# Safety of Water Treatment and Effect of Individualizing the Dialysate in the Hemodialysis Patients

*Essay*

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*By*

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# List of Abbreviations

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| **AAMI** | : | Association for the Advancement of Medical Instrumentation. |
| **BP** | : | Blood pressure |
| **CACL2** | : | Calcium Chloride |
| **CKD** | : | Chronic kidney disease |
| **CRP** | : | C-Reactive protein |
| **CVD** | : | Cardiovascular disease |
| **DI** | : | Deionization |
| **EBCT** | : | Empty bed contact time |
| **ECF** | : | Extra cellular fluid |
| **ERA-EDTA** | : | European renal association-European dialysis transplantation association |
| **ERW** | : | Electrolyte reduced water |
| **ESA** | : | Erythropoietin-stimulating agents |
| **ESRD** | : | End stage renal disease |
| **H2** | : | Dihydrogen |
| **HD** | : | Hemodialysis |
| **IDH** | : | Intradialytic hypotension |
| **IL**-6 | : | Interleukin-6 |
| **ISO** | : | International Organization for Standardization |
| **LAL** | : | Limulus Amaebocyte Lysate |
| **LPS** | : | Lipopolysacchride |
| **NKF**-K/**DOQI** | : | National kidney foundation-Kidney Disease Outcomes Quality Initiative |
| **PEPA** | : | Polyester-polymer alloy |
| **PMMA** | : | Poly methyl methacrylate |
| **PSIPer** | : | Square Inch |
| **PTH** | : | Parathyroid hormone |
| **R2A** | : | Reasoners 2A |
| **RO** | : | Reverse osmosis |
| **TGEA** | : | Tryptone glucose extract agar |
| **UF** | : | Ultrafiltration |

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# Introduction

Hemodialysis patients are particularly vulnerable to contaminants in the water used to prepare concentrate and dialysate, or in water used for reprocessing dialyzers. Compared to healthy individuals, hemodialysis patients are exposed to extremely large volumes of water, have inadequate barriers to such toxins, and cannot easily eliminate contaminants ***(Martin et al., 2003).***

Accumulated experience, combined with the observation that some of the most toxic contaminants arise from municipal water treatment practices, suggests that no municipal water can be considered safe for direct use in hemodialysis applications. All dialysis facilities therefore require a properly designed and maintained water treatment system to safeguard patients ***(Martin et al., 2003).***

Most dialysis facilities obtain their water treatment system from a vendor specializing in such equipment. However, the medical staff of a facility should understand enough about water treatment to critically appraise the system they purchase. The Medical Director of a facility has the ultimate responsibility for ensuring that the patients are treated with water that, at a minimum, meets the contaminant standards set forth by Association for the Advancement of Medical Instrumentation (AAMI) ***(AAMI, 2006).***

Patient safety has become an important focus of the medical community. Although hemodialysis is a routine therapy, it is nonetheless a complex procedure where errors can occur. In particular, errors related to water quality can lead to patient injury and to increased medical costs ***(Rosemary, 2002).***

Epidemiologic techniques provide a framework to identify, correct, and possibly avert these types of errors in the future. While the ultimate responsibility for ensuring water quality rests with the medical director of the hemodialysis unit,patient safety should be a concern of all members of the nephrology community ***(Rosemary, 2002).***

Dialysate composition and preparation along with dialysate use is probably one of the most fascinating topics in nephrology, where the possibilities for innovative tinkering and improvements are plentiful. Furthermore, learning about the art and the science of fashioning dialysates is one of the best ways to further the understanding of the patho-physiologic processes underlying myriad acidbase, fluid, electrolyte, as well as blood pressure abnormalities ***(Ramin, 2006).***

In most outpatient centers the dialysate is prepared centrally such that the composition of the dialysate is the same for all patients. When delivered in this manner most patients tolerate the procedure well ***(Palmer, 2001).***

However, there are patients who tolerate the procedure poorly, which has prompted a great deal of research focused on individualizing the composition of the dialysate in order to improve patient tolerability. One strategy to improve the clinical tolerance to dialysis is to adjust the dialysate composition according to the individual characteristics of the patient ***(Palmer, 2001).***

Not only can the concentrations of different normally present constituents be varied but also many unconventional compounds can be used to enrich a dialysate. In recent years, many reports have surfaced on the addition of urea, phosphorus, ethanol, citric acid, and even iron to a dialysate ***(Doorenbos et al., 2001).***

The need to improve both intradialytic and interdialytic morbidities and long-term outcomes has driven the use of individualized dialysate prescription ***(Lisa, 2010).***

# Aim of the Work

To review water treatment system in hemodialysis units ensuring patient's safety and the effect of individualization of the dialysate for hemodialysis patients (modelling of dialysate sodium,potassium, calcium, glucose, magnesium,bicarbonate, phosphate and temperature).

# Chapter (1)
# Safety of water treatment for Hemodialysis

## Purification of Dialysis Fluid:Historical Background

Tap water was used to prepare dialysis fluid in the early days, when mainly acute patients were treated with dialysis. When dialysis became a chronic therapy, certain clinical symptoms could be connected to the fluid quality and some form of water treatment had to be introduced. The water treatment equipment was empirically developed and consisted of filters and softeners. Sedimentation filters were used to remove particles in order to protect the equipment downstream ***(Ledebo, 2009).***

Dissolved organic matter and chlorine and chloramine, added by municipal water works, were adsorbed by carbon filters. To avoid 'hard water syndrome', softeners were introduced to exchange calcium and magnesium ions for sodium and potassium ions. These three components constituted the water treatment equipment in dialysis units during the early years ***(Ledebo, 2009).***

In the mid-1970s the toxic effect of aluminum accumulation was discovered, manifested as encephalopathy and osteomalacia. This led to the introduction of reverse osmosis modules in order to achieve the low, mandatory levels of aluminum in the water **(Ledebo, *2009*).**

The principle of reverse osmosis is to force water across a membrane that is so tight that only water molecules and the odd ion can pass. Thus, from a chemical as well as a microbiological perspective, very pure water can be produced with an intact RO membrane ***(Ledebo, 2009).***

Furthermore, information about the extent of the microbiological burden in water and dialysis fluid has been brought to the dialysis community through new and sensitive detection and quantification methods for bacteria and endotoxin. Appropriate culturing techniques, suited for bacteria commonly found in water and dialysis fluid, show a more realistic picture of the viable count than old methods ***(Ledebo and Nystrand, 1999).***

Dialysis research in the new millennium has demonstrated significant clinical effects using highly purified compared to standard quality dialysis fluid. The data, although mainly originating from small, single center, non-randomized studies, shows association between fluid quality and several inflammatory parameters ***(Kawanishi et al., 2009).***

Based on this, the European Best Practice Guidelines recommends the use of ultrapure dialysis fluid for all patients and all dialysis modalities ***(ERA-EDTA, 2002).***

# WATER PURIFICATION PROCESSES

Water utilized in hemodialysis applications is generally prepared by a number of different purification processes assembled in a cascade. The most commonly used purification processes consist mainly of the following techniques: Reverse osmosis, Deionization and Carbon filtration ***(AAMI, 2009).***

The combination of water purification processes needed to produce water that consistently meets applicable standards will vary from facility to facility depending upon the nature of the water supply and the applications for which the water is intended ***(Leuhmann et al., 1989).***

The detailed design of a water treatment system will generally be undertaken by a specialist vendor; however, the following process can be used to determine the basic elements of a system and to evaluate the suitability of systems proposed by vendors. An example of the process in one hypothetical situation is provided in (Figure 1) ***(Leuhmann et al., 1989)***

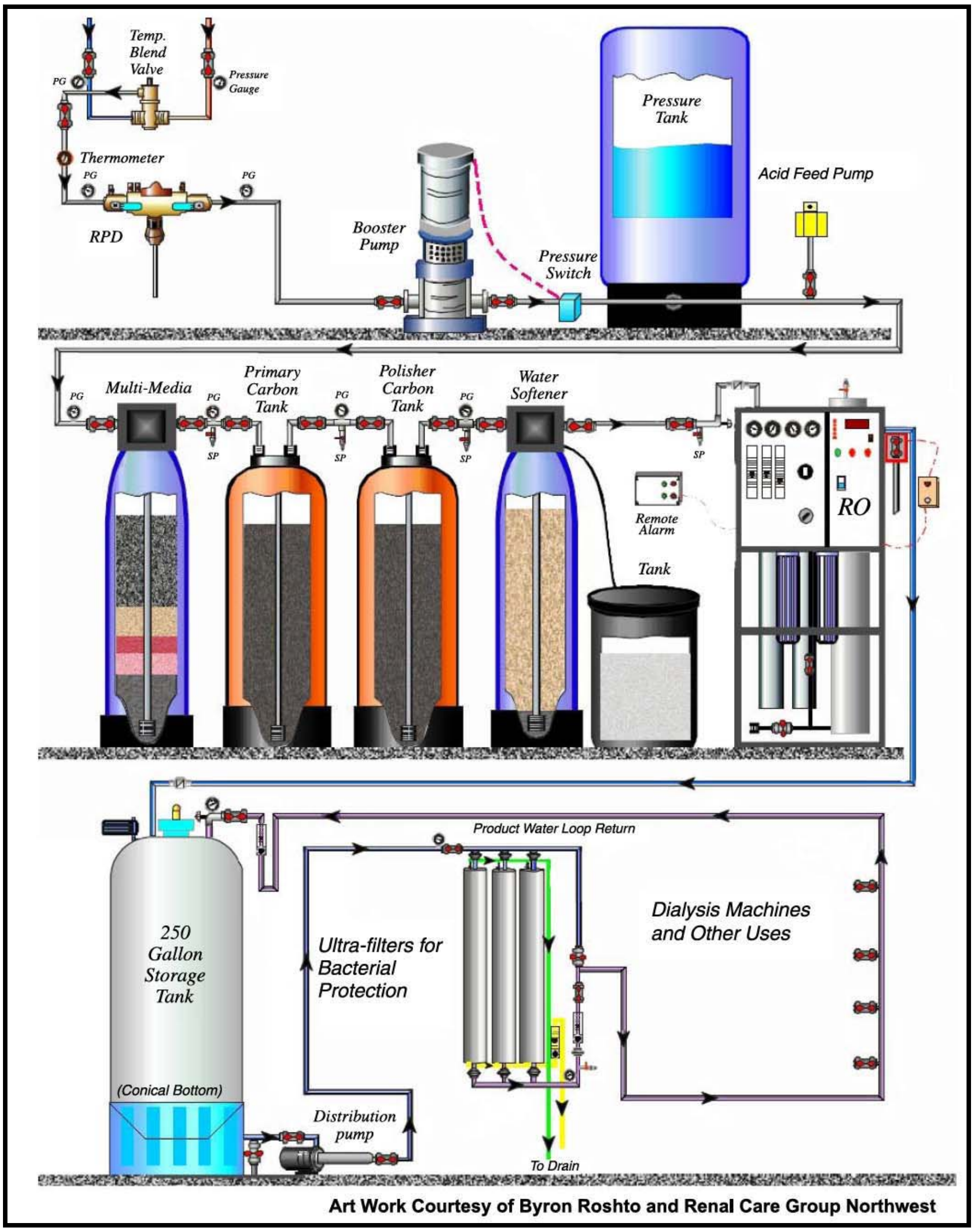


**Figure (1):** Possible water treatment system ***(Northwest Renal Network, 2005)***

## Filters

A variety of filters may be utilized, both as pretreatment for the principal purification processes and at the end of the purification and water distribution system to control microbiological contaminants. Examples include the following:

Depth filters (Figure 2) are used to remove particulate matter from the water. They range from large multi-media filters and cartridge filters which remove dirt from the incoming water to ultra-filters that remove bacteria from product water (***Northwest Renal Network, 2005).***

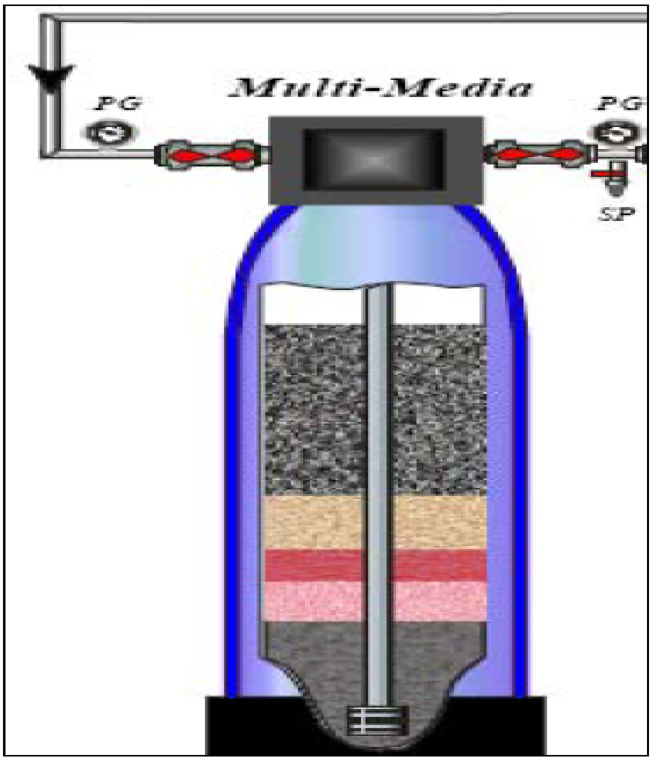


**Figure (2):** Depth filter ***(Northwest Renal Network, 2005)***

## Carbon filtration

Filtration through activated carbon is the standard method used to remove monochloramine (commonly referred to as chloramine) from water. Because chloramine is acutely toxic,