Hemodialysis Water Treatment Systems Review

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Comparisons - Drinking Water and Dialysis Water Volumes

- Average person drinks 10-14 liters/week
- Average dialysis patient is exposed to about 432 liters/week of dialysate.
- 800 ml/min DFR x 180 min/tx. x 3 tx./wk divided by 1000 ml/l = 432 l/wk
Why Water Must be Treated

Average Person
- Drinks 14 liters of water/week
- GI tract more selective
- Functioning kidney

Person on Hemodialysis
- Blood is exposed to 340+ liters of water/week
- Dialyzer membrane is thin, non-selective
- Nonfunctioning kidney
- Can experience harm or death from untreated water

10 - 14 Liters

350 - 450 L.
CONTAMINANTS COMMONLY FOUND IN WATER

- INORGANIC CONTAMINANTS
- ORGANIC CONTAMINANTS
- MICROORGANISMS
Inorganic Contaminants

- Chlorine and Chloramine
- Sediment and Particles
- Salts and Other Chemicals
- Metals and Heavy Metals
Organic Contaminants

- Pesticides
- Herbicides
Microorganisms & Biofilm

- Some bacteria adhere to a surface and secrete a gelatinous substance to protect themselves and offer an endless food supply.
- Difficult to remove.
- Erratic bacterial culture results:
  - No growth one day, Too Numerous to Count (TNTC) another day.
  - The test for endotoxin, called LAL, may be either positive or negative.
Endotoxins

- Part of a bacterial cell wall
- May come into contact with the patient’s blood through the dialyzer membrane
- May cause a pyrogenic reaction which is characterized by fever and chills
- Keeping the bacterial level in the water low helps to control endotoxin levels
Pyrogenic (Endotoxin) Reaction

- Occurs any time during or after treatment
- Severity of reaction is directly proportional to amount of endotoxin exposure
- Symptoms
  - Uncontrollable shaking, chills, fever, nausea and vomiting, low blood pressure
Water Microbiology

Water used to prepare dialysate should meet the following criteria:

**Bacteria:**
- 200 cfu/ml – max limit
- 50 cfu/ml – action level

**Endotoxin:**
- 2 EU/ml – max limit
- 1 EU/ml – action level

Action levels indicate when action should be taken and allow the user to take steps to maintain water quality and patient safety prior to the potential occurrence of adverse events.
Pre-Treatment Components

- City Water Inlet
- Back flow preventer
- Temperature Blending Valve
- Booster Pump
- Depth filter or Multimedia filter
- Carbon Tanks / Carbon Blocks
- Water Softener
City Water Inlet

City water (feed water) is the start of the fluid pathway.
Backflow Preventer

The back flow preventer is a one-way valve that stops water and/or disinfectant from the water treatment area or the dialysis unit from going backwards into the city water supply.
The temperature blending valve blends water from the hot water heater and tap water to achieve the desired temperature as it enters the water treatment system.
Booster Pump

The booster pump boosts water pressure from around 40 psi to around 60-80 psi (pounds per square inch)
Carbon Tanks

- Inlet
- Outlet
- Sample port
- Media bed
- Underbed media

Like a magnet, the charcoal absorbs chloramines.
Two tanks are commonly used and sample ports are placed between the worker and polish carbon.

- Exhausted tanks are replaced or re-bedded as soon as possible after chloramine breakthrough has occurred.
Carbon Blocks

- Basically a large Carbon Filter
- Lighter and smaller making them favorable to larger tanks.
- Don’t Usually last as long as tanks
Micron Filter (1-5 micron)

- Filter is used after carbon tanks to help trap small particles and carbon fines.
- Filter is used before carbon blocks to remove particles that may clog filter surrounding carbon in block.
Chlorine & Chloramine

- Added by municipal water company to kill bacteria, fungi, and viruses
- Both easily cross the dialyzer membrane and can cause HEMOLYSIS - the bursting of red blood cells.
- Testing for chlorine and chloramine is done prior to each patient shift usually between each carbon tank to check for breakthrough.
- Chlorine and Chloramine level should be less than or equal to 0.1 mg/L
The Water Treatment System Components

Water Softener

- Removes calcium and magnesium in exchange for sodium, reducing the hardness prior to RO treatment.
Testing for Hardness

- Water hardness is partially due to the presence of calcium carbonate (CaCO3) and magnesium carbonate (MgCO3) in the water.
- Hardness should be checked prior to every shift to ensure softener is working.
- These chemicals will scale the R.O. membrane.
- Precipitation and scaling is accelerated at pH > 8.0.
Testing for Hardness

- Water hardness is expressed as grains per gallon (gpg) of CaCO3
- Hardness test kits sometimes give results in mg/L or ppm (1 mg/L = 1 ppm)
- 17.1 ppm is equal to 1.0 gpg
RO Inlet Filter (1-5 Micron) Pre Filter

- Helpful in maintaining good operation of the equipment
- Removes particles that can damage pumps and membranes
- Catches solutes or particulate 1.0 - 5.0 microns or greater
The Water Treatment System Components

Reverse Osmosis (R.O.)

- The heart of the water treatment system
- The R.O. is able to filter out 96-99% of contaminants
New RO systems that utilize Heat Disinfection are gaining popularity due to ease of use with automated cycles and end to end disinfection possibility.
Reverse Osmosis

- Produces AAMI quality water for dialysis
- The RO membrane removes:
  - Removes impurities larger than 0.01 microns, including bacteria, endotoxin, viruses
  - 90 - 99% of dissolved impurities such as Na\(^+\), Ca\(^+\) and Chloride
Reverse Osmosis

Overview of Osmosis and Reverse Osmosis

OSMOSIS

Osmotic pressure

Semipermeable membrane

Water
Solution

REVERSE OSMOSIS

Hydrostatic pressure

Water
Solution
**RO Performance**

- We monitor Product TDS and Percent Rejection as quality indicators.
- TDS or Total Dissolved Solids is the amount of electrically charged substances present in water, i.e. Ca, Mg, Cl, fl
- Percent Rejection is a measurement of how well the RO membrane is removing those substances.
TDS Verification

- The RO measures total dissolved solids (TDS) as a means of determining percent rejection.
- For example, if the city water TDS was 200, and the product was 2, then the rejection is 99%.
- This is calculated by taking feed TDS – product TDS / feed TDS x 100.
TDS vs. Rejection

- Feed TDS will fluctuate (based on where water is coming from and how it is treated by municipality) and thus product TDS will also fluctuate.

- Because TDS can vary, Rejection is an important parameter to watch. The TDS gives you more information about the incoming water, whereas the rejection shows you more about membrane performance.

- As Percent Rejection decreases, the quality of Product water decreases also.
DI Tanks (optional)

- Deionizers, if used, must be continually monitored with a temperature compensated resistivity monitor.
- Resistivity must be 1 megohm-cm or greater in order to do dialysis.
- Usually used as back up if RO goes down.
DI - Ion Exchange

Cation Resin Bead

Hydrogen Ions

Anion Resin Bead

Hydroxyl Ions

H₂O
Ultraviolet (UV) Light

Ultraviolet irradiation may be used as a means of destroying water-borne bacteria.
Ultra Filters (optional)

- Filters smaller particles such as bacteria and endotoxin
- Usually used on return loop to storage tank if one is being used.
The Water Treatment System Components

Storage Tank
- Holds product water for future use.
- RO can also be direct feed, therefore eliminating need for storage tank.
RO Cleaning & Disinfection

- A low pH (acid) cleaner is used to remove scale and iron from the RO membrane
- A high pH (alkaline) cleaner is used to remove organics and silt from the RO membrane
RO Cleaning and Disinfection

Key Points:

- Acid cleaner must be performed before base cleaner in order to remove iron and scale.
- Each cleaner must be COMPLETELY rinsed before introducing the next chemical.
- It is recommended that membranes be cleaned prior to disinfection.

Rationale:

- Mixing chemicals used in cleaning can create a reaction which may damage the RO membrane.
- Disinfectants may damage the membrane by reacting with minerals and other materials not cleaned from the membrane.
RO Cleaning and Disinfection

Key Points:
- The RO should be disinfected at least monthly or as needed based on bacteriology results

Rationale:
- This time period may be lengthened or shortened depending upon water culture results.
Current Popular Portable RO Options
Aquaboss RO

- Output 18.5 GPH @ 50° F
- Low pH clean only, with citric acid.
- Must do cleaning prior to disinfect.
- Disinfect with Minncare cold sterilant.
- Dual product hose, break tank, digital display, internal conductivity meter
Millenium

- Millenium, Zyza, etc. all recommend an acid (low pH) clean and a base (high pH) clean prior to disinfect.
- Using an approved acid (low pH) cleaner removes iron and other metals.
- Using an approved base (high pH) cleaner removes silt and organics.
- Disinfect using Minncare.
- Output 31.2 GPH @ 77° F
Millenium HX

- Heat Disinfection
- Color Touchscreen
- In-line sample port
- Output 31.2 GPH @ 77° F
- Pricey?
WRO 300 & 300H

- Heat Disinfect in the H model
- Dual Product Hose (inc. recovery)
- Output 18GPH @ 50° F
- Very quiet
Better Water PB II

- Acid and Base cleaning recommended
- Disinfect with Minncare.
- Output 411.6 GPH @ 77° F
- Possibility of running two HD machines with one RO due to High Output
Ameriwater MROS

- Rather large
- Weighs 132 lbs.
- 33 GPH output @ 77°F
References

Aquaboss® ECO 70 Quick Reference – P/N 51294 Rev E, Fresenius Medical Care, Walnut Creek, CA USA


Mar Cor Purification – Millenium™Reverse Osmosis Unit Operation and Maintenance Manual P/N 1236572 Rev. F


Water Treatment for Hemodialysis App. RD62:2006. Association for the Advancement of Medical Instrumentation. Arlington, VA, USA

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