1.85	< 2 (11.5 typical)
Density (kg/m <sup>3</sup> )	2650	1600	

## Important points on Filter:

1. Normally, pressure sand filter is used to filter suspended solids upto 30 ppm and dual filters form 50-55 ppm and higher suspended solids would require coagulation. Output quality of water from a Pressure Sand Filter is 25 to 50 microns.
2. Normally, velocity for Sand velocity is taken for water treatment / residential liters is taken as 7.5 to 18 m<sup>3</sup>/m<sup>2</sup>/hr for institutional filters 20 to 30 m<sup>3</sup>/m<sup>2</sup>/hr. For recirculation of water like swimming pool velocities can be taken greater than 35 m<sup>3</sup>/m<sup>2</sup>/hr. For recirculation of water like swimming pool velocities can be taken greater than 35 m<sup>3</sup>/m<sup>2</sup>/hr for low turbidity application.
3. Higher velocity will induce higher head loss through the bed and frequency of backwash will increase.
4. Back washing of filter should always be carried out using clean water.
5. Whenever air scouring is provided, it should be done before back washing step.
6. Where strainers are provided at bottom, pebbles and gravels need not be put.
7. 1 NTU is approximately between 2.5 to 3 ppm.

# Ion Exchange Operation

## Ion Exchange Load Calculation

Let us take the following examples :

Feed water analysis as ppm CaCO<sub>3</sub>

Calcium	-	210	Bicarbonate	-	200
Magnesium	-	40	Sulphate	-	85
Sodium	-	120	Chloride	-	70
Potassium	-	5	Nitrate	-	20
		-----			-----
		375			375
		-----			-----

Free CO<sub>2</sub> – 15

Silica – 5

Note :

1. Match total cations to total cations to total Anions. They should be equal. (Error of +- 5% can be considered)
2. Refer to the table for calculating the Resin Quantity. The Ion Exchange load can be taken as mentioned in the table.
3. For eg. For Softening : hardness is 250 ppm, therefore the Ion Exchange load is 250 pm.

$$\text{Ion Exchange Resin Quantity (ltrs)} = \frac{\text{Flow (m}^3/\text{hr)} * \text{Ion Exchange load (ppm)} * \text{Time}}{\text{Ex. Capacity of Resin (gms/ltr)}}$$

### Ion Exchange load w.r.t. different unit Operation

Unit Operation	Ion Exchange Load	Concentration (as ppm CaCO <sub>3</sub> )
Softening	Total Hardness (Ca+Mg)	250
Dealkalization	HCO <sub>3</sub>	
Strongly acid Cation	Total Cations (Ca+Mg+Na+K)	200
Weakly basic Anion	EMA (SO <sub>4</sub> +Cl+NO <sub>3</sub> )	375
Strongly acid Cation after dealkalization	Total Cations – Carbonate Hardness	175
Strongly Basic Anion after WBA	Total Anions – EMA	175
Strongly Basic Anion after Degassing	Cl+SO <sub>4</sub> +NO <sub>3</sub> +SiO <sub>2</sub> (Alkalinity + CO <sub>2</sub> )	225
Strongly basis Anion after degassing and WBA	Total Anion-T.Alk-EMA + SiO <sub>2</sub>	185(assuming 5ppm leakage of CO <sub>2</sub> )
Mixed Bed Resin (Mixture of Cotton / Anion)	Total electrolyte after SBA	10ppm (assuming 5ppm leakage)

### Sizing consideration for Ion Exchange System

<b>Parameters</b>	<b>Cation</b>	<b>Anion</b>	<b>Mixed bed</b>	<b>Degassifier</b>
Velocity*	15-20 mtr/hr	15-20 mtr/hr	30-44 mtr/hr	50-70 mtr/hr
Bed Depth	900-2000 mm	900-2000mm	1000-2000mm	2400-3600mm
Free Board	60-100%	60-100%	60-100%	
Type of Interval	Hub / radial Strain on plate	Hub/ radial Strain on plate	Hub/ radial Strain on plate	Rashing rings Poll rings

- Velocity is based on Ion Exchange resin and will vary from manufacturer to manufacturer resin.
- Free Board is required for down flow unit, for WAC resin the freed board should be 100%

# Softeners

Softening by ion exchange resin is the most common and probably the easiest method of removing hardness (that is calcium and magnesium) from water and render the water suitable for utility purpose. As the name implies ion exchange is a process in which undesirable ions are exchanged for more desirable ions.

## Problems caused by Hard Water

Hard water does not lather easily with soap. This causes problems during washing and bathing and prevents proper cleaning. Hard water can also cause scaling in pipes, fittings and storage tanks. Scaling in geysers can increase the electricity consumption bills. Hard water is also bad for the skin and hair.

## Softening Process Work

The softening process consists of passing raw water containing hardness through a bed of cation resin in sodium form. The hardness ions Ca & Mg are taken by resin and in exchange, the sodium ions are relinquished from the resin. This is called the service cycle.



Where A represents the relevant anions of bicarbonates, sulphates or chlorides R represents the anionic part of the softener resin

# Regeneration of Softener

Raw water will continue to get softened till the resin gets exhausted. Bringing back the resin to its original form is called regeneration. Softener resin is regenerated by sodium chloride of 10-15% concentration. Depending on the softener design, the regeneration may need to be done every day or every few days or every week.



# Softener Operation (Basic Ion Exchange Process)

## Thumb rules of designing a Softener

Step 1 – To Select resin quantity (ltrs) for a particular hardness (ppm) for a particular output (m<sup>3</sup>) per regeneration per hour based on regeneration level 160 gm/ltr, ion exchange capacity = 55, TDS limit = 1500 ppm refer Table 1

$$\text{Resin Quantity} = \frac{\text{Load (ppm as CaCO}_3\text{)} * \text{Flow} * \text{time}}$$

Ex. Capacity

For example

$$\text{Load} = \text{Hardness} = 100 \text{ ppm as CaCO}_3$$

$$\text{Flow} = 5 \text{ M}^3/\text{hr}$$

$$\text{Time} = (\text{Service Cycle}) = 12 \text{ hrs.}$$

$$\text{Ex. Capacity} = 60 \text{ gm as CaCO}_3$$

$$\text{Resin Quantity} = 100 * 5 * 12$$

$$= 60$$

100 litres

Note :

1. Na/Tc and TDS and correction factor should be applied.
2. Actual Resin Quantity = 60\* correction due Na/Tc factor \* Correction due to TH factor = 60 \* 0.96 \* 0.97 = 56 (approximately)

Hence Ion Exchange load for designing a softener is 56. These calculations are based on Ion Exchange resin and will vary from manufacturer to manufacturer resin.

Step 2 – To select vessel model for a selected resin quantity, approx. flow rates based on linear velocity min = 8 m<sup>3</sup>/m<sup>2</sup>/hr and max = 25 m<sup>3</sup>/m<sup>2</sup>/hr, and freeboard 5-100 %, refer Table 2

### **Important points on Softener**

- Linear velocity should not be less than 8m<sup>3</sup>/m<sup>2</sup>/hr and should not be more than 25m<sup>3</sup>/m<sup>2</sup>/hr.
- Regeneration level, hardness leakage desired and correction factors can be found from resin supplier graph Tables for all these are shown but the actual resin supplier graph should be used. These tables can be used for first calculation.

# Suggested vessel selection chart for softeners

Table 1 : Step 1 – To select resin quantity (ltrs) for a particular hardness (ppm) for a particular output (m<sup>3</sup>) per regeneration per hour based on regeneration level 160 gm/ltr. Ion exchange capacity = 55, TDS limit = 1500 ppm)

	Hardness = 150ppm	Hardness = 250ppm	Hardness = 350 ppm	Hardness = 500 ppm	Hardness = 650 ppm	Hardness = 800 ppm	Hardness = 1000 ppm
5	13.5	22.5	31.5	45.0	58.5	72.0	90.0
10	27.	45.0	63.0	90.0	117.0	144.0	180.0
15	39.0	65.0	91.0	1.35	175.5	216.0	270.0
20	52.5	87.5	122.5	180	234.0	288.0	360.0
25	66.0	110.0	154.0	225	292.5	360.0	450.0
30	79.5	132.5	111.3	270	351.0	432.0	540.0
35	91.5	152.5	213.5	315	409.5	504.0	630.0
40	105.0	175.0	245.0	360	468.0	576.0	720.0
45	118.5	197.5	276.5	405	526.5	648.0	810.0
50	132.0	220.0	308.0	450	585.0	720.0	900.0
55	144.0	240.0	336.0	495	643.5	792.0	990.0
60	157.2	262.0	366.8	540	702.0	864.0	1080.0
65	171.0	285.0	399.0	585	760.5	936.0	1170.0
70	184.5	307.5	430.5	630	819.0	1008.0	1260.0
75	198.0	330.0	462.0	675	877.5	1080.0	13500

80	210.0	350.0	490.0	720	936.0	1152.0	1440.0
85	223.0	372.0	521.0	765	994.5	1224.0	1530.0
90	237.0	395.0	553.0	810	1053.0	1296.0	1620.0
90	250.0	417.5	584.5	855	1111.5	1368.0	1710.0
100	262.5	437.5	612.5	900	1170.5	1440.0	1800.0

## BIS Standards for Drinking Water

Characteristic	IS Requirement Limit	IS Permissible Limit	WHO Guidelines	US EPA Limit
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### Essential Characteristics

Colour (in Hazen Units)	5	25	15	15
Odour	Unobjectionable	-	-	-
Taste	Agreeable	-	-	-
Turbidity (in NTU)	5	10	5	-
PH	6.5-8.5	6.5-8.5	-	6.5-8.5
Total Hardness (as CaCO <sub>3</sub> )	300	600	-	-
Iron (as Fe)	0.3	1.0	0.3	0.3
Chlorides (as Cl)	250	1000	250	250
Residual Free Chlorine	0.2	-	-	-

### Desirable Characteristics

Dissolved Solids	500	2000	1000	500
Calcium	75	200	-	-
Copper	0.05	1.5	2	1.3
Manganese	0.1	0.3	0.5	0.05
Sulphate	200	400	250	250
Nitrate	45	100	50	10
Fluoride	1.0	1.5	1.5	4
Phenolic Compounds	0.001	0.002	-	-
Mercury	0.001	0.001	0.001	0.002
Cadmium	0.01	0.01	0.003	0.005
Selenium	0.01	0.01	0.01	0.05
Arsenic	0.05	0.05	0.01	-
Cyanide	0.05	0.05	0.07	0.2
Lead	0.5	0.05	0.01	Zero
Zinc	5	15	3	5
Anionic Detergents	0.2	1.0	-	-
Chromium	0.05	0.05	0.05	0.1
Polynuclear aromatic hydrocarbons	-	-	-	-

Mineral oil	0.01	0.03	-	-
Pesticides	Absent	0.001	-	-
Alkalinity	200	600	-	-
Aluminium	0.03	0.2	0.2	0.05-0.2
Boron	1	5	0.3	-
Radioactive materials				
a) Alpha emitters	-	0.1	0.1	None
b) Beta emitters	-	1	1	None

## Indian Standard for Feed Water and Boiler Water Limits (10392-1982)

	Upto 20 kg/cm <sup>2</sup>	21 to 39 kg/cm <sup>2</sup>	40 to 59 kg/cm <sup>2</sup>	IS35550 1965*	IS3025 1965*
<b>Feed Water</b>					
Total hardness (as CaCO <sub>3</sub> ) mg/L Max	10	1.0	0.5		16.1
pH Value	8.5-9.5	8.5-9.5	8.5-9.5	-	8
Dissolved Oxygen mg/L	0.1	0.02	0.01	25	-
Silica (As SiO <sub>2</sub> ) mg/l Max	-	5	0.5	16	-
<b>Boiler Water</b>					
Total Hardness (of filtered sample as CaCO <sub>3</sub> ) as mg/L max	-	Not Detectable	-	-	16.1
Total	700	500	300	-	13

Alkalinity (As CaCO <sub>3</sub> ) as mg/L max					
Caustic Alkalinity (As CaCO <sub>3</sub> ) mg/L Max	350	200	60	-	15
PH Value	11-12	11-12	10.5-11	-	8
Residual Sodium Sulphite (as Na <sub>2</sub> SO <sub>3</sub> ) mg/l	30-50	20-30	-	-	21
Residual Hydrazine (as N <sub>2</sub> H <sub>4</sub> ) mg/l	0.1-1 (if added)	0.1-0.5 (if added)	0.05-0.3	26	-
Ration Na <sub>2</sub> SO <sub>4</sub> Caustic Alkalinity (as NaOH) or Ration NaNO <sub>3</sub> total alkalinity as NaOH	-	Above 2.5	-	-	20.2 & 15
Phosphates (PO <sub>4</sub> ) mg/L (if added)	20-40	15-30	5-20	14	-

Total dissolved solids mg/L Max	3500	2500	1500	9	12
Silica (as SiO <sub>2</sub> ) Mg/L Max	Less than 0.4 of caustic alkalinity	15	16	30	

# Hundred Ways to Save Water

All of us come in contact with water in all aspects of our lives, at homes, offices, outdoors and at leisure. We all have that opportunity to save water at all those occasions. It is upto us to take that opportunity.

1. When washing dishes, don't let the water run while rinsing. Fill one sink with wash water and the other with rinse water.
2. Evaporative coolers require a seasonal maintenance checkup. For more efficient cooling, check your evaporative cooler annually.
3. Check your sprinkler system frequently and adjust sprinklers so only your lawn is watered and not the house sidewalk, or street.
4. Run your washing machine and dishwasher only when they are full and you could save 1000 gallons a month.
5. Avoid planting turf in areas that are hard to water such as steep inclines and isolated strips along sidewalks and driveways.
6. Install covers on pools and spas and check for leaks around your pumps.
7. Use the garbage disposal less often.
8. Plant during the spring or fall when the watering requirements are lower.
9. Keep a pitcher of water in the refrigerator instead of running the tap for cold drinks.
10. Check your water meter and bill to track your water usage.
11. Always water during the early morning hours, when temperatures are cooler, to minimize evaporation.
12. Wash your produce in the sink or a pan that is partially filled with water instead of running water from the tap.
13. Use a layer of organic mulch around plants to reduce evaporation

and save hundreds of gallons of water a year.

14. Use a broom instead of a hose to clean your driveway and sidewalk and save up to 80 gallons of water every time.
15. If your shower can fill a one-gallon bucket in less than 20 seconds, then replace it with a water-efficient showerhead
16. Collect the water you use for rinsing produce and reuse it to water houseplants.
17. Water your lawn in several short sessions rather than one long one. This will allow the water to be better absorbed.
18. We're more likely to notice leaky faucets indoors, but don't forget to check outdoor faucets, pipes, and hoses for leaks.
19. Periodically check your pool for leaks if you have an automatic refilling device.
20. Only water your lawn when needed.
21. While shopping for a new appliance, keep in mind that one offering several different cycles will be more water and energy-efficient.
22. Time your shower to keep it under 5 minutes. You'll save up to 1000 gallons a month.
23. Install low-volume toilets.
24. Adjust your lawn mower to a higher setting. Longer grass will reduce the loss of water of evaporation.
25. When you clean your fish tank, use the water you've drained on your plants.

26. Water small areas of grass by hand to avoid waste
27. Put food coloring in your toilet tank. It's easy to fix, and you can save more than 600 gallons a month.
28. Plug the bathtub before turning the water on, then adjust the temperature as the tub fills up.
29. Use porous materials for walkways and patios to keep water in your yard and prevent wasteful runoff.
30. Collect and use rain water for watering your garden. (Check to make sure this is legal in your area).
31. Designate one glass for your drinking water each day. This will cut down on the number of times you run your dishwasher.
32. Instead of using a hose or a sink to get rid of paints, oil and pesticides, dispose of them properly to a hazardous waste site.
33. Install rain shut-off device on your automatic sprinkles to eliminate unnecessary watering.
34. Don't use running water to throw food.
35. Choose water-efficient drip irrigation for trees, shrubs, and flowers, watering roots is very effective.
36. Grab a wrench and fix that leaky faucet. It's simple, inexpensive and can save 140 gallons a week.
37. Cut back on the amount of grass in your yard by planting shrubs and ground cover or landscaping with rock.
38. When doing laundry match the water level to the size of the load.

39. Teach your children to turn the faucets off tightly after each use.
40. Remember to check your sprinkler system valves periodically for leaks and keep the heads in good shape.
41. Before you lather up, install a low-flow showerhead. They're inexpensive, easy to install, and can save 500 gallons a week.
42. Soak your pots and pans instead of letting the water run while you scrape them clean.
43. Don't water your lawn on windy days. After all, sidewalks and driveways do not need water.
44. Water deeply but less frequently to create healthier and stronger landscapes.
45. Make sure you know where your master water shut-off valve is located so that you can save water during any emergency.
46. When watering grass on steep slopes, use a soaker hose to prevent wasteful runoff.
47. To get the most from your watering time, group your plants according to their water needs.
48. Remember to weed your lawn and garden regularly. Weeds compete with other plants for nutrients, light, and water.
49. While fertilizers promote plant growth, they also increase water consumption. Apply the minimum amount of fertilizer needed.
50. Avoid installing ornamental water features unless the water is being recycled.

51. Use a commercial car wash that recycles water.
52. Don't buy recreational water toys that require a constant flow of water.
53. Turn off the water while you brush your teeth and save 4 gallons a minute. That's 200 gallon a week for a family of four.
54. Buy a rain gauge to track how much rain or irrigation your yard receives.
55. Encourage your community and local government to help develop and promote a water conservation ethic.
56. Teach your family how to shut off your watering systems so anyone can turn sprinklers off when it storm is approaching.
57. Set a kitchen timer when watering your lawn or garden with a hose.
58. Make sure your toilet flapper doesn't stick open after flushing.
59. Make sure there are aerators on all of your faucets.
60. Choose a low water use plant for ear-round landscape color and save up to 550 gallons each year.
61. Install an instant water heater on your kitchen sink so you don't have to let the water run while it heats up.
62. Use a grease pencil to mark the water level of your pool at the skimmer. Check the mark 24 hours later.
63. Spot spray or remove weeds as they appear.
64. Use a screwdriver as a soil probe to test soil moisture. Proper lawn

watering can save thousands of gallons of water annually.

65. Install a drip irrigation system around your trees and shrubs to water more efficiently.
66. Mow your lawn as infrequently as possible. Mowing puts your lawn under additional stress, causing it to require more water.
67. Don't use the sprinklers just to cool off or for play. Running through water from a hose or sprinkler wastes gallons of water.
68. Make sure your swimming pools, fountains, and ponds are equipped with recirculating pumps.
69. Bathe your young children together.
70. Direct downspouts or gutters toward shrubs or trees.
71. Winterize outdoor spigots to avoid pipes from bursting or freezing.
72. Insulate hot water pipes so you don't have to run as much water to get hot water to the faucet.
73. Drop that tissue in the trash instead of flushing it and save gallons every time.
74. Drop your tissues in the trash instead of flushing it and save gallons every time.
75. If you have an evaporative air conditioner, direct the water drain to a flowerbed, tree, or your lawn.
76. Make suggestions to your employer to save water (and dollars) at work.

77. Use a hose nozzle and turn off the water while you wash your car to save more than 100 gallons.
78. Use a hose nozzle and turn off the water while you wash your car to save more than 100 gallons.
79. Encourage your friends and neighbors to be part of a water-conscious community.
80. Install a toilet dam or bottle filled with water in your toilet to cut down on the amount of water used for each flush.
81. Install water-softening systems only when necessary. Save water and salt by running the minimum number of regenerations.
82. Wash clothes only when you have a full load and save up to 600 gallons each month.
83. Prune back heavy foliage. Reducing leaf area reduces water needs.
84. Report significant water losses from broken pipes and errant sprinklers to the property owner or your water management district.
85. If your grass is brown, it's not dead, it's just dormant. Dormant grass only needs to be watered every three weeks.
86. Start a compost pile. Using compost when you plant adds water-holding organic matter to the soil.
87. Listen for dripping faucets and toilets that flush themselves. Fixing a leak can save 500 gallons each month.
88. Listen for dripping faucets and toilets that flush themselves. Fixing

a leak can save 500 gallons each month.

89. More plants die from over-watering than from under-watering. Be sure only to water plants when necessary.
90. Adjust your watering schedule to the season. Water your summer lawn every third day and your winter lawn every fifth day.
91. Adjust your watering schedule according to the season. Water your summer lawn every third day and your winter lawn every fifth day.
92. Turn the water off while you shampoo and condition your hair and you can save more than 50 gallons a week.
93. Bathe your pets outdoors in an area in need of water.
94. Choose new water-saving appliances, like washing machines that save up to 20 gallons per load.
95. Water only as rapidly as the soil can absorb the water.
96. Aerate your lawn. Punch holes in your lawn about six inches apart so water will reach the roots rather than run off the surface.
97. Select the proper size pans for cooking. Large pans require more cooking water than may be necessary.
98. For lawn watering advice, contact your local conservation office.
99. Turn off the water while you shave and you can save more than 100 gallons a week.
100. Spread awareness and knowledge of water conservation to all your friend and acquaintances.

**There are a number of ways to save water, and they all start with you.**

## **Rain Water Harvesting Basics**

Rain water harvesting system can be as simple as an inverted umbrella that collects the rain water and directs it into a container. Alternatively, it can be a complex system that harvests every drop of rain that falls in your premises and then plus it back into your water supply system. The choice of the system depends on the size of the catchment area the amount of rainfall received, the end use of the harvested water and of course your budget. The rain water harvesting system can not only be incorporated in a new construction but can also be added to any existing structure.

## **Five Components of Rain Water Harvesting Systems**

- Catchment Area
- Collection System
- Filtration System
- Storage / Recharge System
- Reuse System

### **Catchment Area**

The area of your premises in which the rain water falls is the catchment area. The nature of the catchment area determines the amount and the quality of the rain water that can be harvested. The various common surfaces, have been assigned certain values of Run –off coefficients depending on the amount of rainfall that runs off their surface. The rainwater runs off the hard and smooth surfaces faster than off the soft surfaces. Hence the run off coefficient for harder surfaces is mor ethan that of the soft surfaces.

The annual rain water harvesting potential of your premises can be calculated by multiplying the respective type of area to the run-off factor and the amount of rainfall that is received annually. The ideal rain water harvesting system aims to harvest the maximum portion of this potential and achieve “zero-run-off” in your premises.

## **Collection System**

The collection system directs the rainwater falling in your premises into the filtration system through a system of drainage pipes and channels. The collecting pipes collect the rain water falling onto the roof, running off the driveway and flowing off the other open areas and deposit it into the filtration chamber. The designing of the collection system is done in a way so as to collect the maximum of amount of run-off that is generated in the premises.

## **Pre-storage / Recharge Filtration**

The rainwater dissolves the impurities that are present on the surface as it flows through the premises into the collection system. Therefore it is advisable to keep the catchments area free of any chemical or other harmful impurities. At times, it is also advised that the run-off of the first few minutes of the rain be allowed to flow out of the premises. This washes away most of the impurities that may be possibly present on the surfaces. However this calls for certain design modifications and vigilant users. Therefore, it is always safer to make the rainwater run-off pass through a simple filtration pit before it flows into the storage or the recharge structures. This way, most of the impurities that get dissolved in the rainwater run-off get removed before storage / recharge.

## **Storage / Recharge System**

Depending on the amount of the water that needs to be harvested and the proposed end use of the harvested rainwaters, an appropriate storage or recharge system is designed. In areas with rainfall evenly spread over the year. Simple storage cistern can be designed on the basis of the daily water requirements. However in areas where the rainfall is restricted to a few

months of the year, recharge systems are most appropriate. The design and the location of these recharge systems is site specific and needs to be evolved as per the requirements.

## **Re-Use System**

The reuse system depends on the need of the individual owners and the amount of harvested rainwater. The harvested rainwater that has been passed through the simple pre-storage filtration system can be utilized for all uses except drinking and bathing. After adequate filtration the same water can also be made fit for human consumption. A harvested water distribution system can be worked in the premises for gardening the green areas or for use in the toilets. Again the re-use distribution system shall be site specific and the design shall be dictated by the site specification.