St George Hospital Renal Department; INTERNAL ONLY

Water quality for haemodialysis

The Bottom line

- AAMI standards are the **accepted <u>minimum</u> standards** for water pre treatment for haemodialysis, however the use of more rigorous standards is acceptable for systems in NSW – and is strongly recommended.

- Haemodialysis, including high flux and haemodiafiltration should never take place without a minimum: multimedia filter, carbon filtration, a 1 micron filter and reverse osmosis unit.

- The exception is when the Reverse Osmosis (RO) unit is bypassed in an emergency situation under strict guidelines (refer to bypassing RO - Sutherland hospital only). In this instance haemodialysis is the only form of treatment to be used.

- Written policies, practices and procedures should be in place covering the protocol and methodology for chlorine and/or chloramine testing and the appropriate responses to results showing a high concentration of chlorine and/or chloramine (refer to elevated results protocol).

- To ensure safe chlorine and chloramine levels in pre treated water, water for haemodialysis should be tested after the start of each dialysis shift, once the water plant is fully running and recorded daily (refer to daily water testing procedure).

- In the event of water or power failure, refer to the Emergency Procedures Manual located at the nurse's desk for detailed management.

What this guideline covers

- Essential water management
- Greater Metropolitan Committee Taskforce (GMCT) guidelines
- Guideline recommendations CARI and others
- Background information from GMCT
- Evidence for water management protocols
- Suggestions for clinical care
- Water testing
    - Quality Control
    - Policies and Procedures
    - Water utility communications

Essential water management

Monitoring:

- Daily chloramine testing by nursing staff (refer to daily water testing procedure).
- 6 monthly chemical elements (heavy elements) collected by Gambro Pty Ltd at the end of the water purification cascade and at the most distal point in each water distribution loop.
- Bimonthly micro-organisms collected by Gambro Pty Ltd technicians at the point where water enters the equipment used to prepare concentrates and dialysate.
- Yearly endotoxins collected by Gambro Pty Ltd.
- 6 monthly infusate testing for HDF water purity (see nursing procedure).
- Monthly filter change for HDF machines (see nursing procedure).

WATER TESTING

(Based on Greater Metropolitan Committee Taskforce (GMCT) guidelines)

Table 3.4 – summary of recommended water testing frequency for dialysis water pre treatment system.

Water test	**Frequency**
Water hardness, pre and post softener	During design and commissioning, six monthly or after carbon change
Chlorine	During commissioning. At least once per dialysis shift
Bacteria	During commissioning. Monthly
Endotoxin	During commissioning. Six monthly
Chemical contaminant and heavy metal levels	During commissioning. Six monthly or after carbon or RO changes.

GMCT Guidelines

- All servicing, maintenance, interventions and changes to the water pre-treatment plant should be recorded in water folder, available in a convenient location. Currently managed by ECO Water and Gambro Pty Ltd.

- Water quality and plant function should be reviewed by a multidisciplinary committee made up of at least, senior nursing, medical and technical staff and other appropriate stakeholders second monthly.

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- Minutes should be circulated to appropriate health service authorities, to indicate safe running of the dialysis unit and the dialysis water pre-treatment plant including the Clinical Practice Improvement Unit (CPIU), Director of Renal Medicine and Division of Medicine and Critical Care.

- Dialysis staff should be trained and deemed to be competent in water quality risk management. Staff education on water management should be held annually.

Guideline Recommendations – CARI

AAMI

Water:

Bacterial count: 200 CFU/ml; >CFU/ml warrants corrective action
Endotoxin count: <2 IU/mL; 1 IU/mL warrants corrective action

Dialysate:

Bacterial count: <200 CFU/mL; >50CFU/mL warrants corrective action
Ultrapure < 0.1 CFU/mL; Endotoxin < 0.03 IU/mL for high flux

Chemical:

Listed in AAMI guidelines

EBPG

Water:

Bacterial count: <100CFU/mL; Ultrapure < 0.1 CFU/mL for high flux
Endotoxin count: < 0.25 EU/mL; Ultrapure < 0.03EU/mL for high flux

Chemical:

European Pharmacopoeia standards (which are the same as AAMI standards)

What do the other guidelines say?

Kidney Disease Outcomes Quality Initiative: In practice, appear to use AAMI recommendations.

Water:	Bacterial count < 200 CFU/mL; > CFU/mL warrants corrective action. Endotoxin count < 2 IU/mL; > 1IU/mL warrants corrective action.
Dialysate:	Regular as for water.
	Ultrapure: Bacterial < 0.1 CFU/mL; Endotoxin, 0.03 IU/mL.
Water:	Chemical contaminants. As listed in ANSI/AAMI RD62:2001.

British Renal Association:
Concentrates and water for dialysis: Lists concentrate standard prEN 13867: 2002 and water standard BS ISO 13959:2001 (Good Practice).

For haemodiafiltration: water microbial count should not exceed 0 CFU/ml and endotoxin should be < 0.015 IU/ml. Incubate at 20-22^{o}C.

European Best Practice Guidelines:

Water:	Bacterial count: Regular < 100 CFU/mL; Ultrapure < 0.1 CFU/mL (High flux dialysis or on-line fluid production). Endotoxin count: Regular < 0.25 EU/mL; Ultrapure < 0.03 EU/mL.
Chemical:	European Pharmacopoeia standards.

International guidelines: no recommendation

CARI guidelines: Based on level 1 or 2 evidence

Canadian Society of Nephrology: no recommendation

Background (GMCT Home Haemo Supplement)

Appropriate water quality is one of the most important aspects of ensuring safe and effective delivery of haemodialysis. Haemodialysis may expose the patient to more than 300litres of water per week across the semi permeable membrane of the haemodialyser. The near 30 times increase in water exposure to dialysis patients requires control and monitoring of water quality to avoid excesses of known or suspected harmful elements being carried in the water transmitted to the patient.

The water used for the preparation of haemodialysis fluids needs treatment to achieve the appropriate quality. The water pre-treatment system includes various components such as sediment filters, water softeners, carbon tanks, micro-filters, ultraviolet disinfection units, reverse osmosis units, ultrafilters and storage tanks. The components of the systems are determined by the quality of feed water and ability of the overall system to produce and maintain appropriate water quality.

Failure to ensure adequate water quality may have dire consequences to patient safety and welfare. Patients undergoing haemodialysis may show signs and symptoms caused by contamination, which can lead to patient injury or death. Some of the important possible signs and symptoms due to water contamination are listed below in Table 1.

Table 1: Haemodialysis Risks associated with water contamination[1]

Symptoms	**Possible water contaminants**
Anaemia	Aluminium, chloramine, copper, zinc
Bone Disease	Aluminium, fluoride
Haemolysis	Copper, nitrates, chloramine
Hypertension	Calcium, sodium
Hypotension	Bacteria, endotoxin, nitrates
Metabolic acidosis	Low pH, sulphates
Muscle weakness	Calcium, magnesium
Neurological deterioration	Aluminium
Nausea and vomiting	Bacterium, calcium, copper, endotoxin, low pH, magnesium, nitrates, sulphates, zinc
Death	Aluminium, fluoride, endotoxin, bacteria, chloramine

[1]NOTE: Revised from Food and Drug Administration (FDA). (1989). A manual on water treatment for haemodialysis.

What is the evidence? (Based on CARI guidelines)

Chemical contaminants

Aluminium, chlorine compounds (including trihalomethanes such as chloramine), nitrates, sulphates, copper and zinc are the most important of the substances known to have particular toxicity for haemodialysis patients. The effects include dementia, osteomalacia, haemolytic anaemia, nausea, vomiting and acidosis (Alfrey et al 1976;

Ward et al 1978; Kaiser 1985; Eaton et al 1973; Ward 1996; Carlson 1970; Comty et al 1974; Ivanovich 1969; Petrie 1977; AAMI 2004).

The second group of chemical contaminants are usually not present in excess quantities in municipal water treated by modern methods. The maximum allowable limits are set at 10% of the U.S. Environmental Protection Agency Safe Drinking Water Act. Examples include arsenic chromium, lead and selenium.

The third group is physiological substances which if present in excess amount, may cause injury. Examples include calcium, potassium and sodium.

There are no significant differences between AAMI and EBPG with regard to the maximum allowable limits for most chemicals in these three groups.

Chlorine and chloramine toxicity is a well established phenomenon. Haemolytic anaemia is the major consequence; potentially fatal hyperkalaemia may follow severe haemolysis. Resistance to erythropoietic agents has been reported at chloramine levels of 0.1-0.2 mg/L (Perez-Garcia & Rodriguez-Bernitez 1999). Free chlorine can damage some reverse osmosis membranes (AAMI 2004, p. 9)

Aluminium removal requires reverse osmosis; pre-treatment water softening may reduce some of the load. Deionisers may be less effective if aluminium is present in significant amounts at neutral pH, mostly in colloidal form, because it does not carry a charge and is therefore not removed by the process (AAMI 2004).

Chlorine products require carbon adsorption in certain situations such as when high natural levels of N chloramines or high pH is present or use of phosphates (ortho or poly). Unpredictable variations in feed water levels, especially in summer, may exceed the filter's absorption capacity. Chloramines require 4-5 times longer than does free chlorine to be effectively adsorbed (AAMI 2004).

Pyrogenic reactions have been associated with bacterial contamination of dialysate, usually from the water delivered to the dialyser, at levels in excess of 2000 cfu/ml (Favero 1998).

Contamination with water-based organisms (usually slow growing Gram negative Pseudomonads) may cause clinical and subclinical consequences. Pyrogenic reactions due to exo/endotoxins have been associated with excess microbial levels in the dialysate system. Fungal, yeast or algal organisms have occasionally been implicated, especially when treatment methods have been either not functioning or below common standards (Pouria et al 1998).

There is some controversy regarding the extent of passage of bacterial products across dialyser membranes. Low –Flux membranes may be more resistant to such penetration. Concern has focused on the more permeable membranes used for high-flux dialysis and diafiltration (with on-line production of replacement fluid). Lonnemann and colleagues (2001) reported that at moderate levels (Pseudomonas endotoxin 50EU/ml) of bacterial contamination of dialysate for in vitro dialysis with highly permeable synthetic membranes of poysulphone or polyethersulphone, there was no evidence of significant change in human mononuclear cell content of proinflammatory cytokines such as interleukin -1 beta or tumor necrosis factor alpha
This field has been confused by issues regarding endotoxin antibody measurement, endotoxin plasma levels or mononuclear cell response releasing cytokines likely to promote a chronic inflammatory state (Summary: AAMI 2004, p32).

Ultrapure water is defined as bacterial count < 0.1C FU/ml and endotoxin < 0.03 EU/ml and is recommended by both European and American guidelines for use with high-flux dialysers.

Sterile fluid, defined as containing, CFU/100L and endotoxin < 0.03 EU/m is required for on-line replacement during haemodiafiltration. Ledebo (2002) has demonstrated the capacity to produce such fluid quality by the use of ultra-pure feed water, dialysate and subsequent endpoint ultrafiltration. Both AAMI and EBPG support this standard, which is required by the respective Pharmacopeia regulations.

Testing frequency depends on the items being tested. More intense testing is recommended in the initiation phases or after any break in the closed circuit for repair or maintenance.

Water system design should minimise opportunities for microbial growth and chemical contamination. It should incorporate excess capacity or fail-safe mechanisms to ensure that unexpected equipment failure does not cause the unsafe dialysis treatment of patients.

Contaminants Causing Toxic Effects (Levy, Morgan et al. 2004)	
Contaminant	***Effect***
Aluminium	Microcytic anaemic, encephalopathy, dementia, bone disease (osteomalacia)
Calcium (magnesium)	Nausea, vomiting, headache, weakness, hypertension
Copper	Nausea, headache, haemolysis, hepatitis
Zinc	Anaemia, nausea, vomiting, fever
Sodium	Hypertension, pulmonary oedema, thirst, confusion, headache, fits, coma
Lead	Neurological disorders
Chloramines	Haemolysis, anaemia, methhaemoglobinaemia
Fluoride	Osteomalacia
Nitrate	Cyanosis, methhaemoglobinaemia, nausea, hypotension
Sulphate	Nausea, vomiting, acidosis
Microbial pyrogens, endotoxin	Nausea, vomiting, fever, hypotension, shock, enhanced dialysis amyloid formation

Suggestions for clinical care (CARI)

(Suggestions are based on level III and IV evidence)

- Ensure regular testing and auditing of water treatment systems and quality of water produced for dialysis.
- Infusion fluid for haemodiafiltration must be produced with strict observance of the manufacturer's validated process. Final filtration must ensure 7 log reduction in bacterial count of ultra pure fluid.
- Ultra pure water may reduce long-term risk of accelerated vascular damage, improve response to erythropoietic agents and reduce catabolic nutritional state.
- European Best Practice Guidelines (EBPG) should be the basis for optimal dialysate production.
- Be familiar with local practice in municipal water treatment and testing procedures.

WATER TESTING

The purity of water used for haemodialysis is important because the dialyzer membrane cannot select which ions need to be absorbed or rejected during the process of diffusion which may result in toxic levels in dialysis patients.

Chemical standards for water used for hemodialysis, in accordance to AMMI (2004) are:

CONTAMINANT	SUGGESTED MAXIMUM ALLOWABLE LEVEL (Mg/L)
Calcium	2
Magnesium	4
Sodium	70
Potassium	8
Fluoride	0.2
Chloride	0.5
Chloramines	0.1
Nitrates	2.0
Sulfate	100
Copper, barium, zinc	Each 0.1
Aluminium	0.01
Arsenic, lead, silver	Each 0.005
Cadmium	0.001
Chromium	0.014
Selenium	0.09
Mercury	0.0002

QUALITY CONTROL

Every haemodialysis unit should have written policies and procedures for the safe operation of the water pre-water treatment systems, including :- education policies, obtaining water samples, testing of samples, recording and trending results, identifying trends in results, action to be taken when high test results are obtained and Occupational Health and Safety principles. Currently Gambro is responsible for water testing and reporting of results, requiring both St George and Sutherland to review the results and act accordingly until the results have returned to safe levels. Medical, nursing and technical staff working in dialysis units share responsibility for the safe operation of the water pre treatment plant and should participate together in regular committee meetings to review the safe operation of the water pre-treatment plant. Dialysis nurses should participate in audits and ongoing training, continuing education and accreditation.

Audits, training and continuing education.

The operation of the water pre-treatment systems and the ongoing training of persons involved in the operation of the system should be audited on a 12 monthly basis and reported to the Nurse Unit Manager of St George and Sutherland sites.

Audit reports and recommendations should be reviewed and managed by the site committee and resolved with the contracted company: Gambro Pty Ltd.

POLICIES AND PROCEDURES

Education

Dialysis nursing staff should be educated on overall water management and be aware of who manages water quality. Currently Gambro provides water treatment maintenance along with the hospital's engineers. Such persons involved with the water pre treatment system should be educated in the operation of their area of responsibility and records maintained within the respective area: Engineering & Gambro.

Operation of the water pre-treatment systems

The operation of the water pre-treatment system should only be carried out by persons who have been trained and accredited. Records of who is responsible for the operation of all or part of the water pre-treatment system should be maintained within the dialysis unit. Currently Gambro and the hospital engineers manage the plant. The Sutherland site is educated on bypassing the RO but under strict guidance from Gambro Pty Ltd. Due to geographical barriers and a poor OH&S environment St George nursing staff are not to perform this task.

Obtaining suitable water samples

Water samples for testing should be obtained from the appropriate location as detailed in the operational policies and procedures for the dialysis unit. These policies and procedures should include information on how to collect the water sample, where the sample is collected from, and what the water sample is collected in and how the sample is maintained up to the time it is tested. Currently this is the responsibility of Gambro Pty Ltd as part of the Price Per Treatment (PPT) agreement.

Testing of samples

Testing of water samples should be carried out by trained and accredited persons or laboratories and records maintained within the dialysis unit, managed by Gambro Pty Ltd and records kept in the dialysis facilities.

Recording and trending results

All water test results should be recorded and trended over time. Trending may be done on a graph (eg with the results being obtained by averaging the last ten test results). The trending result will show if there is any slight changes of test results over time. Test results and trending graphs should be maintained in a Quality folder. Trends are reported biannually to the Renal Department as part of the Quality process for both sites.

Identifying trends in results

The trended water test results should be reviewed by an approved staff member on a regular basis. Regular reviewing of results should show any trend that may require intervention to prevent contaminated product reaching the haemodialysis equipment of patients. Individual sites review water results and liaise with Gambro Pty Ltd when deviations occur to ensure action is taken and results return to acceptable limits.

Action when high test results are obtained

Every dialysis unit should have policies and procedures in place to detail what action is required when any test result is high. It is essential that any high results are promptly communicated to responsible senior staff. Gambro is responsible for retesting abnormal results and communicating changes until results return to acceptable levels.

Occupational Health and Safety principles

Every dialysis unit should have safe work practice statements for every procedure undertaken on the water pre-treatment system. Safe work practice statements should be developed while carrying out a risk management procedure. These safe work practices should be followed by all persons working on any part of the water pre-treatment system, currently attended by StG engineers and ECO Water. There should also be safe work practice statements for persons collecting and testing water samples (Responsibility of contractor: Gambro Pty Ltd).

All contractors should complete a site induction and a written risk management procedure before commencing any work on the water pre-treatment system. Records of all risk management procedures, safe work method statements, contractor inductions should be maintained by Gambro and the Engineering Department**.**

Committee meetings

On a second monthly basis, water quality and safe functioning of the water pre-treatment system should be reported to a multidisciplinary committee made up of senior nursing, medical and technical staff and other appropriate stakeholders, any issues resolved and minutes kept. These minutes should be circulated to appropriate health service authorities, to indicate safe running of the dialysis unit's and the dialysis water pre-treatment plant.

WATER UTILITY COMMUNICATIONS

NSW Health recommends that water utilities communicate with hospitals and dialysis units when an interruption of water supplies occurs or is planned to avoid or minimise adverse impact on patients.

Hospitals and dialysis units provided with water services by Sydney Water are to be notified of changes to water quality when chlorine or chloramine concentrations exceed the agreed maximum chlorine and chloramine concentration.

Acceptable levels of chlorine and chloramine

The AAMI maximum level for chlorine is 0.5mg/L and for chloramine is 0.1mg/L. If using an on-line chlorine Meter the acceptable maximum level for total chlorine is 0.1mg/L. When trending of test results indicate an increase in the level of chlorine then the carbon shall be replaced earlier than twelve monthly.

Bacteria and endotoxin testing

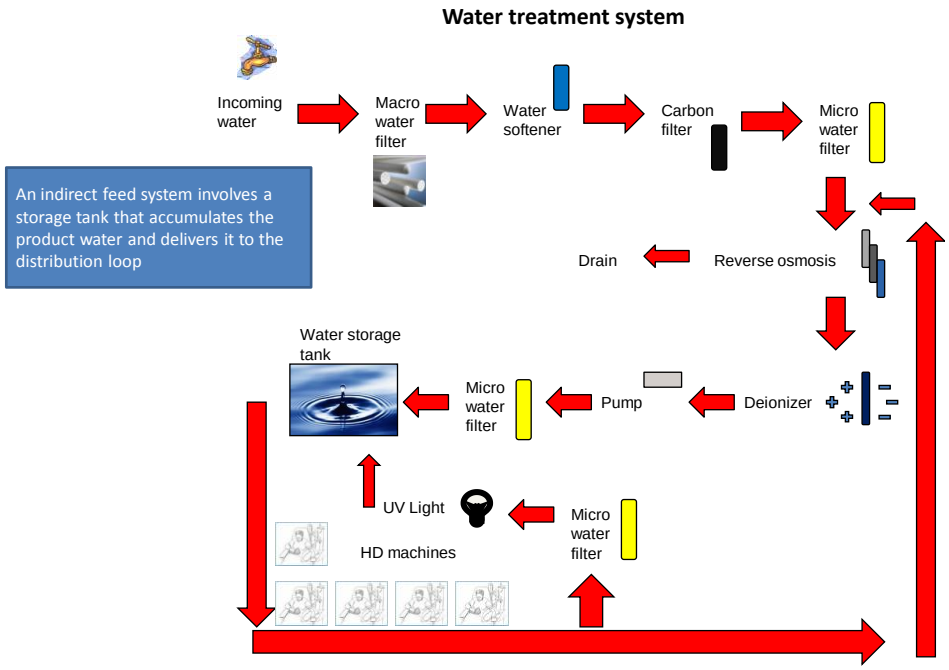
Bacterial levels should be tested monthly at the points where all haemodialysis equipment connects to the distribution piping system (post RO, post water loop). This includes dialysis machines, bicarbonate filling stations, etc. Bacteria levels shall not exceed 200 colony forming units/ml (CFU/ml) – with an action level of 50 CFU/ml.

Endotoxins should be measured 6-monthly. According to AAMI the endotoxin content in product water shall not exceed 2 IU/ml, or as required by national legislation or similar. Current recommendation from Gambro Pty Ltd is annually for endotoxin level. These measurements apply to sampling at the point of delivery to haemodialysis equipment (post RO, post water loop). At the outlet of water treatment (post RO), no more than 1 iU/ml is the requirement. When monitoring haemodialysis equipment, rotation among sites should assure that each is tested with a cycle of several months. The presence of endotoxins can be tested using the Limulus Amoebocyte Lysate (LAL) assay.

The EBPG have somewhat more stringent criteria than AAMI. They are indicated here for comparison. Many Australian dialysis units now seek to conform to these more stringent guidelines.

MICROORGANISMS	**AAMI: RD52**	**EDTNA/ERCA BASED ON EP**
CFU/ml Max	200	100
CFU/ml Action	50	25 (typ)
ENDOTOXINS		
EU/ML OR IU/ml Max	2	0.25
EU/ml or IU Action	1	0.03

Figure 1. St George Dialysis Units Water Treatment System Diagram



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