Water Treatment Systems

And Monitoring To Ensure Patient Safety
Objectives

At the end of this presentation the learner will be able to:

- Understand where our water comes from. Understand how our water is treated before it gets to us.

- What chemicals are added and their effects on patients if exposed.

- Understand components of water treatment system and how each one operates and is monitored to ensure water integrity and PATIENT SAFETY

- Understand the importance of creating a culture of safety.
WATER
The SOURCE OF LIFE
Water for hemodialysis patient can be a great hazard if not:

- Properly purified
- Properly monitored
- Properly Tested
- Properly mixed when preparing solutions.
The average healthy adult drinks 10 to 15 liters of water per week.
A Hemodialysis patient is exposed to greater than 300 liters of water per week

Why is this important?
Where does our water come from?

2 main water sources

- Ground water (wells and springs)

- Surface water (lakes, ponds, rivers, streams)
Ground Water

- Often high in iron, calcium and magnesium
- Lower in microorganisms (bacteria, viruses and endotoxins)
Surface Water

- Usually high in pesticides, industrial waste, sewage and micro-organisms
City municipalities have to remove organic and inorganic items from the water...
Municipal Water Treatment

Screen Filtered
- To remove large debris such as leaves, rocks, twigs etc..

Clarity
- Aluminum Sulfite and Calcium Hydroxide are added to bind with small particles and sink to the bottom.
Municipal Water Treatment

Disinfection

- Chlorine and/or Chloramines are added to control bacteria and viruses.

- Other chemicals may be added to obtain proper pH balance to prevent corrosion of pipes or leaching of metals into the water supply.

- Fluoride may also be added to prevent tooth decay.
Flint Michigan
Municipal Water Treatment

- These chemicals are harmful to dialysis patients...

- Chemicals MUST be removed before providing hemodialysis treatments.
### Chemical Contaminants and their effects

<table>
<thead>
<tr>
<th>Chemical Contaminant</th>
<th>Maximum limit in Dialysis Quality Water</th>
<th>Symptom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>0.01</td>
<td>Neurological damage</td>
</tr>
<tr>
<td>Endotoxins</td>
<td>&lt;1EU/ml</td>
<td>Fever and chills</td>
</tr>
<tr>
<td>Chlorine/Chloramines</td>
<td>0.10</td>
<td>Hemolysis of red blood cells</td>
</tr>
<tr>
<td>Fluoride</td>
<td>0.20</td>
<td>Bone disease</td>
</tr>
<tr>
<td>Nitrates</td>
<td>2.0</td>
<td>Hemoglobin cannot transport oxygen</td>
</tr>
<tr>
<td>Lead</td>
<td>0.005</td>
<td>Metallic taste; anemia</td>
</tr>
</tbody>
</table>
Why is WATER so IMPORTANT??

- Every patient, every shift is exposed to water treatment system.

- Water treatment system is the “heart” of the dialysis facility. Without water you cannot perform treatments.
Why is WATER so IMPORTANT??

- One mistake can be serious, and worse deadly!
Ensure Safety

- Education, Education, Education!
- Policy and Procedures
- Audits for compliance
Ensure Safety

- Understand each component of your water system and how to monitor the system and notify your biomedical staff when there are changes.

- Understanding rules, regulations, policies and procedures.
Rules and Regulations

- Centers for Medicare and Medicaid Services (CMS) Conditions For Coverage (CFC)
  - Last updated 2008

- Adopted Association for the Advancement of Medical Instrumentation (AAMI) standards as regulation. (RD52, RD62, RD47)

- Regulations for water treatment and maintenance including comprehensive interpretive guidance.
# AAMI Water Analysis

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Maximum Concentration mg/L (Unless otherwise noted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>2 (0.1 mEq/L)</td>
</tr>
<tr>
<td>Magnesium</td>
<td>4 (0.3 mEq/L)</td>
</tr>
<tr>
<td>Potassium</td>
<td>8 (0.2 mEq/L)</td>
</tr>
<tr>
<td>Sodium</td>
<td>70 (3.0 mEq/L)</td>
</tr>
<tr>
<td>Antimony</td>
<td>0.006</td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.005</td>
</tr>
<tr>
<td>Barium</td>
<td>0.10</td>
</tr>
<tr>
<td>Beryllium</td>
<td>0.0004</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.001</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.014</td>
</tr>
<tr>
<td>Lead</td>
<td>0.005</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.0002</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.09</td>
</tr>
<tr>
<td>Silver</td>
<td>0.005</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.01</td>
</tr>
<tr>
<td>Total Chlorine</td>
<td>0.10</td>
</tr>
<tr>
<td>Copper</td>
<td>0.10</td>
</tr>
<tr>
<td>Fluoride</td>
<td>0.20</td>
</tr>
<tr>
<td>Nitrate</td>
<td>2</td>
</tr>
<tr>
<td>Thallium</td>
<td>0.002</td>
</tr>
<tr>
<td>Sulfate</td>
<td>100</td>
</tr>
</tbody>
</table>
AAMI Water Analysis

- At installation of new water systems
- No less than annually
- When RO membranes are changed
- Seasonal variations in source water
- RO Rejection rate falls below 90%
- Tap, RO product
The Water Room Tour
The Water System...

- Consists of 3 main sections
  - Feed water components
  - Pre-treatment components
  - RO product water and distribution components
4 Questions?

1. What is it?
2. What does it do?
3. How do we monitor it?
4. What is the adverse impact on the patient?
Water room access MUST be restricted for patient safety
Water Treatment Room

- Should be clean in general
- Access to all components including meters, gauges, and sample ports
- No clutter
- No supplies on the floor
- Spills cleaned immediately
- No leaks
Water System Diagram
Water System Diagram

- Schematic of the water system.

- Reflects the actual layout of the water system and its components.

- Identifies valves, gauges and sample locations and flow direction.

- Must be updated if the components are changed.
Water system Labeling

- Identifies the device.
- Functionality.
- How performance is verified.
- Actions to take in the event of malfunction.
- Piping labeled with direction of flow.
Feed Water Components

- Backflow Prevention
- Booster system
- Water Heater
- Tempering valve
Backflow Prevention

- Anti syphon device
- Prevents reverse flow of water.
- Visual monitoring for leaks and pressure drops.
- If it fails must be repaired by certified licensed plumber
- Could result in temporary facility closure.
Variable Speed Booster System

- A pump with computer controlled variable speed
- Maintain optimum system pressures
- Visual monitoring for leaks and pressure drops.
- If fails there may not be enough pressure for system to operate.
- Could result in temporary facility closure.
Water Heater

- Heating of incoming water.
- Assist in the maintenance of optimal water temperature.
- Monitored by temperature gauge.
- May cause reduced RO production during the winter months.
Tempering Valve

- Heating of incoming water.
- Assist in the maintenance of optimal water temperature.
- Monitored by temperature gauge.
- May cause reduced RO production during the winter months.
Pre-Treatment Components

- Sediment (multimedia) Filter
- Water Softener/Brine tank
- GAC Tanks
Multimedia Filter

- A multimedia filter consists of layers of different sized particles.
- Remove suspended solids from incoming feed water.
- Visual monitoring for leaks, pressure drops and timers.
- If not back washed properly could cause decreased pressure and possible disruption of RO machine operation.
Multimedia Filter

- Typically contains 3 layers of media, anthracite coal, sand and garnet and a non filtering layer of gravel.
- Filters down to approximately 10 microns
Control Head

Must verify time of day is correct.

Notify biomedical technician if timer isn't incorrect.
Sediment Filter Regulation

- Opaque housing
- Fitted with gauges
- Monitored daily for Delta P
- Timers checked daily and logged
Water Softener

- Contains ion exchange resins that attract positively charged ions.
- Removes calcium and magnesium ions via ion exchange.
- Visual monitoring for leaks, pressure drops, timers and total hardness.
- Undetected hardness breakthrough could result in damage to RO membranes decreasing their ability to filter bacteria and endotoxin.
Water Softener

Heavy concentration of calcium and magnesium ions in raw water

Sodium ions

Ion exchange beads

Calcium ions & magnesium ions get attached to resin beads

Hard water laden with calcium and magnesium ions come in contact with millions of sodium ions which are attached to the resin beads.

The process of ion exchange takes place where in the sodium ions are exchange for calcium and magnesium ions resulting in the formation of soft water.
Brine Tank

- Filled approximately ½ with water and salt pellets.
- Used in the regeneration of the softener tank.
- Visual monitoring for leaks, salt level (above the water level) and salt usage.
- If brine concentration is not maintained, proper softener tank regeneration will not be achieved resulting in possible hardness breakthrough.
Salt Bridging

- A dome of salt is formed just above the water level.
- Can result in inadequate softener regeneration.
- Caused by too much salt being put into the tank at one time
Water Softener Regulation

- Auto regeneration softeners must be fitted with a lock out to prevent water containing high levels of sodium chloride from entering the product water line during regeneration.
- Timers must be checked at the beginning of each day and should be interlocked with the RO machine to ensure that the RO is stopped during the regeneration cycle.
Water Softener Regulation

- The softener brine tank should be monitored daily to ensure that saturated brine solution exists in the brine tank.
- Salt pellets should fill at least ½ of the tank.
- Total hardness should be measured at the end of each operating day using a total hardness measuring method that is recommended by the manufacturer.
Carbon Tanks

- Contains Granular Activated Carbon (GAC).
- Removes Chlorine, Chloramines and other organic and inorganic materials.
- Visual monitoring for leaks, pressure drops, timers and total chlorine levels.
Carbon Tanks

- There must be 2 tanks or banks of tanks in series.

- Minimum 10 minutes Empty Bed Contact Time.

- Tested approximately every 4 hours for total chlorine.

The empty bed contact time:

\[ EBCT = \frac{V}{Q} \times 7.48 \]

- \( V \) is the volume of carbon
- \( Q \) is the flow rate in gallons per minute
Carbon Tanks

- Carbon tank malfunction resulting in chlorine breakthrough is extremely hazardous and even deadly for dialysis patients. When this occurs, treatments MUST be stopped immediately.
Carbon Adsorption Regulation

- Minimum 2 tanks or banks of tanks in series.

- Sample ports following the first and second tanks.

- Minimum EBCT of 5 minutes per tank.
Carbon Adsorption Regulation

- Granular Activated Carbon
  - Minimum Iodine number 900
  - Acid washed
  - 12X40 mesh size

Regenerated carbon may not be used.
Carbon Adsorption Regulation

- Chlorine Testing
  - Performed prior to the start of the first patient treatment of the day and before the start of each patient shift. If there is no set patient shift, testing should be performed approximately every 4 hours.
  - Tests used must be of sufficient sensitivity to indicate levels at or below 0.1ppm total chlorine
  - Reverse Osmosis system must be running for at least 15 minutes prior to drawing the specimen.
Chlorine and Chloramine are very hazardous to Dialysis patients!

- To ensure patient safety intensive monitoring of the carbon bed performance is necessary.
- When breakthrough occurs on the first tank Dialysis treatments MUST be stopped immediately.
- The Medical Director must be notified and with his/her approval treatments may be continued with increased testing frequency at the second output of the second carbon bed.
- Exhausted carbon media must be replaced within 72 hours.
RO product Water and Distribution System Components.

- Reverse Osmosis Machine
- Water Storage Tanks
- UV lights
- Ultra Filters
Reverse Osmosis (RO) Machine

- Primary purification device.
- Filters bacteria and endotoxin primarily.
- Visual monitoring for leaks, pressure drops, Total Dissolved Solids (TDS) and Rejection rate.
- Failure could result in temporary facility closure pending repairs.
Reverse Osmosis (RO) Machine

Direct feed

• Product water goes directly to patient stations and mixing equipment.

• Machine runs continuously throughout the treatment day.

Indirect feed

• Product water goes to a storage tank.

• Machine runs periodically depending on demand.
Reverse Osmosis (RO) Machine Regulations

- Follow MFG instructions for feed water monitoring.

- Documented daily on a log for trending purposes.

- Equipped with on-line monitors to allow determination of rejection rates and product water conductivity.

\[
\% \text{Rejection} = \frac{\text{Tap TDS} - \text{RO TDS}}{\text{Tap TDS}} \times 100
\]
Reverse Osmosis (RO) Machine Regulations

- Audible and visual alarms present when conductivity exceeds preset alarm limit.

- Alarms must be audible in the patient care area to alert staff that there is a water quality issue.

- Fitted with product water diversion devices which are activated when water quality parameters are violated.
Water storage tank

- Water storage and distribution device.
- Water distribution to dialysis stations.
- Visual monitoring for leaks.
- Failure could result in temporary facility closure pending repairs.
Water Storage Tank Regulations

- Conical or bowl shaped base and drain from the lowest point.
- Have a tight fitting lid and vented through a hydrophobic 0.2 micron air filter.
- A pump made of inert materials.
Distribution Loop Regulation

- Configured as a continuous loop (no dead legs) to minimize bacteria proliferation.

- Must be constructed of materials that will not leach chemicals or metals into the product water; aluminum, copper, lead, zinc. Etc..

- Maintain minimum flow velocity of 3ft/sec for indirect feed systems and 1.5 feet/sec for direct feed systems.
Ultra-violet irradiation (UV)

- Bacteria control device
- Causes DNA mutation in bacteria that disrupts the reproduction process.
- Monitored daily for irradiance.
- Failure could result in increased levels of microorganisms in the patient loop.
Ultra-violet irradiation (UV)

How It Works Part I

- Exposure to UV light between 200 and 300 nanometers alters the DNA of bacteria and microorganisms.
- Bacteria and microorganisms become unable to reproduce or infect other organisms.
Ultra-violet irradiation (UV) Regulation

- Low pressure mercury lamp that emits light at a wavelength of 254 nm and 30 milliwatt-sec/cm²

- Equipped with UV intensity meter or on line monitor of radiant energy output that activates a visible alarm.

- Lamp replacement on a predetermined schedule based on IFU.

- Must be followed by ultra filtration.
Ultra Filtration

- Membrane filter

- Filters bacteria and endotoxin from the water loop.

- Visual monitoring for leaks, pressure drops.

- Failure may result in bacteria proliferation in the water distribution loop.
Ultra Filtration Regulation

- Must have opaque housing.
- Included in routine disinfection.
- Pressure drops must be monitored daily.
- Cross flow filters must be monitored for flow rates and pressure drops.
- Data must be recorded on a log.
Water Testing

- AAMI analysis
- Hardness
- Total Chlorine
Water Testing

- MUST be performed per manufacturers IFU. Details are important..

- Completed at required intervals.

- Documented accurately

Patient safety is primary!
Major items to monitor to ensure safety in water distribution system

- Chlorine and Chloramines
- LAL and Colony Counts
- AAMI Water Analysis
- Documentation
- Percent Rejection
- Water Temperature
- TDS or Permeate Conductivity
- Empty Bed Contact Time (EBCT), Flow Velocity
- Alarm Status/Function
Creating a positive safety culture
What is a safety culture?

- The way safety is perceived, valued and prioritized.
- Reflects the real commitment to safety at all levels.
- How people behave when no one is watching.
Why is safety culture important

- Maintain high standards of performance.
- Ensure safety of staff patients and visitors.
- Reduce injuries and near misses.
- Comply with state and federal regulations.
Perception

- Based on prior knowledge and experiences.
- May be influenced by circumstances or situations
- Varies from person to person
- Can change over time
Perception of risk

- Perception of risk may be affected by pressure to complete a task on time.
- While performing tasks, staff will do risk assessments often evaluating risk against reward.
- An individual’s perception of safety may affect the decision making process.
- Continuous monitoring and educational reinforcement is needed to make sure that the right decisions are made.
pollination

If you can get 1 staff member to buy into the safety concept.......
They will pollinate the rest of the staff.