Management of water quality in some dialysis centers between 1 April 2020 and 31 March 2021 in Cairo hospitals, Egypt

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Abstract

End-stage kidney disease is a major public health problem worldwide, so dialysis water must be strictly monitored to avoid transfer harmful elements to the patient. Dialysis patients are exposed weekly to more than 40 times water than healthy individual's drink. The main aim of present study to develop a dialysis water safety plan (DWSP) appropriate to the water quality and conditions of each dialysis unit to protect patients from dialysis water contaminants. Analysis study carried out in 15 hospitals in Cairo. 180 samples were taken from drinking water which feed dialysis centres before treatment and 325 samples after treatment from dialysis water units (24 units) monthly over a 12-month period. Microbiological and chemical analysis were performed according to the American standard methods for the examination of water and wastewater. All 180 drinking water samples were applicable to Egyptian and WHO limits. But hemodialysis water results were not applicable chemically in 0.3% samples for ammonia and residual free chlorine, 1.5% nitrites, 3.69% calcium, 4% magnesium and 0.6% for increasing total dissolved solids. While microbiological analysis for dialysis water samples were not applicable for total coliforms in 2.7%, 1.8 %E. coli, 4.6% Pseudomonas aeruginosa, 2.15% Streptococcus faecalis, heterotrophic plate count showed increase by 3.3%, 3.6% at 35^0C and 22^0C respectively.Therefore, it is necessary to have a DWSP within each unit according to its components and the quality of the water it feeds, and to develop an understanding of the unit's system and its ability to provide safe dialysis water.

Key-words: Hemodialysis, drinking water, chemical, microbiological, Cairo.

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1. Introduction

Chronic kidney disease (CKD) is a growing, global public health priority that is associated with markedly high morbidity, mortality and excess health-care costs. In 2017, CKD resulted in 1.2 million deaths and was the 12th leading cause of death worldwide [1]. Also, end stage renal disease (ESRD) is a widespread public health problem worldwide that is associated with cardiovascular diseases, stroke and death [2]. A Dialysis Centre is a clinical establishment that provides the treatment of patients with renal failure [3].

Hemodialysis is the most common form of kidney replacement therapy in the world [4]. During dialysis, a patient is exposed to more than 40 times more water than a healthy person is exposed to water per week. Therefore, increased exposure for water requires regular control and rigorous monitoring of water quality to avoid transfer to the patient of suspected harmful elements carried in the water [5].

Many of permitted levels of chemical substances in drinking water are potentially dangerous for dialysis patients [5]. There is one source for the water in Cairo governorate. The water source for 15 hospitals was surface water.

Patients undergoing haemodialysis may show signs and symptoms related to water contamination, which can lead to patient injury or death [6]. So, adequate water quality control is one of the most important aspects of ensuring safe water for dialysis.

To minimize patient exposure to potential contaminants of drinking water therefore, additional purification treatment is necessary for water used in dialysis. A series of purification processes such as deionization, carbon filtration and reverse osmosis (RO) are generally used to remove chemical pollutants from water used in Hemodialysis. These processes are also an effective barrier against microbiological contaminants [7].

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This study examined how to prevent risk factors that may be in dialysis water. Where each chemical produces a specific reaction; for example, sulfate (>200 mg/l) lead to nausea, vomiting, and metabolic acidosis [8]. Adverse events have been reported in Hemodialysis patients due to exposure to certain toxic chemicals aluminum [9], fluoride [10], chloramine [11], sulfur [12], and nitrate [13] as water treatment fails.

So, reference to water safety plans (WSP) which consider the most effective means of consistently ensuring the safety of a drinking-water supply is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in the water supply from catchment to consumer [14]. So, the purpose of this study is protect haemodialysis patients from adverse effects arising from known chemical and microbiological contaminants found in water by providing guidance for the provision of safe dialysis water for patients by implementing a dialysis water safety plan (DWSP). This includes the following:

Development of an understanding of the specific system and its capability to supply water that meets dialysis water quality standard;

Identification of potential sources of contamination and how they can be controlled;

Validation of control measures employed to control hazards; implementation of a system for operational monitoring of the control measures within the water system;

Timely corrective actions to ensure that safe dialysis water is consistently supplied.

Also, the United Nations sustainable development goals aim to reduce premature mortality from non-communicable diseases by one third by 2030. So, implementation of the DWSP in all units will be an important consideration for reaching these goals.

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2. Methods

All items are analyzed according to Standard Methods for the Examination of Water and Wastewater [15].

2.1 Study design

A descriptive study was conducted to identify the water quality and potential cause of the Applicable water sample in 24 hemodialysis centers in Cairo.

2.2 Applicable definition

2.2.1 Applicable drinking water sample:

Violate sample for Egyptian limits in Ministerial decision 458 for the year 2007 for drinking water which contain Chemical, Microbial and physical limits.

2.2.2 Applicable dialysis water sample:

Violate sample for Egyptian limits in Ministerial decision 63 for the year for dialysis water which contain Chemical, Microbial limits.

Table (1) Methods of analysis used during this study

Parameter		Method No.
Chemical	Residual free chlorine	SMWW (4500-Cl)
	Chloramine	SMWW (2350 B)
	Total Dissolved Solid (TDS)	SMWW (2540 C)
	Ammonia	SMWW (4500-NH3)
	Nitrite	SMWW (4500-NO2)
	Nitrate	SMWW (4500-NO3)
	Fluoride	SMWW (4500-F)
	Sulphate	SMWW (4500-SO4)
	Sodium	SMWW (3500-Na)
	Potassium	SMWW (3500-K)
	Calcium	SMWW (3500-Ca)
	Magnesium	SMWW (3500-Mg)
	Aluminium	SMWW (3500-Al)
	Barium	SMWW (3500-Ba)

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	Copper	SMWW (3500-Cu)
	Iron	SMWW (3500-Fe)
	Manganese	SMWW (3500-Mn)
	Lead	SMWW (3500-Pb)
	Selenium	SMWW (3500-Se)
	Zinc	SMWW (3500-Zn)
	Cadmium	SMWW (3500-Cd)
	Chromium	SMWW (3500-Cr)
	Arsenic	SMWW (3500-As)
Microbiological	Total Coliform	SMWW (9221-B)
	Escherichia coli	SMWW (9221-H)
	Pseudomonas aeruginosa	SMWW (9217-B)
	Streptococcus faecalis	SMWW (9230-B)
	Heterotrophic plate count	SMWW (9215-B)

2.3 Samples collection:

Water samples were collected according to Standard Methods [15]. The bottles were made from glass or plastic for the analysis of water. The glass containers were previously washed with the same solvent used for extraction and the plastic containers were previously washed with the same sample to be collected except bacteriological samples where the glass containers previously sterilized in the oven. From April 2020 to March 2021, samples of water from drinking water before treatment and dialysis water after treatment collected from 15 hospitals monthly with antiseptic precautions. 180 samples of drinking water were collected before treatment and 325 samples were collected after treatment from 24 dialysis units in these hospitals.

2.3.1 Microbiological analysis:

The samples for microbiological testing were collected aseptically in sterile glassware. The sampling port should be

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sterilized with alcohol immediately before sampling. According to table (1) estimate the number of *Total coliform, E. Coli, Pseudomonas aeruginosa* [16], *Streptococcus faecalis, heterotrophic plate count* (HPC) at 35 ^{o}c and 22^{o}c [17].

2.3.2 Chemical analysis:

Residual free chlorine was measured in the field during the sampling. The rest chemical parameters were examined according to table (1) (chloramine, ammonia, nitrite, nitrate, fluoride, sulphate, sodium, potassium, calcium, magnesium, total dissolved solids, aluminium [18], Barium, cadmium, chromium, copper, iron, manganese, lead, selenium, zinc and arsenic) and were measured in comparison to Egyptian limits for drinking water and dialysis water.

2.4 Field visits to Hemodialysis water treatment units:

Visiting the treatment units once a month to monitor any change or inefficiency in any part of the unit. The dialysis treatment unit in these hospitals consists of a sand filter, a carbon filter, a softener filter, a reverse osmosis (R.O) membranes, and finally a ultraviolet lamb (U.V) and a 0.2 micron bacterial filter.

2.5 Statistical Analysis :

Statistical analysis was done by excel sheets software, version 2013. The arithmetic mean and standard deviation were calculated for all chemical parameters, and the percentage of samples that did not applicable microbiologically.

Results

All chemical and microbiological test performed in triplicate. The results expressed as the mean value ± standard deviation.

3.1 *Drinking Water*:

3.1.1 Chemical analysis:

All the 180 drinking water samples from 15 hospitals, the chemical parameters were applicable to national standards for drinking water.

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3.1.1.1 Residual Chlorine (R. Cl): The mean value of R.Cl in drinking water recorded 0.928±0.04 mg/l within the Egyptian national standards.

3.1.1.2 Total dissolved solids (TDS): The mean value for all samples was 265.798±10.24 mg/l.

3.1.1.3 Ammonia (NH_3): The average value for ammonia in Cairo studied drinking water hospital was 0.017±0.02 mg/l during the sampling period and within Egyptian standard and the WHO guideline for drinking water.

3.1.1.4 Nitrite (NO_2): The mean value was 0.0044±0.014 mg/l.

3.1.1.5 Nitrate (NO_3): The mean value for the studied drinking water hospitals was 0.018±0.04 mg/l.

3.1.1.6 Sulphate (SO_4): The mean value for all samples was 39.749±1.67 mg/l.

3.1.1.7 Aluminium (Al): The average value for aluminium was reported 0.067±0.008 mg/l

3.1.1.8 Barium (Ba): The mean value for all samples was 0.0076±0.013 mg/l.

3.1.1.9 Cadium (Cd): The mean value for all samples was 0.000078±0.00003 mg/l.

3.1.1.10 Chromium (Cr): The mean value for all samples was 0.00027±0.0003 mg/l.

3.1.1.11 Copper (Cu): The mean value for all samples was 0.0234±0.023 mg/l.

3.1.1.12 Iron (Fe): The mean value for all samples was 0.001 mg/l.

3.1.1.13 Manganese (Mn): The mean value for all samples was 0.0005 mg/l.

3.1.1.14 lead (Pb): The average value for hospitals drinking water during the study period recorded 0.00007±0.0003 mg/l.

3.1.1.15 Selenium (Se): The average value for Selenium during the study period recorded 0.00003±0.0001 mg/l.

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3.1.1.16 Zinc (Zn): The mean value for all samples was 0.034±0.038 mg/l.

3.1.1.17 Arsenic (As): The mean value for all samples was 0.000006 mg/l.

3.1.2 Microbiological analysis:

The microbiological results during study period were applicable to national standards for drinking. *Total Coliform, Escherichia coli (E.Coli), Streptococcus faecalis, Heterotrophic plate count at 35^{0}c and 22^{0}c*

3.2 Hemodialysis Water:

3.2.1 Chemical analysis:

The results of 325 samples from Hemodialysis water were chemically applicable in all months except: One sample was not applicable for ammonia and residual free chlorine. Whereas, five (1.5%) samples contained nitrites, total dissolved solids (TDS) were not applicable in 2 (0.6%) samples, Calcium was not applicable in 12 samples with percentage (3.69%) and Magnesium was not applicable in 13 samples with percentage 4%. Table (2) illustrate mean values of chemical parameters in the examined dialysis water compared to Egyptian Limits in the studying period.

Table 2. Mean values of chemical parameters in the studied dialysis water in comparison to Egyptian Limits

Parameter	**Egyptian Limits (Mg/l)**	**Mean ±SD**
Aluminium	0.01	0.0005±0.0008
Ammonia	Nil	0.000625±0.003
Arsenic	0.005	0.00019±0.0003
Barium	0.1	0.0055±0.014
Cadmium	0.001	0.000004±0.000005
Calcium	5	0.814±1.1
Chloramine	0.1	N.D
Chromium	0.014	0.00005±0.0001
Copper	0.1	0.0046±0.015

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Fluoride	0.2	0.0339±0.021
Free residual chlorine	0.2	0.00125±0.006
Iron	0.1	0.002±0.0005
Lead	0.005	0.00006±0.00008
Magnesium	4	0.39±0.52
Manganese	0.1	0.001±0.0005
Nitrate	Nil	N.D
Nitrite	Nil	0.00365±0.016
Potassium	5	0.14±0.21
Selenium	0.09	0.00005±0.00006
Sodium	70	8.59±2.8
Sulphate	100	2.96±2.6
Total dissolved solids	200	26.91±16.8
Zinc	0.1	0.004±0.002

Mg/l, milligram per liter; SD, standard deviation

3.2.2 Microbiological analysis:

The results of 325 samples from Hemodialysis water were microbiologically applicable in all months except: - *Total coliforms* found in nine samples, *E. Coli* found in six samples, *Pseudomonas* was isolated in 15 and *Streptococcus* was isolated in seven samples. While *Clostridium perfringens* did not appear in any sample permanently. Table (3) shows the percentage of microbiological results in the studied dialysis units that recorded results higher than the Egyptian limits. While table (4) illustrate percentage of heterotrophic plate count by a colony-forming unit (CFU) in samples that exceed about Egyptian limits.

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Table 3: The percentage of microbiological results in the studied dialysis water units that recorded results higher than the Egyptian limits

Parameter	Unit	Egyptian Limits	(%) Of Positive Samples
T. Coliform	MPN/cm^3	Nil	2.7%
E. Coli	MPN/cm^3	Nil	1.8%
Pseudomonas aeruginosa	MPN/cm^3	Nil	4.6%
Streptococcus faecalis	MPN/cm^3	Nil	2.15%
Clostridium perfringens	MPN/cm^3	Nil	0.0%

Table 4: The percentage of heterotrophic plate count (HPC) results in the studied dialysis water units that recorded results higher than the Egyptian limits

Parameter	Unit	Egyptian Limits	(%) Of Positive Samples
HPC at 35^0C	CFU	50 Cell /1 cm^3	3.38%
HPC at 22^0C	CFU	50 Cell /1 cm^3	3.6%

CFU, colony-forming unit

3. Discussion

This study examined drinking water that feed 15 hospitals before entering the hemodialysis water treatment unit (180 samples) and after treatment to use in hemodialysis process (325 samples) from April 2020 to March 2021. There is a source of water that: surface water source only that feed Cairo hospitals.

Despite this, drinking water must be treated according to the standards to get rid of the concentrations of elements that are good for a healthy individual, but at the same time, they are not suitable and may be harmful to the dialysis patient. So, Water purification system in hemodialysis Centers especially, reverse osmosis leads to a sufficient decrease in the amount of contaminant parameters [19].

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The present study revealed that dialysis water chemical parameters results of hemodialysis water samples were not applicable to the national standards, for nitrite but it still applicable for AAMI standards, where the allowed limits is 2 mg/L. And after maintenance of R.O membranes and re-sampling, the samples became applicable. These results have agreed with chemical results of study done on water used in dialysis centers of five hospitals in Isfahan, central Iran in 2016 [19].

In previous study in Benghazi hospitals, demonstrated that the tap and dialysis water success to meet the all chemical and microbiological requirements in (A) area inside hospital of Benghazi center. In generally to prevent the risk of contaminants for hemodialysis patients need to a high water quality management program and development of water treatment system in hemodialysis Centers [20].

On the contrary, the results of our study were much better than a previous study of two units in Alexandria, it was found that percentages of acceptable samples of drinking water were 67% from unit A and 66.7% from unit B, while the dialysate samples showed higher acceptability at unit B (86.1%) than unit A (51.7%). Eleven samples were detected as having *Total Coliform* [21].

4.1 The chemical results of drinking water were applicable to the national standards [22].

4.2 The microbiological results of drinking water were applicable to the national standards for drinking water.

4.3 The chemical results of hemodialysis water samples were not applicable to the national standards, for one sample due to the high residual chlorine and ammonia, five samples contained nitrites, total dissolved solids TDS were not applicable in 2 samples, calcium was not applicable in 12 sample and magnesium was not applicable in 13 samples. But after maintenance of carbon filter and R.O membranes and re-sampling, the samples became applicable.

4.4 The microbiological results were applicable to *Clostridium perfringens* and heterotrophic plate count but not applicable to national standards, for *total Coliform* in nine samples, *E.coli* in six samples, *Pseudomonas aeruginosa* in 15 samples, *Streptococcus faecalis* in seven samples. While all samples were applicable for. But after sterilization of the dialysis units and changing the bacterial filter all samples were applicable.

4. Conclusion

5.1 In the end we conclude that drinking water in all hospitals under study applicable to the microbiological and chemical Egyptian limits and the World Health Organization guidelines [23].

5.2 The results of the dialysis water samples were applicable except for very limited samples, but after maintenance of the carbon filter, R.O membranes, disinfection and changing the 0.2 micron bacterial filter, all samples after returning became applicable.

5.3 Thus, it is clear that the Dialysis Water Safety Plan (DWSP) should be implemented by developing an understanding of the system and its ability to provide safe dialysis water by:-

5.3.1 Identify potential sources of pollution and how they can be controlled;

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5.3.2 Implementation of an operational monitoring system that ensures rapid detection of any deviation for timely corrective action;

5.3.3 Management and communication plans describing actions to be taken during normal operation or incident conditions and documenting system evaluation, including upgrade and improvement planning, monitoring and communication plans and support programs;

5.3.4 Basic technical training and technology transfer for dialysis management to staff of Kidney dialysis centers, which include various requirements aimed at ensuring the safe treatment of dialysis patients [24, 25].

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