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Original article

Water quality for some Dialysis Centers of Hospitals in Sharqia Governorate and its Improvement Approaches

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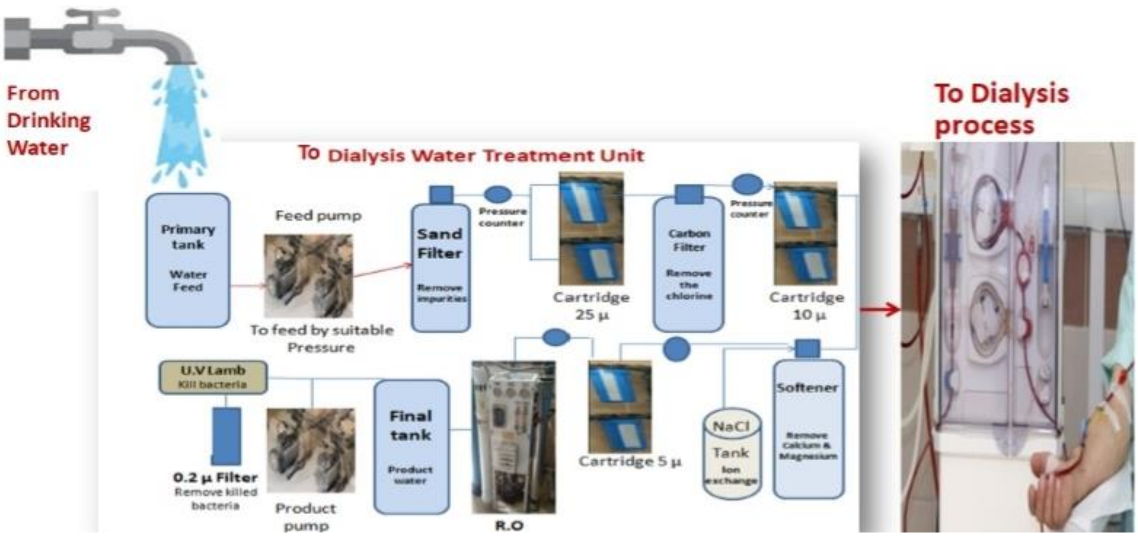
ABSTRACT

Hemodialysis patients are exposed to 500 liters of water per week compared to healthy individuals who ingest 12 liters orally. This research aims to evaluate dialysis water quality to design a dialysis water safety plan (DWSP) appropriate to the conditions of each unit and water quality to avoid morbidity and mortality caused by dialysis pollutants. This study was conducted in 21 dialysis centers in 16 hospitals from April 2020 until March 2021. 192 samples of the hospital's drinking water were taken before treatment, and 271 samples were taken after treatment. American standard methods for the examination of water and wastewater were used in the chemical and microbiological examinations. Results for drinking water matched the Egyptian standard, except for 1.56% of total dissolved solids, a percentage of Total coliform, and *Escherichia coli* 1.04%. However, chemically in dialysis water samples, residual chlorine and cadmium are not compatible in one sample. Also, ammonia and nitrite are non-compatible, but at the same time compatible with other international standards. Microbiology is not compatible with Total coliform and Escherichia coli (2.2%), *Pseudomonas aeruginosa*, *Streptococcus*, and total bacterial counts (0.7%). DWSP-recommended correction measures, however, made all samples compatible. Following the recommended DWSP correction measures, all samples were compatible. Therefore, it is necessary to have DWSP and implement it within each dialysis unit according to the water source quality, and the ability of the unit's components to treat it, to provide safe dialysis water that meets the standards to protect the health of dialysis patients.

Graphical abstract



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1. Introduction

Worldwide, chronic kidney disease (CKD) is a serious public health issue, this is linked to higher mortality and morbidity. The 12th most frequent cause of death was CKD in 2017, accounting for 1.2 million deaths [1]. The most popular type of kidney replacement therapy worldwide is hemodialysis [2]. Multiple levels of chemicals allowed in drinking water may be dangerous for dialysis patients [3]. Dialysis water needs additional filtration to reduce the patient's exposure to potential contaminants in drinking water. Chemical and microbiological contaminants are removed from dialysis water using several purification techniques, including softening, deionization, carbon filtration, and reverse osmosis (RO) [4].

Water sources vary in the Sharquia Governorate. Eleven hospitals used surface water as their water source, two used groundwater, and three used a mixture of surface and groundwater. Iron concentrations in groundwater are higher than those in surface water; while the organic content is lower [5].

Although drinking water should be treated by recommendations to eliminate elements beneficial to human health, it is harmful to dialysis patients and is not suitable. Reverse osmosis, shown in Figure 1, is one of the water filtration methods used particularly by dialysis facilities to sufficiently reduce the number of contamination agents [6]. One of the most crucial components of making sure the water is safe for hemodialysis is having enough control over the water quality. More than 40-fold increased exposure to water during hemodialysis demands regular water quality monitoring to prevent excessive usage of potentially dangerous or recognized substances [7].

This investigation looked at how to keep risk factors out of possible dialysis water sources. Each chemical has a unique reaction, such as sulfates, which can cause vomiting, nausea, and metabolic acidosis (>200 mg/L). Dialysis patients have experienced negative side effects after being exposed to some hazardous substances, such as aluminum [8], chloramine, fluoride, nitrates [9], and sulfur due to a failure in water purification.

The Dialysis Water Safety Plan's (DWSP) goal is to safeguard dialysis patients from the dangers of chemical and microbiological water pollutants.

The number of avoidable deaths from non-communicable diseases must be reduced by a third, according to the 2030 Sustainable Development Goals [10]. To achieve these goals, deploying DWSP in all units will be necessary.

Even if the required resources are not right away accessible, the plan should nevertheless list all intended actions, including both little upcoming tasks and significantly larger tasks deemed critical. The most serious issues should be given priority [11].

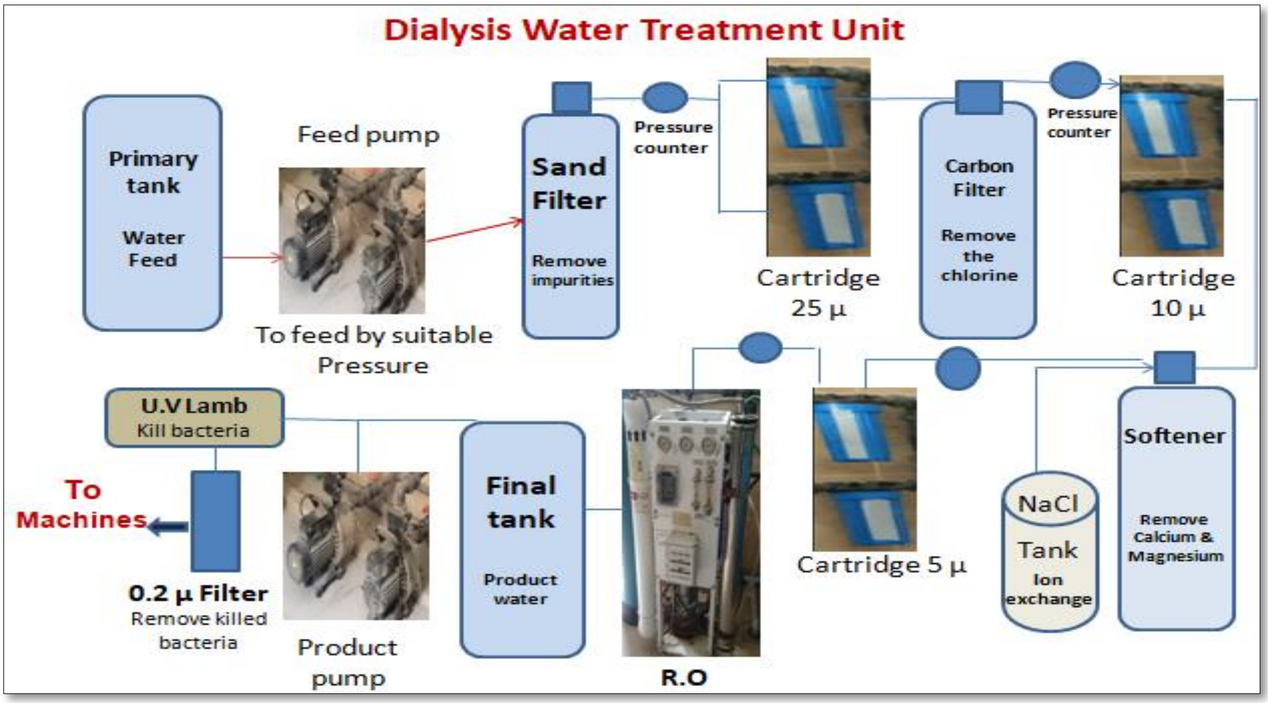

Fig. 1 Installation of a water treatment system for hemodialysis.

2. Materials and methods

The study was conducted to identify the water quality and potential cause of the non-compatible water sample in 21 hemodialysis centers in Sharquia.

2.1. Non-compatible definitions

Non-compatible drinking water sample: Violate sample for Egyptian standards in Ministerial decision 458 for the year2007for drinking water which contain chemical and microbial limits.[12].

Non-compatible dialysis water sample: Violate sample for Egyptian limits in Ministerial decision 63 for the year 1996 for dialysis water which contains chemical and microbial limits.

2.2. Samples collection

From April 2020 to March 2021, all samples were taken, using antiseptic precautions and monthly sampling of pre-treatment drinking water and post-treatment dialysis water from 16 hospitals. Among the 21 dialysis units in these hospitals, before treatment, 192 samples of drinking water were collected, and after treatment 271 samples were collected. Just before sampling, the sample port should be cleaned with alcohol. Residual-free chlorine was determined during field sampling. For the analysis of each sample, conventional techniques for water and wastewater testing were employed. [13].

2.3. Bacterial analysis

Aseptically and in sterile glassware, samples were collected for microbiological analysis. *Total coliform*, *Escherichia coli*, *Pseudomonas aeruginosa* [14], *Streptococcus faecalis* and Total Bacterial Count at 35 and 22 °C [15].

2.4. Chemical analysis

Chemical characteristics were assessed about the Egyptian regulatory requirements for the water before and after treatment in hemodialysis water. In the field, while sampling, residual free chlorine was assessed. The remaining chemical variables are chloramine, ammonia, nitrite, nitrate, fluoride, sulfate, salt, potassium, calcium, magnesium, total dissolved solids (TDS), aluminum [16], barium, cadmium, chromium, copper, iron, manganese, lead, selenium, zinc, and arsenic.

2.5. Visiting the hemodialysis water treatment facility

Observing any changes or inefficiencies in the unit's components, which include a sand filter, carbon filter, softener filter, reverse osmosis (R.O.) membranes, an ultraviolet lamp (UV), and a 0.2-micron bacterial filter, once a month; identifying potential sources of contamination and determining how to control them. Analyze the operational monitoring system to ensure prompt detection of any deviation and prompt corrective action. Describing the steps that were taken and working to document them during normal operation or incident settings.

2.6. Statistical analysis

The experiments were done from three replicates, and the results were expressed as mean value, standard deviation, and percentage of chemically unviable water, also the percentage of microbiologically unviable water for these readings.

3. Results

3.1. Drinking water results

3.1.1. Chemical outcomes

Except for three samples during the study period where total dissolved solids (1.56%) were not relevant, all 192 samples of drinking water satisfied national standards and WHO standards [17] for drinking water in terms of their chemical characteristics.

3.1.2. Results of microbiology

The microbiological findings over the course of the investigation, except for two samples that included Total Coliform and *E. coli* (1.04%), were not compliant with national criteria for drinking water.

3.2. Hemodialysis water results

3.2.1. Microbiological results

Figure 2 shows that Total coliform and E. coli were not compatible in six samples (2.2%), and Pseudomonas aeruginosa and Streptococcus faecalis were not compatible in two samples (0.7%).

Only two samples during the study period exceeded the Egyptian limitations for the total bacterial count and Table (1) displays the percentage of TBC samples in the examined dialysis water units that were above Egyptian limits.

Table (1): Total Bacterial Count (TBC) data from investigated hemodialysis water units in comparison to Egyptian Standards

Parameter	Unit	Egyptian Standards	(%) Of Samples above the Egyptian limits
TBC at 35^{0}C	CFU*	50	0.7%
TBC at 22^{0}C	CFU	50	0.7%

*CFU, Colony-Forming Unit

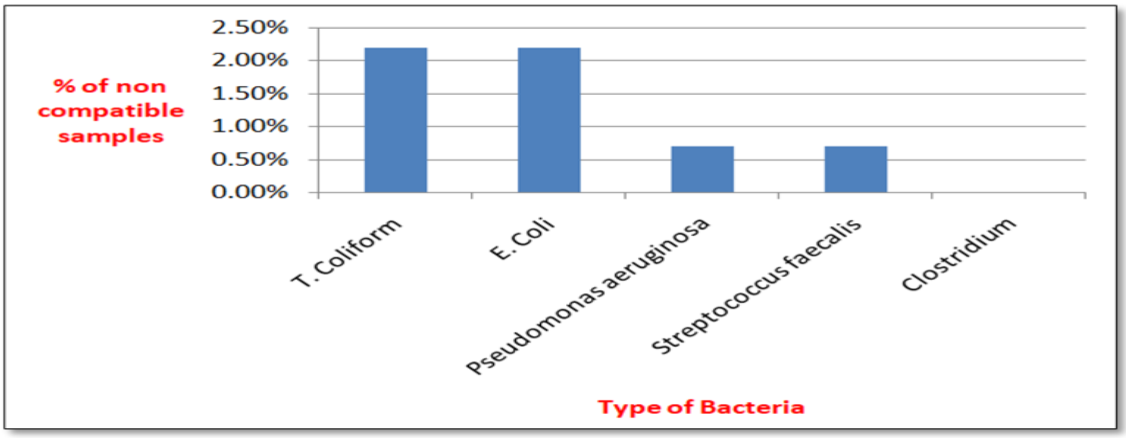

Fig. 2 The percentage of non compatible dialysis water samples for *T. coliform, E. coli, P. aeruginosa, S. faecalis and Clostridium*

3.3. Chemical results

Hemodialysis water samples (271) were not compatible with residual chlorine in one sample (0.37%), ammonia in two samples (0.73%), nitrites in four samples (1.5%), and cadmium in one sample (0.37%).

As compared to the Egyptian limit during the study period, Table (2) displays the average of chemical items in the hemodialysis water under investigation. As ammonia and nitrite are completely prohibited by standards, chemical parameters were not compatible with them.

Table (2) Mean chemical items values in investigated hemodialysis water compared with Egyptian Standards

Items	Egyptian Standards (mg/l) *	Mean±standard deviation
Ammonia	Nil	.0052±0.01
Aluminum	.01	.00022±0.00022
Arsenic	.005	.00002±0.00005
Barium	0.1	.0022±0.001
Calcium	5	.09±0.2
Chloramine	0.1	Not Detected
Cadmium	0.001	.000263±0.0007
Chromium	0.014	.0005±.0005
Copper	0.1	.00328±.002
Fluoride	0.2	.0012±.003
Free residual chlorine	0.2	.0017±.007
Iron	0.1	.0029±.002
Lead	0.005	.0001±.0001
Manganese	.1	.0026±0.0024
Magnesium	4	.014±0.05
Nitrate	Nil	Nil
Nitrite	Nil	.0004±.001
Potassium	5	.203±0.3
Sodium	70	6.58±3.3
Selenium	.09	.00005±.00009
Sulphate	100	6.34±4.2
Total dissolved solids	200	17.25±9.01
Zinc	0.1	.0024±0.001

*mg/l, Milligram /liter

3.4. Corrective action during field visits to hemodialysis water treatment units

3.4.1. Maintenance during incident conditions

Maintaining a carbon filter, softener, and R.O. membranes for a sample of dialysis water that is chemically incompatible.

For microbiologically non-compatible dialysis water samples, maintenance of U.V lamp and bacterial filter. When non-compatible samples were re-sampled after maintenance, all samples became compatible. Documenting the corrective measures that were done during routine operations or emergencies.[18].

4. Discussion

Because kidney transplants are rare, many patients must be treated with kidney replacement therapy. Therefore, the quality of drinking water fed to the targeted hospitals and treated water used in dialysis centers was examined. Sharquia receives its water from both surface and ground sources. Groundwater has a low percentage of organic matter but a higher percentage of inorganic materials such as iron [5].
So, the water filtration system in dialysis centers, in particular, reverse osmosis effectively reduces the quantity of pollution-causing substances.[6].

Except for three samples out of 192 that did not apply to high dissolved solids, all drinking water's chemical values were following the national standard, because they were in hospitals with groundwater intake, but after resampling, they were found to be compatible.

The microbiological results, except two samples of total coliform and E. coli, were pertinent to the national drinking water standard. The re-sampling results were compatible after the water distribution system had been cleaned and sanitized.

Apart from one sample because of a high free residual chlorine content, the chemical results of 271 dialysis water samples were following Egyptian regulations, because 5 mg/L of chlorine is the maximum permitted quantity in drinking water, nonetheless, the maximum permitted concentration following dialysis is 0.2 mg/L, but when the carbon filter was activated, resampling of these samples was necessary. Moreover, nitrite was detected in four samples, cadmium in one sample, and ammonia in two samples, however, the samples became compatible following R.O membrane maintenance and re-sampling.

Egyptian standards were compatible with the microbiological findings of 271 dialysis water samples, except for total coliform and *E. coli* were not compatible in six samples, *Pseudomonas aeruginosa*, *Streptococcus faecalis,* and TBC were not compatible in two samples. However, after the dialysis units were sterilized, each sample was appropriate.

These results are consistent with chemical results from research on the water used in hemodialysis facilities at five hospitals in central Iran's Isfahan [6]. Our investigation's findings, however, did not agree with the microbial findings of a study done in Nigeria, where E. *coli* was the most common organism found in treated water in all facilities. Instead, our study recorded the lowest number of isolates. [19, 20].

5. Conclusion

As a result, it was concluded that all hospital drinking water complies with Egyptian standards, except for a few samples. In chemical results, three samples were non-compatible due to high total dissolved solids, but according to WHO, no health-based guideline value for TDS has been proposed. However, none of the dialysis samples showed an increase in dissolved solids because of the ability of RO to remove TDS.

Except two samples of total coliform and E. coli, the microbiological findings were pertinent to Egyptian drinking water regulations. Because the distribution system needed to be disinfected and immediately after disinfection, all drinking samples became microbiologically compatible.

The chemical outcomes of the dialysis samples met Egyptian standards, except for one sample with high residual chlorine but after activation of the carbon filter, all samples became compatible. In addition to ammonia in two samples, nitrite in four samples, and cadmium in one sample, after the maintenance of RO membranes all samples became compatible.

The microbiological results of the dialysis water were by national norms, except total coliform and E. coli, which were not compatible in six samples each, and Pseudomonas aeruginosa, Streptococcus faecalis, and HPC, which were not compatible in two samples. However, immediately after UV lamp maintenance, disinfection, and change of the 0.2 μm bacterial filter, all samples were now microbiologically usable.

Hospital dialysis staff members should be aware of any dangers that could result from the increase of chemicals in the distribution water system in the hospitals. The DWSP should be put into action by learning about the system and its capability to supply secure dialysis water through:

- Determine probable contaminant sources and how to manage them.
- Implement a system for operational monitoring that ensures prompt detection of any deviations so that appropriate remedial action can be taken.
- Plans for managing the system's development and improvement, monitoring, communication, and support activities as well as the actions to be taken in normal and emergencies are documented in management plans.

Building the technical skills of the dialysis staff and transferring the technology of dialysis management will ensure that patients receiving dialysis are treated safely.

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