Emergency Preparedness Guidelines for Water Treatment Systems

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While many dialysis facilities prepare for loss of power and water in disaster situations, it is equally important to prepare for loss of quality drinking water. Natural disasters like hurricanes, floods, earthquakes, and tornadoes can affect the quality of the potable water delivered for dialysis by adding contaminants. This article presents a checklist of how to prepare the water treatment system against natural disasters and what to do after an event occurs.

Many dialysis facilities prepare for loss of power and water in disaster situations; however, it is equally important to prepare for loss of quality drinking water. Natural disasters like hurricanes, floods, earthquakes, and tornadoes can affect the quality of the potable water delivered for dialysis by adding contaminants. Further, municipalities that supply drinking water will treat the unknown water with more chemicals, such as aluminum sulfate (alum) and chlorine/chloramine, to counteract the effects of the event. Alum is one of many types of flocculants that are added when colloidal matter is high. Colloidal matter is suspended particles like silt and dirt that will not settle out untreated. Flocculants will aggregate the suspended material and force it to separate from the water. During a natural disaster, it is likely more alum would be used to treat the contaminant overload. Microbes are also a concern during disasters, so water suppliers would be inclined to add more disinfectants such as chlorine or chloramine. There are many documented incidents in the dialysis setting such as hyperaluminemia and hemolysis emanating from water contaminants (see Table 1).

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A Checklist to Prepare Water Treatment System

The following is a checklist of how to prepare the water treatment system against natural disasters and what to do after an event occurs.

1. Know your water supplier, and have one or two names as contacts. If you have not done so already, call them and introduce yourself, let them know of your special needs as a supplier of dialysis and how imperative it is that you receive a steady supply of water within the Environmental Protection Agency (EPA) limits (see Table 2). Make sure they are aware that patients can become sick and even die from inadequately treated water. You should be the first on their list to call if there is a water quality issue (natural disaster or not). Ask them to routinely supply their water testing results, and find out what their emergency plans are if there should be a natural disaster. Both are available for public review. Contact them during a disaster to get updated water quality reports on an ongoing basis until the disaster and water quality are stabilized.
2. Know your **supply** water. Tests readily available in dialysis facilities are pH, total chlorine, hardness, and conductivity (microseimens). Testing the feed water on a weekly basis will familiarize the staff with the current water and may alert them to significant changes. Logging and trending the results over time may indicate seasonal changes and tolerances of the water treatment system.
   - In emergency situations it may be possible to use water that has only been pretreated with softening, carbon, and ultrafiltration for hemodialysis treatments. In fact, there are areas in the U.S. that almost meet the AAMI standards with the tap water they receive. To know if this is a viable option, perform an AAMI analysis on the effluent water from the pretreatment tanks, just before the reverse osmosis (RO)/deionization (DI) purification process on at least a yearly basis. Make sure that ultrafiltration exists for removal of bacteria and endotoxin. Remember though, in a natural disaster, the incoming water quality may change, and the pretreated water may no longer meet the AAMI standards unless reverified with analysis. However, it is the medical director's ultimate responsi-

Table 1
Signs and Symptoms and Possible Water Contaminant-Related Causes

Symptom	Possible Water Contaminant
Anemia	Al, chloramines, Cu, Zn
Bone Disease	Al, Fl
Hemolysis	Cu, nitrates, chloramines
Hypertension	Ca, Na
Hypotension	Bacteria, endotoxin, nitrates
Metabolic acidosis	Low pH, sulfates
Neurological deterioration	Al
Nausea and vomiting	Bacteria, Ca, Cu, endotoxin, low pH, Mg, nitrates, sulfates, Zn
Death	Al, Fl, endotoxin, bacteria, chloramine

Note: Revised from Food and Drug Administration (FDA). (1989), A manual on water treatment." Washington, DC: FDA.

bility for deciding whether the final quality of the water is suitable for hemodialysis.

3. Clearly label all the water treatment components and equipment. Have an updated flow schematic of the system in the water treatment room, and put a copy in the emergency box.
4. Be prepared for a complete loss of water that could last indefinitely. An emergency supply of back-up water could be delivered in tanker trucks if planned ahead. Dialysis facilities have been known to pump water from swimming pools to use for dialysis treatments during emergency situations. Plumbing modifications must be made to use alternate sources, so have available additional flexible

Table 2
AAMI and EPA Maximum Allowable Levels of Contaminants in Water

Contaminant	AAMI Maximum Concentration for Dialysis Water (mg/L)	EPA Maximum for Drinking Water (mg/L) 2000 (condensed list)	Lowest Concentration Associated with Dialysis Toxicity (mg/L)
Calcium	2 (0.1 mEq/L)	Not regulated	88
Magnesium	4 (0.3 mEq/L	Not regulated	
Potassium	8 (0.2 mEq/L)	Not regulated	
Sodium	70 (3.0 mEq/L)	Not regulated	300
Antimony	0.006	0.006	New to AAMI 2001
Arsenic	0.005	0.05	
Barium	0.10	2	
Beryllium	0.0004	0.004	New to AAMI 2001
Cadmium	0.001	0.005	
Chromium	0.014	0.10	
Lead	0.005	0.015**	
Mercury	0.0002	0.002	
Selenium	0.09	0.05	
Silver	0.005	0.10*	
Aluminum	0.01	0.05-0.2*	0.06
Chloramines	0.10	4.0*	0.25
Free Chlorine	0.50	4.0*	
Copper	0.10	1.3**	0.49
Fluoride	0.20	4.0	1.0
Nitrate (as Nitrogen)	2.0	10	21
Sulfate	100	250*	200
Thallium	0.002	0.002	New to AAMI 2001
Zinc	0.10	5*	0.2
Bacteria	200 cfu/ml (action level 50 cfu/ml)	HPC Bacteria: 500 cfu/ml Coliform bacteria: 0***	
Endotoxin	2 EU/ml (action level 1 EU/ml)	Not regulated	

Key
*Unenforceable maximum contaminant level goal (Secondary Standard)
**Action level at 90th percentile
***95% of the samples (all positive results must be resolved)

Note: From Association for the Advancement of Medical Instrumentation (AAMI). (2001). *AAMI Standards vol. 3: Dialysis, WQD.* Richmond, VA: AAMI.

plumbing fittings, hoses, pumps, and plumbing tools. Have a contingency plan with a dialysis facility in another district to temporarily dialyze your patients if suitable water for dialysis cannot be obtained. Assign the staff to work at this alternate facility and plan to add a night shift or two to accommodate all the patients.

5. Be prepared for an indefinite loss of electrical power. Back-up generators should be used for vital equipment only such as RO systems, DI resistivity monitors, and dialysis machines. Assure that the fuel supply is sufficient and stored in a safe place, ideally a cabinet approved for flammable items and vented to the outside. Install emergency lighting for the water treatment room.

6. Assign staff members to assess and operate the water treatment system after a disaster and before running patients. Due to the possibility of the water supply being overburdened with chlorine/chloramine, microbes, and alum flocculants, increase the frequency of monitoring and testing the system as follows:

   Draw water samples for:

   - AAMI analysis at least daily or per each tankard of delivered water. The AAMI analysis will take approximately 48 hours to receive results. In a pinch, the final ***dialysate*** can be evaluated for salts and other contaminants, such as aluminum, lead, and copper, at a local hospital lab similar to a chem 22 or panel 21 assay. The protein bias must be removed since the sample is not a blood specimen. Assess the lab's ability by discussing with them what is in an AAMI analysis ahead of time (see Table 2).
   - Hardness test pre and post the water softener at minimum each patient shift. Testing for hardness will indicate softener function and help prevent mineral scale fouling of the RO membrane.
   - Total chlorine pre and post the first carbon tank at least hourly. Testing the incoming water before the first carbon tank will alert the staff to any unusual fluctuations in the chlorine/chloramine levels and after will indicate chlorine/chloramine breakthrough.
   - Check conductivity in microseimens pre and post the RO/DI with an independent device at least each patient shift. Also, monitor continuous read-outs of the percent rejection and water quality display per shift. If the water quality readings, either conductivity (microseimens) or total dissolved solids (TDS), have quickly deteriorated by doubling the salt passage or more (e.g., TDS increases from 5 mg/L to 10 mg/L), an AAMI analysis will determine whether the water is suitable for dialysis. If the percent rejection, which indicates membrane performance, has also diminished by 5%-10%, cleaning the RO membranes may be in order to bring the performance back, which in turn may increase water quality.
   - Bacteria levels pre and post the RO/DI every day. Bacteria cultures require 48 hours to grow, but many bacteria will appear at the 24 hour mark, so check these results also. It would be convenient and wise to have an incubator with the commercially available bacteria sampling kits available in the dialysis facility for testing bacteria levels during a crisis. The more independent a facility is and the less reliant on outside help during a catastrophic event, the better.
   - Limulus amobocyte lysate (LAL) testing for endotoxin should be done after the RO/DI at least everyday. Purchase LAL kits to perform endotoxin testing on site. LAL tests quickly indicate whether or not waterborne gram-negative endotoxin-producing bacteria are present and shedding chemicals from their cell walls into the system. Dialysis treatments can be initiated if the preliminary results of the LAL tests are negative, or less than 2 EU/ml, while waiting for the bacteria cultures to grow.
   - Compare all readings, pressure gauges, water quality, and testing to previous values prior to the event.

7. If DI is used after the RO as a polisher, assure there are newly regenerated tanks on-line. If there is DI off-line or "dry" as an emergency back-up to the RO, place them on-line. Flush the tank(s) thoroughly and perform bacteria, LAL, and AAMI analysis post the tank(s). The resistivity monitor should be plugged into a red emergency generator outlet. DI will operate without electricity as long as there is water flowing through the tank. Therefore, it is imperative that the water quality be measured. If DI is not currently used in the facility, it is possible to make arrangements ahead of time to receive an emergency supply. Contract with a qualified vendor able to supply medical grade or potable water, designated resins delivered upon request.

8. Do not delay preventative maintenance. Keep the water treatment system as "fresh" as possible to handle any reasonable contaminant burden during a sudden emergency.

   - Rebed carbon tanks routinely, and arrange to have an emergency back-up tank delivered or a supply of carbon on hand. Along with chlorine and chloramine, carbon will remove other low molecular weight organic chemicals such as pesticides, herbicides, and industrial solvents.
   - Change out the prefilters routinely. During an emergency event, increase this to at least daily since water supplies may have larger amounts of particulates. Have a back-up supply on hand.
   - Clean the RO membrane(s) and disinfect the entire system simultaneously on a routine basis. For disinfection, include the RO, storage tank, distribution loop, dialysis machines, and reuse equipment. During a crisis, clean the RO membranes, and disinfect the entire water treatment system before running patients. Increase the frequency of both cleaning and disinfecting based on monitoring and test results. Consider that the water supply may be more contaminated with bacteria, chemicals, and particu-

lates that will foul the water treatment system.
- If after cleaning the RO membranes with high and low pH cleaners, the percent rejection remains 5%-10% below initial new RO membrane percent rejection and/or the TDS/conductivity has doubled in salt passage since the newly installed value, RO membrane replacement may be in order. This is essentially true if the current readings are unable to meet AAMI Standards.

9. Check the pretreatment head valves on the multimedia, softener, and carbon tanks to assure that the timers are set to the correct time. Power failures will cause the timers to be off and the tanks may back-wash and regenerate during patient treatments.
10. Do not reprocess hemodialyzers until the water supply returns to predisaster conditions. This will also conserve water. Further, consider dialyzing patients on conventional dialyzers unless the water distribution loop has either ultrafiltration present or the dialysis machines have the ability to ultrafiltrate the dialysate, which removes bacteria and endotoxin, before it enters the dialyzer.
11. Instruct patients and staff to drink bottled water or boil the water they use for consumption and cooking. Water may be contaminated with infectious bacteria and microbes that can be especially harmful to debilitated and immune compromised patients. Reinforce strict fluid and dietary intake with patients during disasters as dialysis may be rationed.
12. Be prepared to use alternate drainage for water and dialysis machines should a natural disaster sever sewer lines. Discontinue the use of restroom facilities, and use portable facilities.
13. In case of irreparable damage to the RO system or building and there is not an alternate facility available for the patients, seek out a supply of small portable RO systems and/or DI tanks, or sorbent dialysis machines, etc., and ration dialysis.

Many natural disasters will be unexpected; but with careful planning and forethought, dialysis facilities can supply adequate dialysis for the patients.