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Determination of Some Heavy Metals in Dialysis Concentrates in Two Centers of Dialysis in Baghdad, Iraq

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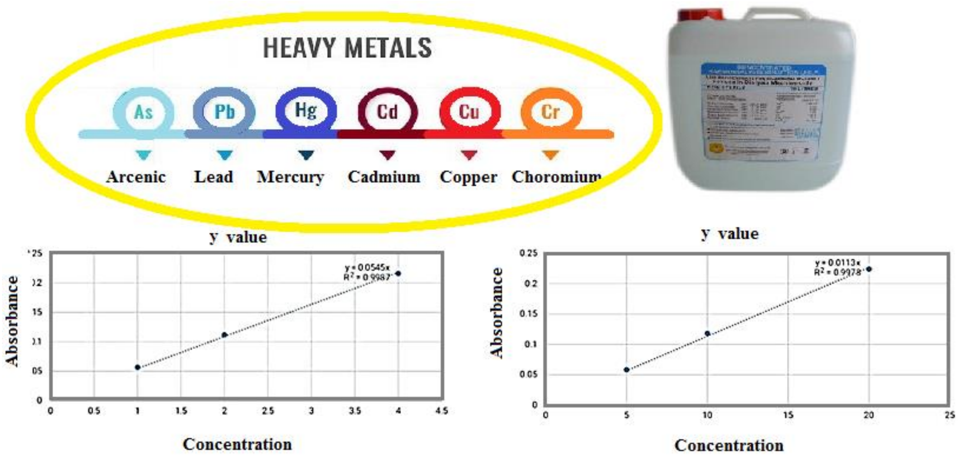
ABSTRACT

The patients with renal failure require hemodialysis treatment and dialysis fluid is thus an essential component of such a treatment.
Hemodialysis is a method of treating renal failure which makes use of dialysis fluid to aid in re-establishment of electrolyte and acid-base balance. The water utilized for this process is derived from drinking water, although it has undergone an extra purification.
The purpose of this study is to evaluate the quality of dialysis fluids in two dialysis centers in Baghdad, over four seasons, from November 2020 to July 2021. A total of 24 water samples were analyzed as a part of the evaluation from three sites at each dialysis facility (tap, dialysis, and dialysis network distribution) of water samples. Chemical investigations were carried out after sampling water from the dialysis centers. The technique of Atomic Absorption Spectroscopy was used to determine the concentration of heavy metals in the water under investigation.
The findings revealed that there was a fluctuation in the quality of the observed dialysis water. 25% of water samples for Al level (normal 0.01 mg/L) was above the normal range for dialysis water. The highest value of aluminum was (0.04 mg/l) during the autumn and the lowest value was (zero) during the spring. 62.5% of water samples for chloramine level (normal 0.1 mg/l) were above the normal range for dialysis water. The highest level was (0.505 mg/l) during the autumn. When compared to the international standards, it was found as unacceptable. According to the results of the chemical investigation, the dialysis water quality suffers from the high Chloramine concentrations in all dialysis facilities.

GRAPHICAL ABSTRACT



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Introduction

Water treatment is critical to ensure a safe and the efficient water supply for Hemodialysis HD [1]. The primary source of feeding water used in hemodialysis centers is the municipal water (*i.e.* the drinking water) which is pretreated at multiple stages to remove contaminants [2].

(HD) is a major kidney replacement therapy that is used worldwide [3], with the primary component of the dialysis process being an exchange of blood and dialysis fluid through a thin semipermeable membrane [4].

[Forwarded from Sadiq Ali]

In 2017, CKD resulted in 1.2 million deaths and was the 12th leading cause of death worldwide [5], and also there are more than 20 dialysis centers, the majority of which have similar units for dialysis water output [6]. Patients typically undergo (HD) three times per week for three to four hours [7]. In a single dialysis treatment, dialysis patients are exposed to a large amount of dialysis fluid (about 192 L) [8,9]. The chemical and bacterial contamination of dialysis water is likely a cause of such a high mortality rate, the International Organization for Standardization [10] and a similar standard from the American National Standards Institute [11] have issued the standards and recommendations to ensure that the water quality required to reduce the incidence of endotoxemia and chemical hazard for HD patients. These standards will be used to compare the findings of this study, to assess the quality of the produced dialysis water, and to recommend the best strategy for bringing this water up to the international standards. Because no national standards for dialysis water have been issued, the international standard will be considered.

Materials and Methods

In this study, several apparatuses and instruments were used for water analysis:

1. Atomic absorption spectrometer AA7000 (Shimadzu).
2. Atomic absorption spectrometer for measuring mercury (NovAA 400).
3. Free chlorine meter (Romavia).
4. Sample collection bottles.
5. Chemical materials used for water analysis (Ethanol, Hydrochloric acid, N,N-diethyl-P-phenylenediamine DPD, and others).

This study conducted in two kidney dialysis centers in Baghdad hospitals which are mentioned as follow:

1. Al-Imam Ali dialysis center which is located in Sadar City (Al-Jawder) at Al-Rasafa side of Baghdad which was established in 2014.
2. Al-Hayat dialysis center at Al-Karama teaching hospital which is located at Al-Alawy City, Street 6 and was established in 2011.

The locations of the hospitals are depicted in Figure 1.

The study was extended for the period of four seasons, from November 2020 to July 2021, where the water samples were collected from the above-mentioned stations from three locations (tap, dialysis (RO), and the dialysis distribution network hemodialysis machine water).

The glass bottles were used for collecting the water samples for heavy metals assays after washing them with the concentrated nitric acid and the water samples were distilled for three times. Then, they were transported within 1–2 hours at a low temperature (4 °C) for chemical testing.

Atomic Absorption Spectroscopy was used to determine the concentration of heavy metals in the water by atomizing their solutions such as aluminum (Al), cadmium (Cd), and lead (Pb), because the high toxicity of mercury (Hg) was determined by the atomic absorption with cold vapor.

For total and free chlorine, a chlorine test device was used and the tests were conducted for the models according to the following steps. 10 ml of the sample was withdrawn and placed inside the cell of the device to level off the device, then a tablet of *N,N*-diethyl-*p*-phenylenediamine DPD was added, the cell was shaken well, and thus the color of the water turned from colorless to pink. Next, the cell was placed inside the device and the reading number was recorded in mg/l for three times.

The chloramine level was measured by calculating the difference between total chlorine level and free chlorine.

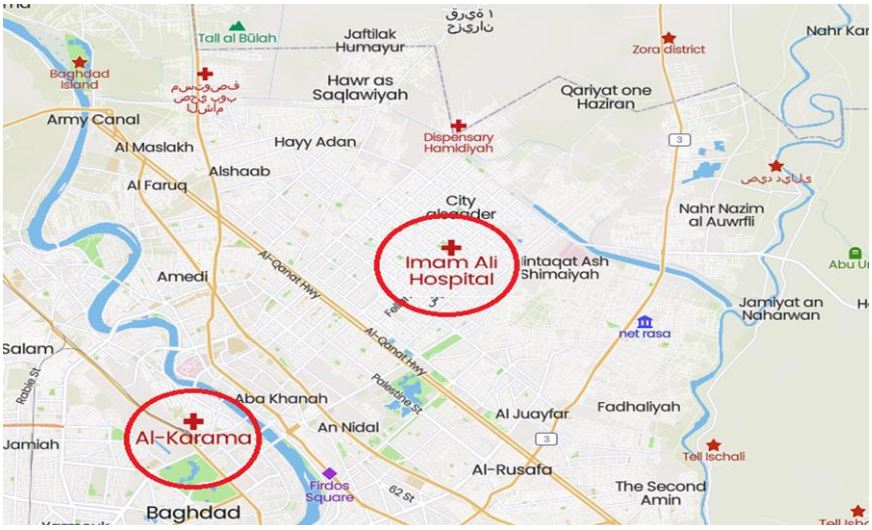

Figure 1: The map of Baghdad City, Iraq, in which the areas of the two hospitals are located for the study

Statistical analysis

The Statistical Analysis System, (SAS (2012) program), was applied to detect the effect of difference factors in the studied parameters. The least significant different LSD test (i.e. Analysis of Variation (ANOVA)) was used to compare the significance level between mean values in this study.

Results and Discussions

The standard curves were drawn for the concentration vs. the absorbance of the heavy metals, as presented in the following figures.

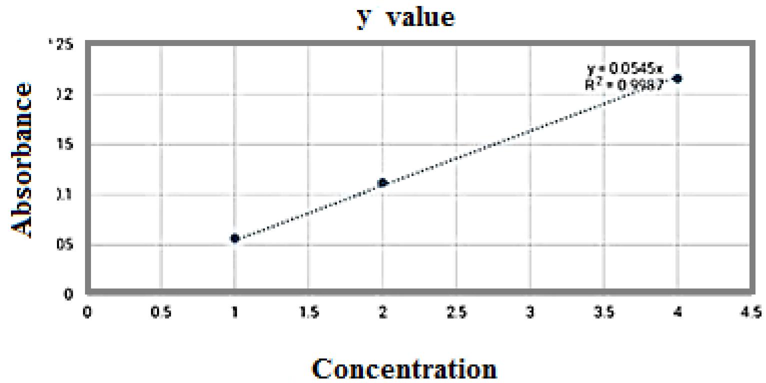

Figure 2: The standard curve for Pb ion concentration

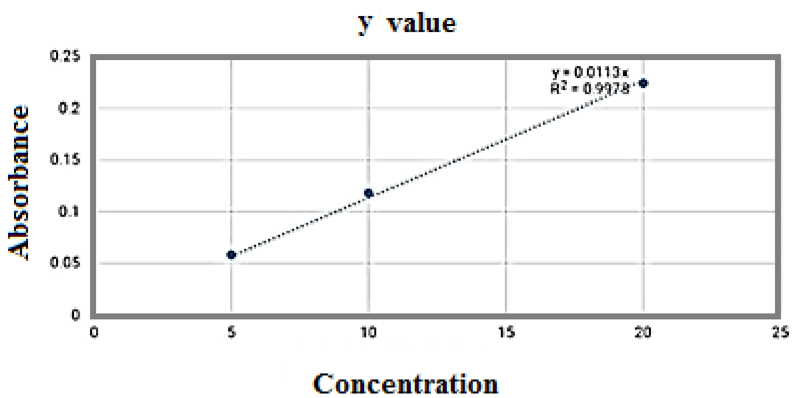

Figure 3: The standard curve for aluminum ion

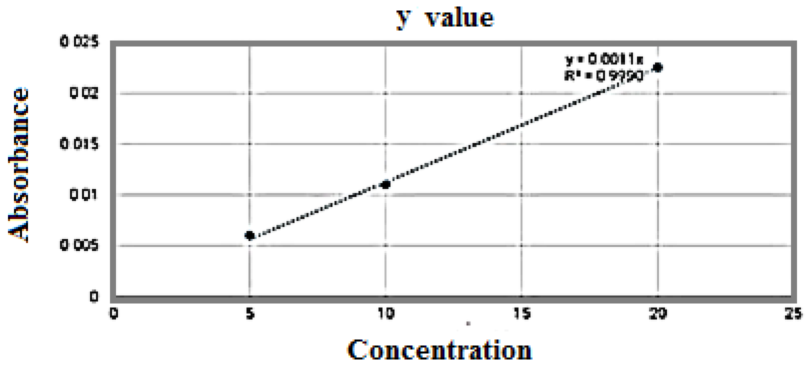

Figure 4: The standard curve for mercury ion

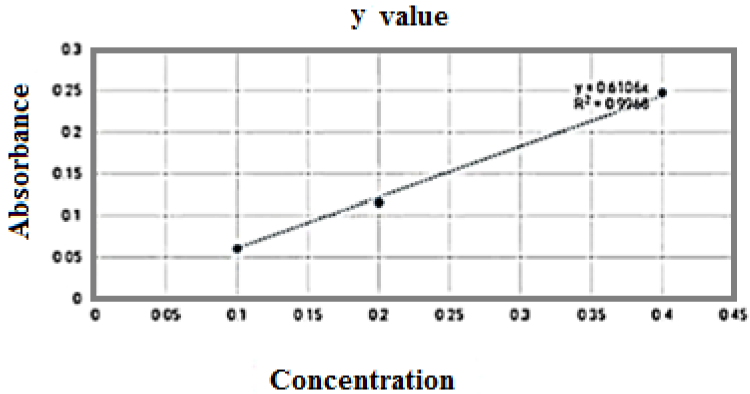

Figure 5: The standard curve for cadmium ion

The results are indicated in Table 1. 25% of the water samples for Al level (normal 0.01 mg/l) as well as 62.5% of the water samples for chloramine level (normal 0.1 mg/l) were above the normal range for dialysis water, as demonstrated in Table 1.

Table 2 illustrates the recommended maximum which is the permitted chemical contaminant levels according to (ANSI/AAMI 23500, 2019) [11] for dialysis fluid and these are used as the standard levels to compare with the results of dialysis water samples.

Table 1: The chemical analysis of dialysis water at each hospital dialysis center during the study period

Parameters mg/L	Hospital	Season				LSD value
		Winter	Spring	Summer	Autumn	
Al	Al-Karama	0.006	0.00	0.00	0.040	0.0109 *
	AL-Imam Ali	0.003	0.00	0.00	0.020	0.0018 *
T-test		0.0022 *	0.00 NS	0.00 NS	0.011 *	---
Pb	Al-Karama	0.001	0.003	0.00	0.00	0.0019 *
	AL-Imam Ali	0.003	0.006	0.00	0.00	0.0023 *
T-test		0.0014 *	0.002 *	0.00 NS	0.00 NS	---
Cd	Al-Karama	0.002	0.00	0.00	0.002	0.0019 *
	AL-Imam Ali	0.002	0.00	0.00	0.003	0.0018 *
T-test		0.001 NS	0.00 NS	0.00 NS	0.0012 NS	---
Hg	Al-Karama	0.00	0.00	0.00	0.00	0.00 NS
	AL-Imam Ali	0.00	0.00	0.00	0.00	0.00 NS
T-test		0.00 NS	0.00 NS	0.00 NS	0.00 NS	---

* ($P \leq 0.05$),
NS: Non-Significant.

Table 2: The AAMI/ANSI maximum permitted chemical contaminant levels in dialysis water

Contaminant	Normal Level in mg/L
Aluminum	0.01
Cadmium	0.001
Lead	0.005
Mercury	0.0002
Chloramine	0.1
Free chlorine	0.5

The comparison of the results for the water samples with the standard levels demonstrated that there is a fluctuation in concentration of the heavy metals and chloramine levels as well as in the quality of water.

Aluminum (Al^{+3}) concentrations in the samples taken from dialysis water were exceeded the permissible international level of (0.01 mg/l) for dialysis fluid according to AAMI and ISO standards [11] by as much as 25 percent. The highest value was (0.04 mg/l) during the autumn and the lowest value was (0.0) during the spring. This is a clear indicator that single pass RO treatments in dialysis centers are not adequate for reducing (Al^{+3}) concentrations to a satisfactory level, or that the piping system is not suited for this purpose. It is toxic to dialysis patients, and because it is sequestered in bone for an extended period of time, it causes the dynamic bone disease, osteomalacia, and Alzheimer disease in these people. Likewise, the well-documented dialysis encephalopathy syndrome can cause as a result of this condition [12][13].

The majority of the results of lead (Pb^{+2}) concentration in dialysis fluid are within the permitted international guideline of 0.005 mg/l in dialysis fluid.

Cadmium [Cd^{+2}] levels were higher than the normal values in dialysis water in 50% of samples. The highest value was (0.003 mg/l) during the autumn, while the normal level was (0.001 mg/l) according to the AAMI and ISO standards [11].

[Cd^{+2}] can be removed from the drinking water using a variety of processes, including acid cation resin, reverse osmosis, distillation, and lime (calcium hydroxide) softening. Improving and re-changing RO membranes are necessary to ensure that cadmium levels in dialysis water meet the international standards. Bone disease, heart disease, and infertility are among health problems associated with the high cadmium levels [14][15]. Mercury (Hg^{+2}) was not detected in a sample of dialysis water maximum level. The permitted level of mercury in dialysis water is (0.0002 mg/l) according to AAMI and ISO [11]. Because mercury is very toxic and its short-term exposure causes heart and liver disease which lead to die [16].

62.5% of the results of chloramine level in dialysis water was above the permitted levels of (0.1 mg/l according to AAMI and ISO standards [11], the highest level was (0.505 mg/l) during the autumn. The activated carbon and the catalytic activated carbon used in the water treatment system effectively reduced chloramine level in dialysis water. The elevated chloramine levels can cause hemolytic anemia when presented in dialysis process water [17].

Conclusion

The results of a field monitoring research revealed that the majority of the dialysis water did not match the standards for the international specifications for dialysis fluid. It is important to add a submicron filter after the storage tank and before distributing dialysis water to the patients in order to boost the quality of dialysis water. The obtained results demonstrate that it is essential to alter the architecture of the water systems. The treatment units are installed in all hemodialysis centers to ensure that the water produced is in comply with the international standard and the need to establish national guidelines for dialysis fluid quality.

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Authors' contributions

All authors contributed toward data analysis, drafting and revising the paper and agreed to responsible for all the aspects of this work.

Conflict of Interest

We have no conflicts of interest to disclose.

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