Water Treatment Systems

SKC In-service

June 2017

Dialysis requires a lot of water!

- Single treatment session, 4 hrs, dialysate flow 500-800 ml/min = 120-190 liters of water, 30-50 gallons.

Dialysis Water

- Membranes do not allow the passage of bacteria
- Membranes will allow the passage of electrolytes, minerals, chemicals with ease
- Dialysis membranes are not uni-directional, particles easily move from dialysate to blood
- Because of the vast quantity of water dialysis patients are exposed to contaminants even in small concentration can be toxic due to strong diffusive gradient into the blood and large amount of exposure

Water Contaminants

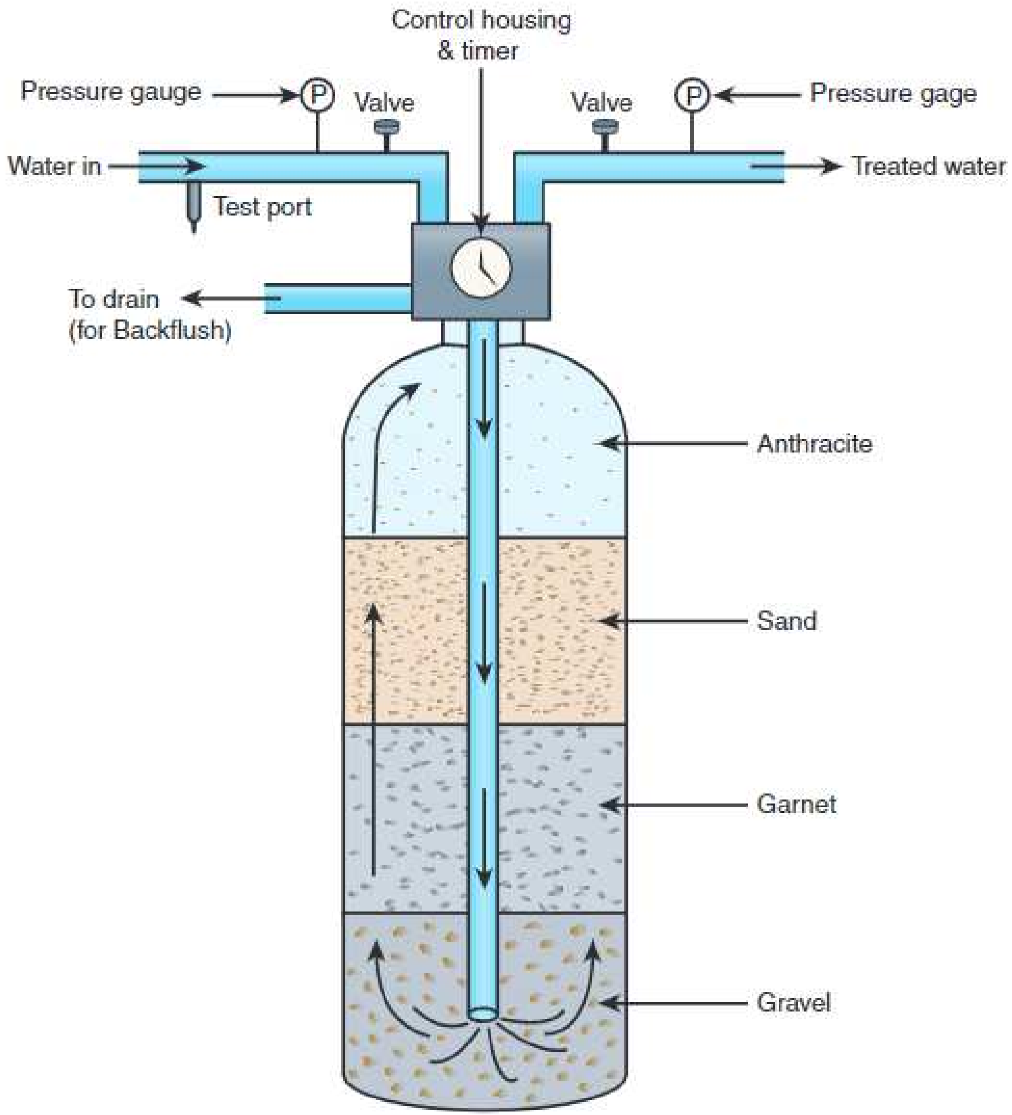
Contaminant	Maximum allowable concentration
Contaminants with documented toxicity in dialysis patients (mg/l)	
Aluminum	0.01
Total Chlorine	0.1
Copper	0.1
Fluoride	0.2
Lead	0.005
Nitrate (as N)	2
Sulfate	100
Zinc	0.1
Electrolytes normally found in dialysate (mmol/l)	
Calcium	0.05
Magnesium	0.15
Potassium	0.2
Sodium	3
Trace Elements (mg/l)	
Antimony	0.006
Arsenic	0.005
Barium	0.1
Beryllium	0.0004
Cadmium	0.001
Chromium	0.014
Mercury	0.0002
Selenium	0.09
Silver	0.005
Thallium	0.002

Signs and symptoms of exposure

Contaminant	Sigs/Symptoms of Exposure
Aluminum	Intoxication, seizures, neurologic symptoms, bone disease, anemia
Calcium	Confusion, lethargy, nausea, vomiting
Copper	Hemolysis, acidosis, nausea, seizure, shock
Chlorine / Chloramines	Hemolysis, methemoglobinemia
Fluoride	Intoxication, pruritis, headache, nausea, chest pain, ventricular fibrillation
Lead	Neuropathy, anemia, abdominal pain, confusion, seizure
Nitrate	Methemoglobinemia, cyanosis
Sodium	Hypertension, thirst, pulmonary edema, confusion, seizure
Sulfate	Nausea, vomiting, chills, fever
Zinc	Nausea, vomiting, fever, anemia

Mincare (peroxyacetic acid), cleans similar to peroxide: Hemolysis

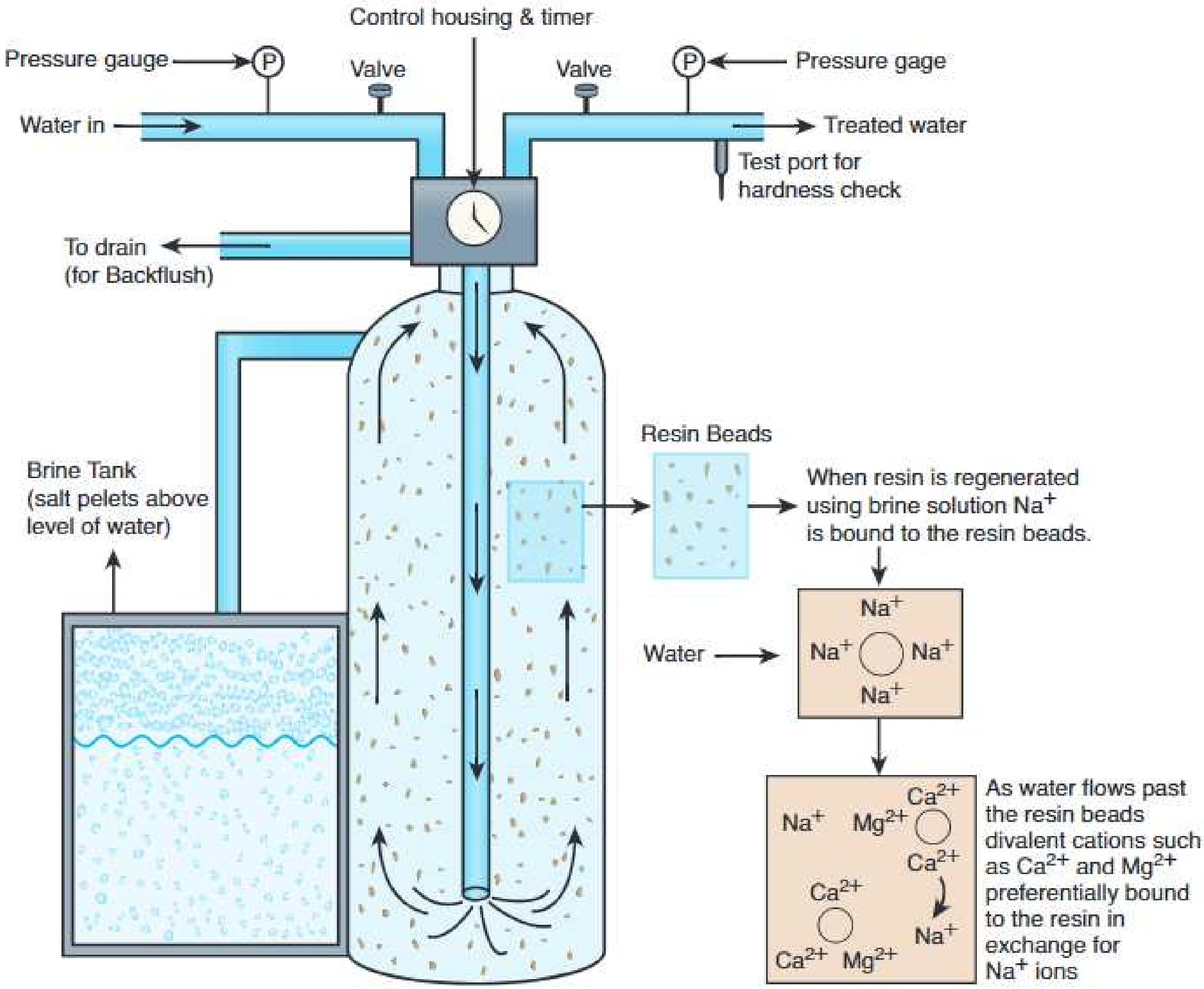
Multimedia Filter



Monitoring Multimedia Filter

- With use, the multimedia filter can become obstructed with debris. To prevent this, the filter is backwashed daily at a time when patients are not on dialysis.
- Pressure gauges should be present pre and post filter to measure the difference between the two. If the filter is occluded with debris the pressure drop will increase. The pressure difference (delta) across the filter should be monitored regularly. Trends in pressure changes should be established and investigated if abnormal.
- Pressure delta of > 10mmHg above baseline across the multimedia filter indicates a problem.
- If automated systems are utilized for backwashing of the filter, backwash timers should be monitored regularly to ensure that rinsing of the filter occurs during off hours, when patients are not on dialysis.

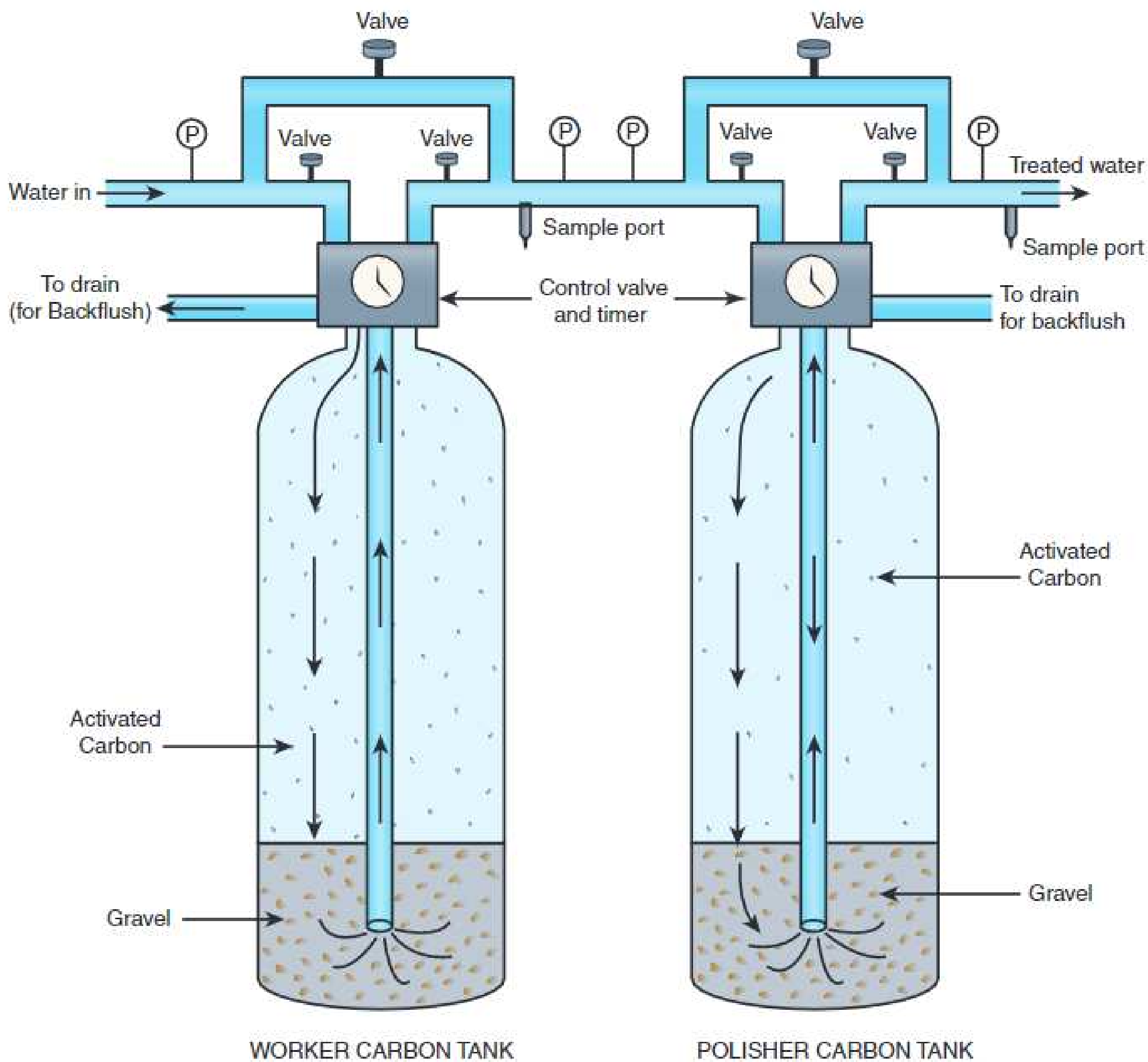
Water Softener



Monitoring the Water Softener

- Measurement of water hardness in grain per gallon (GPG) or parts per million (PPM) is used to monitor the efficiency of the water softener.
- Water hardness can be measured on site using colorimetric test strips. Personnel performing the testing should be able to distinguish between the colors on the test strips. There should be a well labeled water sample port post water softener for the measurement of hardness.
- Source water hardness should be compared with treated water hardness periodically.
- After treatment by the water softener the water should measure 1 GPG (17 PPM) or less.
- The hardness should be checked at the end of the day so that the capacity of the water softening system is fully appreciated.
- The brine tank should be checked daily to ensure that the solution is adequately supplied with sodium chloride (e.g. salt pellets are above the level of the water and are not forming a salt bridge).
- Pressure drop across the softener should be monitored regularly. Pressure change of > 10 mmm Hg above baseline suggests a problem with the resin bed.
- Regeneration of the softener resin should take place during a time when patients are not on dialysis.
- Timers set for automatic softener regeneration should be monitored to ensure that regeneration does not occur during facility operating hours. There is potential for high concentration of sodium to enter the water if regeneration occurs during dialysis treatments. Conductivity monitors on the RO system should alarm if high sodium concentration is detected, however, they should not be relied upon exclusively.

Carbon Tanks



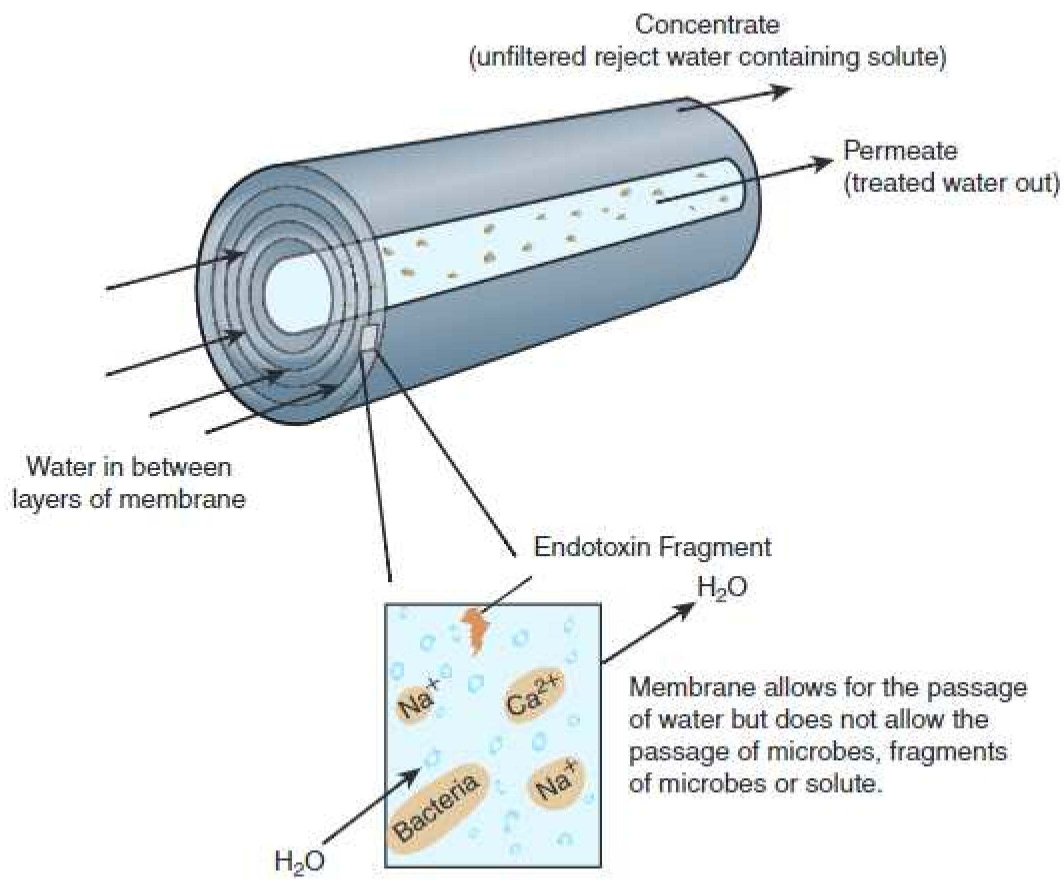
Monitoring the Carbon Tanks

- Testing for chlorine and chloramine is utilized to monitor the function of the carbon tanks.
- The allowable limit for chlorine is 0.5 PPM and for chloramine 0.1 PPM.
- There is no way to directly test for chloramines. Indirectly it can be measured by comparing the difference between the total chlorine and free chlorine.
- Chloramine Level = Total Chlorine Level – Free Chlorine Level
- Most units do not check both free and total chlorine. It is acceptable and simpler to test only total chlorine with an allowable limit of < 0.1 PPM.
- Chlorine tests are usually done with colorimetric strips. Personnel performing the tests should be able to distinguish differences in color change.
- Alternatively, on-line monitors can be used in accordance with manufacturer's specifications.
- The testing should be done after the first carbon tank (worker) from a well labeled sample port. If the worker sample is not acceptable then the water should be tested from a sample port following the second carbon tank (polisher). If the polisher sample is acceptable then dialysis can continue but plans should be made to replace the failing worker carbon tank and consideration should be given to increasing the frequency of testing while running on a single tank. If the sample post polisher does not meet the allowable limit then dialysis cannot continue until the problem is fixed.
- Testing should be performed at the start of the day and every 4 hours while patients are on dialysis.
- Testing at the start of the day should occur after allowing the system to run for 15 minutes.

Monitoring the Carbon Tanks

- The carbon tanks must supply an EBCT of at least 10 min. The EBCT should be calculated periodically to ensure that the goal is met. In addition, changes in water flow (such as when adding stations to a unit) or carbon tank volume should prompt a recalculation of the EBCT.
- Pressure drop across each of the carbon tanks should be monitored with > 10 mmHg difference above baseline suggesting a problem such as fouling of the tank with particulate matter.
- Back-flushing of the carbon tanks should occur during hours when the facility is not in operation. Timers set for automatic back-flushing should be monitored regularly to ensure that they are set to the correct time.
- The risk for patient injury when the carbon tanks fail is high. Therefore, rigorous monitoring and routine recording and review of the function of the carbon tanks are mandatory.

Reverse Osmosis



Monitoring the RO system

- Pressure and flow are measured at various points in the RO system to ensure proper function
- Conductivity is utilized to monitor the removal of solute by the RO system. Conductivity describes the ability of the water to conduct electrical charge. If more dissolved solute is present, water will conduct electricity more readily.
- The conductivity of product water from the RO is monitored continuously during RO operation and often displayed as total dissolved solids or TDS.
- The percent rejection of a RO system describes the ability of the system to remove solute thus reducing conductivity in the product water, and can be thought of as the percent of solute that was removed from the water during reverse osmosis. The percent rejection is calculated using the following formula:

  % Rejection = [(Feed water conductivity – Product water conductivity) / Feed water conductivity] * 100
- Modern RO systems will monitor and display the percent rejection in real time during operation.
- There is no absolute value that is desirable for the percent rejection. Rather, the dialysis facility should use the percent rejection to monitor the efficiency of the RO over time.
- The dialysis facility should take into account the source water composition, the percent nominal passage through the RO of each of the water contaminants with the given RO specifications from the manufacturer, the composition of the treated permeate water and based on these values; calculate the lowest % rejection at which the treated water still meets AAMI requirements as listed in table 1. Alarms set points can then be established on the RO system when the desired % rejection is not achieved.

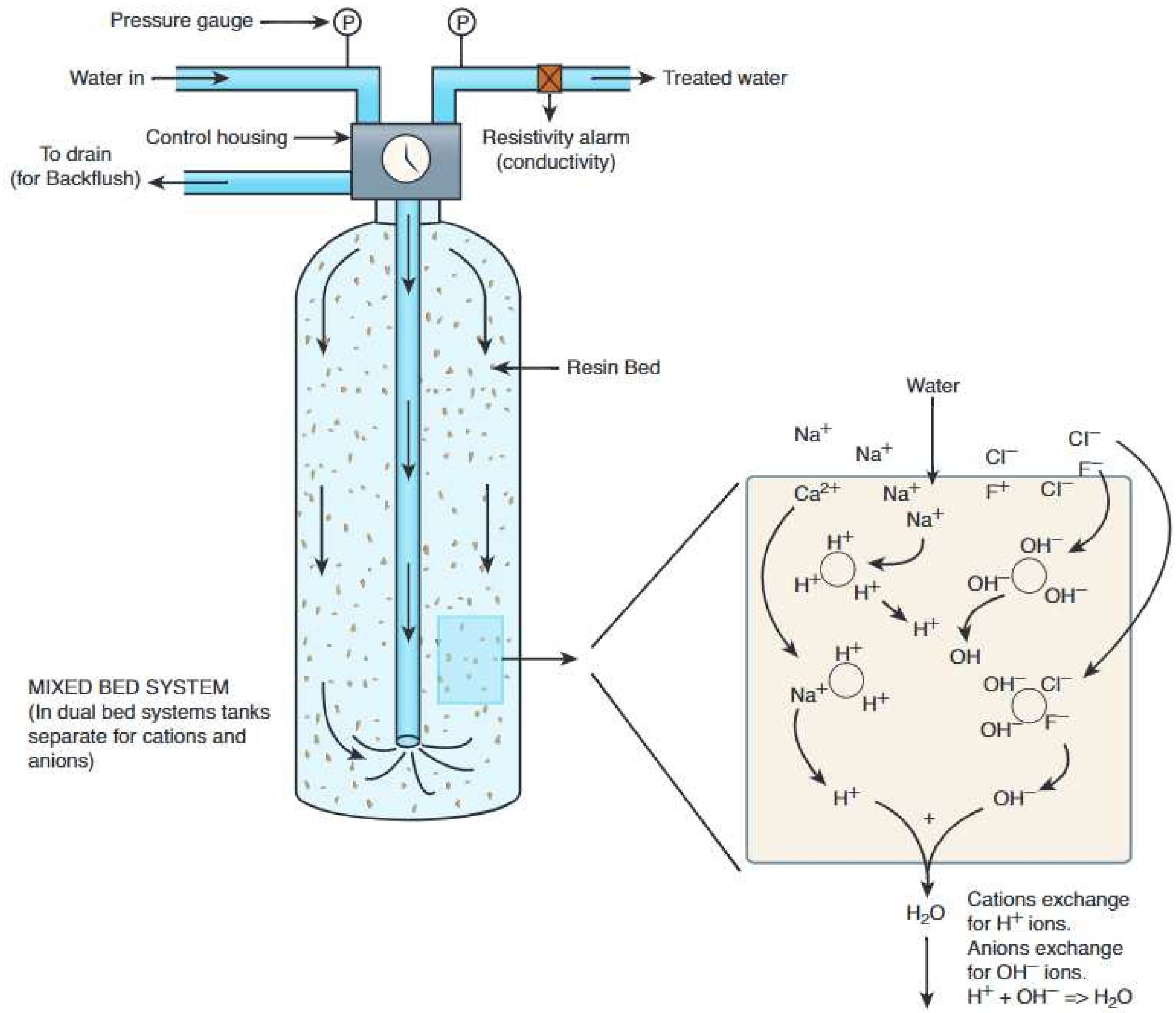
Monitoring the RO System

- Percent recovery (also known as the water conversion factor) can be used to monitor the performance of the RO system. The percent recovery can be calculated using the following formula, where Q is the flow rate:

  % Recovery = [Permeate Q / (Permeate Q + Reject Q)]*100

- The percent recovery does not inform water quality. Rather, it is useful for trending the performance of the RO membrane. Membranes that become fouled over time will drop their percent recovery. Permeate flow rate can vary due to changes in pressure and temperature as well. For example, a seasonal decrease in water temperature would be expected to decrease the percent recovery.
- The various measures of RO function; pressure, flow, conductivity, % rejection, %recovery, etc., should be recorded in a daily treatment log for regular review and trending analysis.

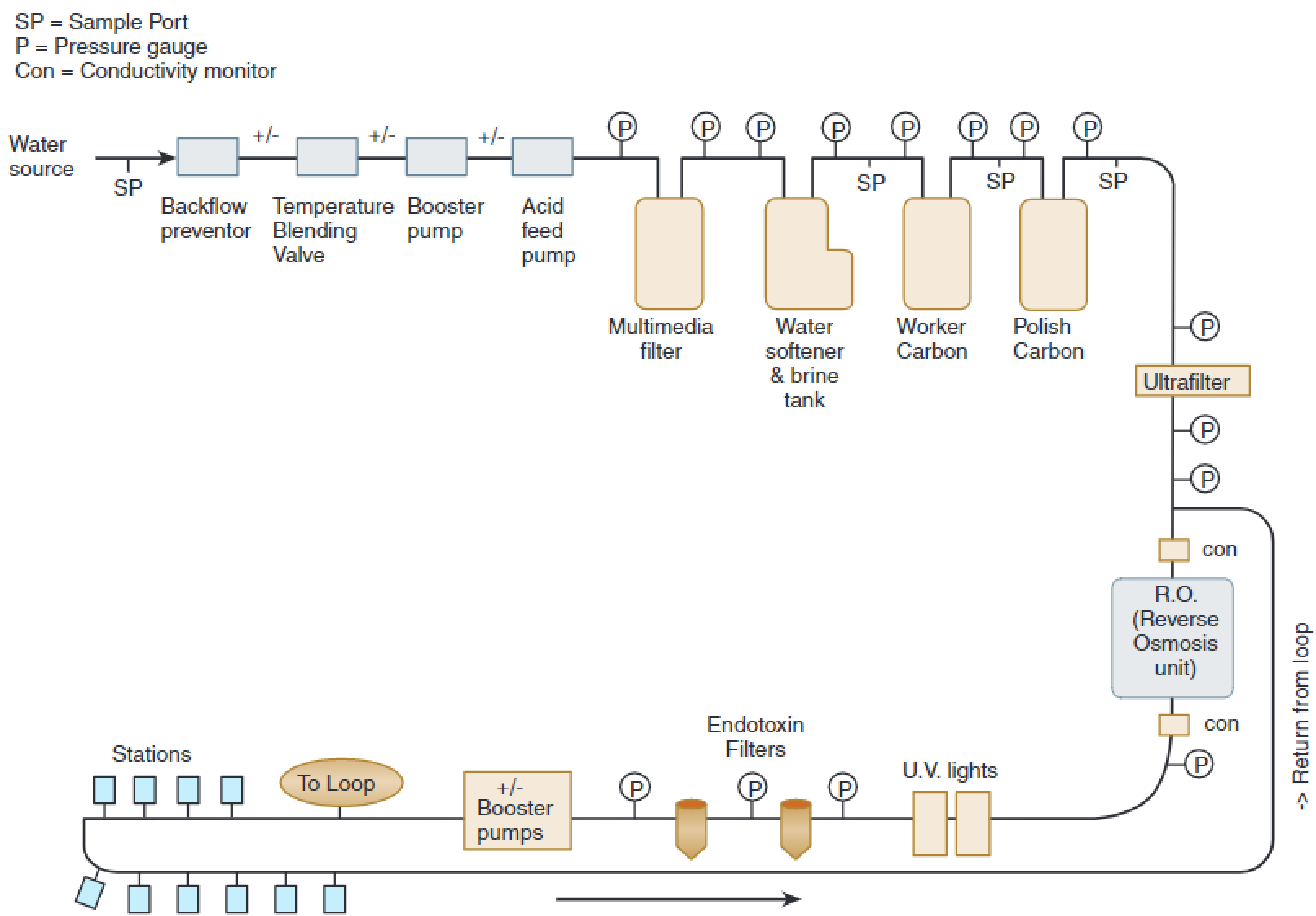
Deionization (DI)



Monitoring the DI

- Deionizers are monitored continuously using a resistivity meter. Resistivity is the inverse of conductivity and describes the opposition of water to electrical current. The higher the resistivity, the more pure, or solute poor, the water.
- Treated water should have a resistivity of 1 MΩ·cm or more. Water with resistivity less than 1 MΩ·cm should not be used. Pure water has a resistivity of around 18 MΩ·cm. Resistivity monitors should be equipped with alarms to alert staff when resistivity is not appropriate. There should be an automatic divert to drain if the resistivity drops below 1 MΩ·cm.
- Resistivity should be recorded at least twice daily and trends reviewed regularly.
- Deionizer systems are prone to contamination with bacteria and should be monitored closely for microbiologic contaminants.
- Pressure pre and post deionizer should be monitored. Pressure drop of > 10mmHg above baseline can indicate de-ionizer fouling with particular matter or resin breakdown.

Loop Design


SP = Sample Port
P = Pressure gauge
Con = Conductivity monitor
Water source
SP
Backflow preventor
+/-
Temperature Blending Valve
+/-
Booster pump
+/-
Acid feed pump
P
SP
Multimedia filter
Water softener & brine tank
Worker Carbon
Polish Carbon
Ultrafilter
con
R.O. (Reverse Osmosis unit)
-> Return from loop
U.V. lights
Endotoxin Filters
+/- Booster pumps
To Loop
Stations

Monitoring the Loop

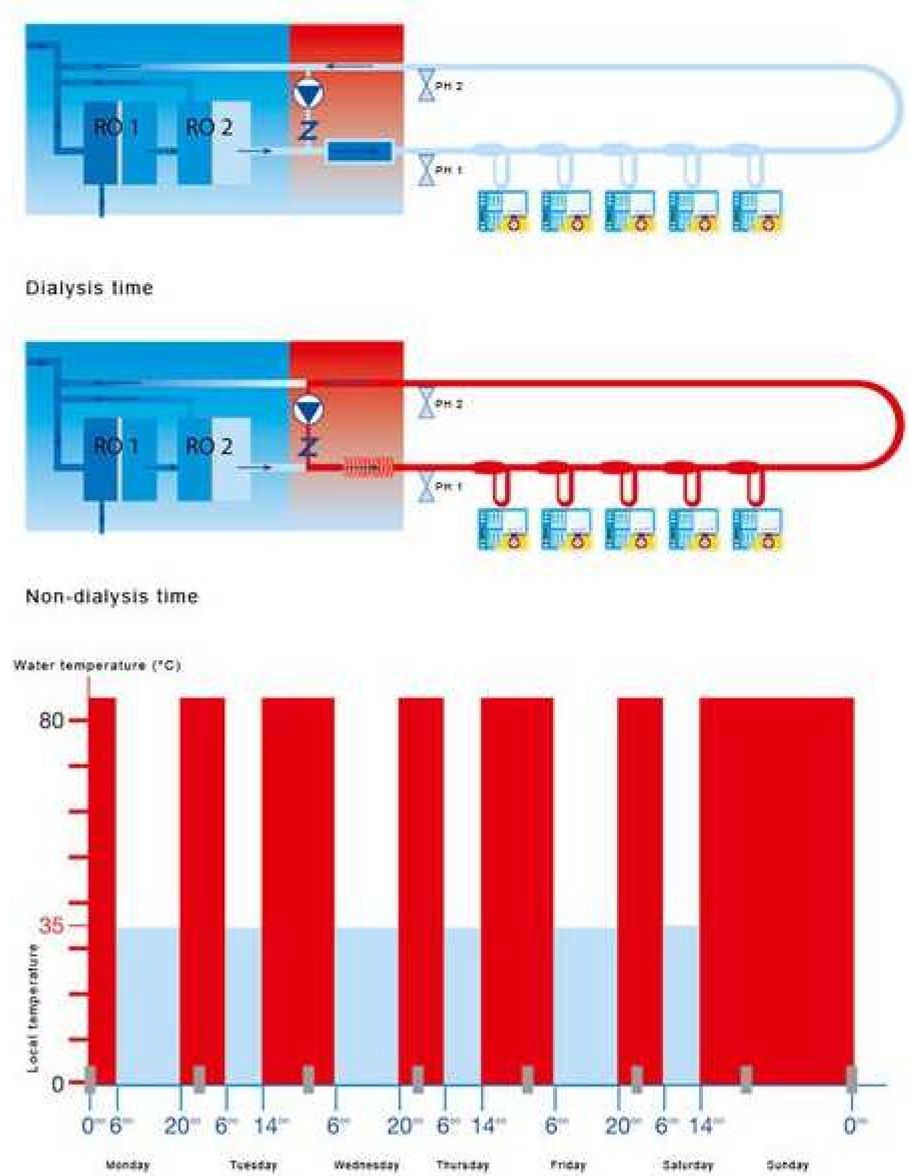
- Flow velocity through the loop should be at least 3 ft/s for indirect systems and at least 1.5 ft/s in direct systems. Flow velocity is calculated using the following formula $V = Q / A$, where V is the flow velocity, Q is the flow and A is the cross sectional area of the pipe.
- Flow rate should be measured at the end of the loop during peak usage.
- Regular flow rate measurements can be used to calculate flow velocity to ensure that the velocity is meeting requirements. Measurements should be documented for routine review.

New System: Aquaboss (Lauer)

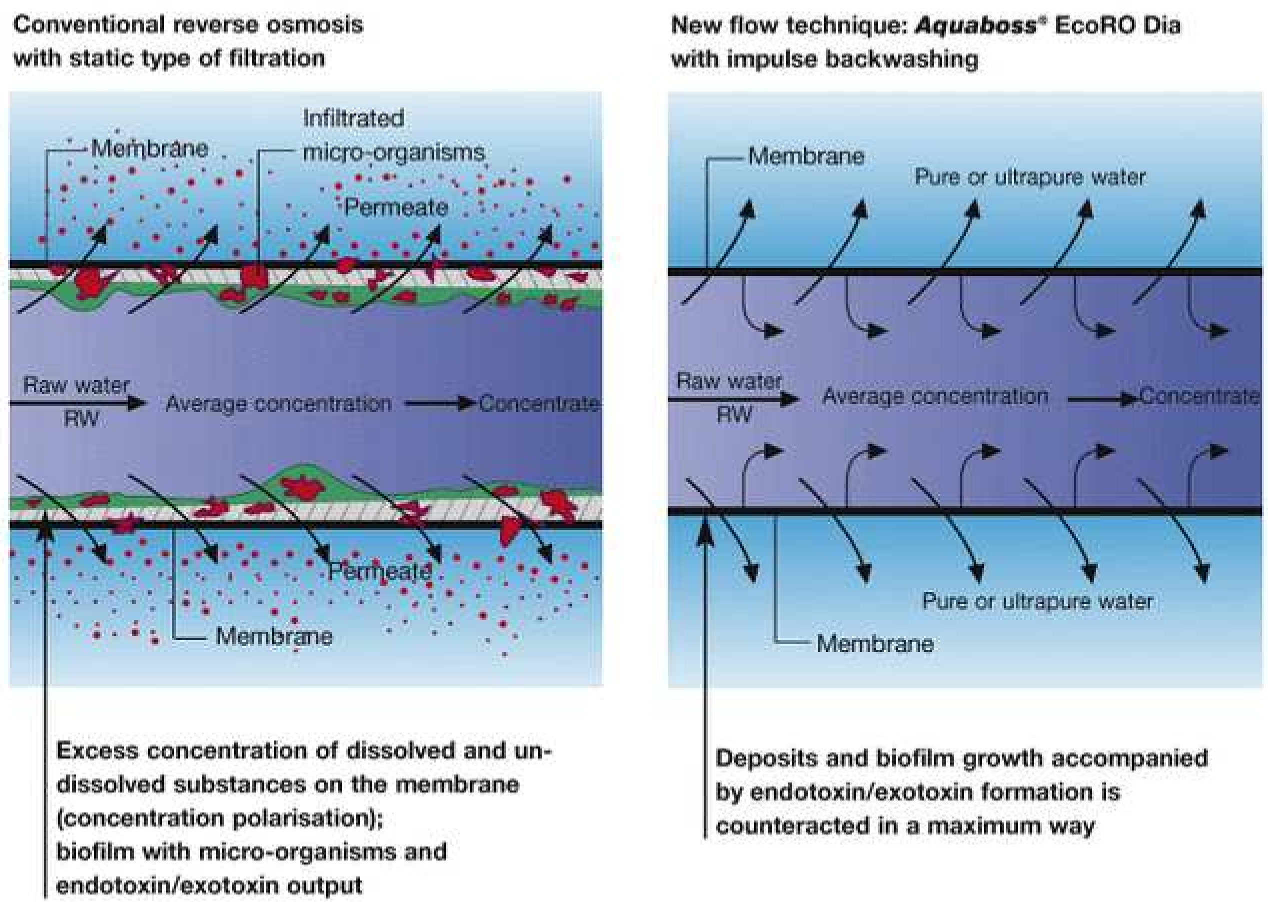
More water efficient than system currently in use

Heat Disinfection

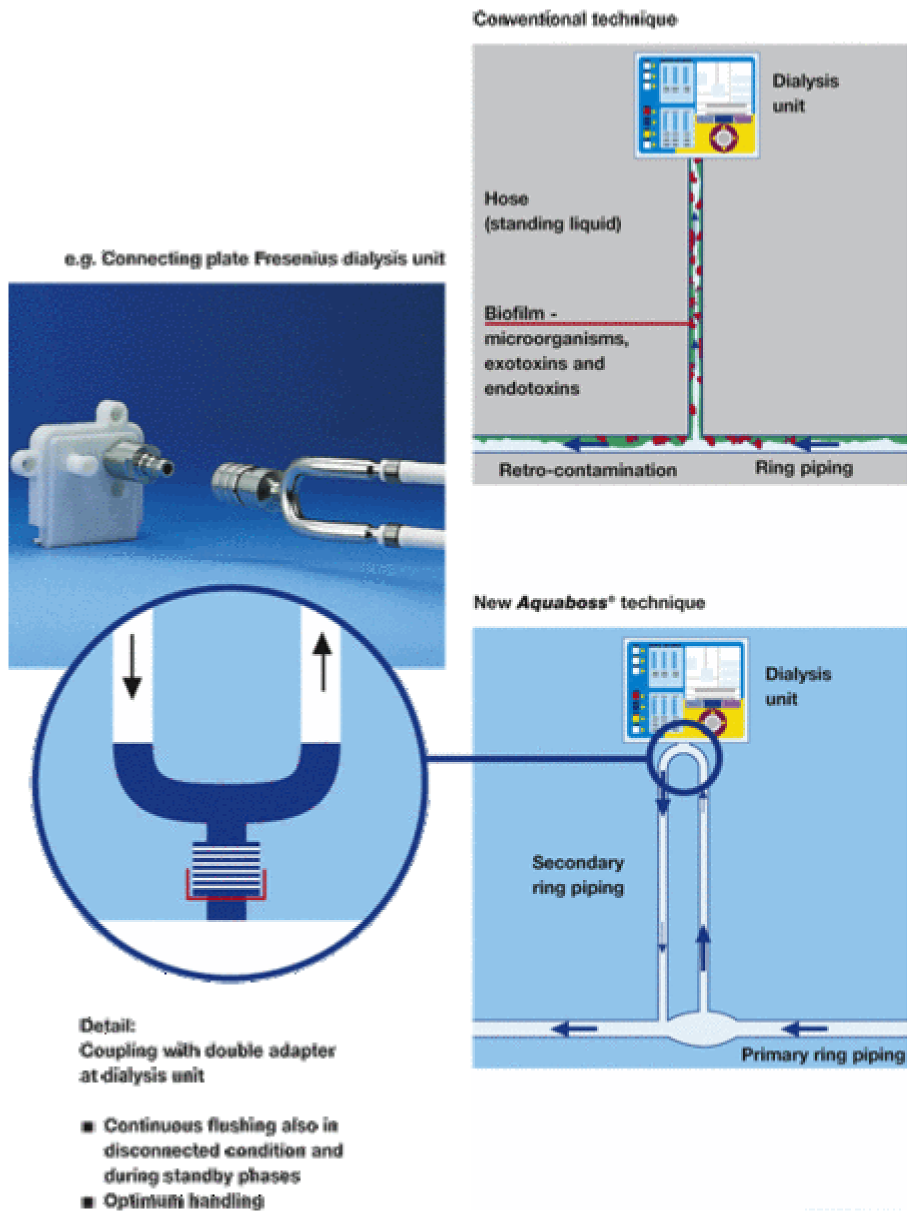
- No more mincare!
- May provide better sterility of loop



RO membranes backwash



Less Dead Space in Loop



Water treatment is important!

- When water systems change patients can be vulnerable to system failures
- Water system will be monitored closely after installation
- Keep a eye out for any potential problems and take action quickly to ensure patient safety