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SHORT COMMUNICATION article

Evaluation of hemodialysis water quality regarding heavy metal levels at Nalut Central Hospital in Libya

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Abstract: The kidney is the first target organ of heavy metal toxicity due to its capacity to reabsorb and accumulate divalent metals. Hemodialysis therapy is used to purify the blood of individuals with impaired kidney function. This study aimed to evaluate the quality of treated water used in the hemodialysis unit at Nalut Central Hospital, Nalut, Libya, by determining the concentrations of selected heavy metals and comparing them with international standards. A descriptive analytical approach was adopted. Water samples were collected post-treatment from the reverse osmosis system using sterile containers under strict hygienic conditions. Laboratory analyses were conducted using an atomic absorption spectrophotometer to measure the concentrations of zinc, cadmium, chromium, lead, copper, and aluminum. The results revealed critical variations; elements such as zinc (0.93 mg/L), cadmium (0.16 mg/L), and copper (0.57 mg/L) significantly exceeded the permissible limits set by AAMI standards. Conversely, chromium (0.002 mg/L) was within acceptable parameters, and neither lead nor aluminum was detected. This study concludes that the treated water does not fully comply with international safety standards, indicating a partial inefficiency in the current water treatment system. It is highly recommended to enforce rigorous maintenance procedures for the reverse osmosis system and implement routine monitoring protocols to mitigate health risks associated with heavy metal accumulation in hemodialysis patients.

Introduction

The quality of water utilized in hemodialysis units is a critical factor directly impacting patient safety [1-3]. Patients suffering from renal failure are exposed to vast quantities of water during dialysis sessions, often exceeding 120 liters per session. Consequently, any chemical or biological contamination in the water can transfer directly into the patient's bloodstream across the dialyzer's semi-permeable membrane [4]. Treated water is essential for preparing the dialysate, and it must possess extreme purity, free from heavy metals such as Lead (Pb), Cadmium (Cd), Copper (Cu), Zinc (Zn), and Chromium (Cr). The accumulation of these elements can lead to severe complications, including heavy metal poisoning, neurological disorders, and anemia [5, 6]. While hospitals generally employ specialized water treatment systems such as reverse osmosis (RO) to eliminate impurities, the efficiency of these systems can be compromised by inadequate maintenance, aging equipment, or poor source water quality. The core problem lies in the uncertainty regarding the exact water quality in the hemodialysis unit at Nalut Central Hospital, Libya, specifically concerning heavy metal concentrations and their compliance with international standards. This study aims to evaluate the quality of water used in the hemodialysis unit at Nalut Central Hospital, Nalut, Libya. The specific objectives include measuring the concentrations of selected heavy metals, evaluating the efficiency of the water treatment system, comparing the analytical results with WHO and Association for the Advancement of Medical Instrumentation (AAMI) standards, and assessing the potential health risks to patients [7].

Materials and methods

This study utilized a descriptive analytical method to evaluate the water quality in the hemodialysis department at Nalut Central Hospital, Nalut, Libya. The water treatment system evaluated relies on pre-filtration, water softening, and primarily on an RO unit designed to purify water from salts and heavy metals.

Study population and sample: The study population consisted of the treated water generated by the RO system used for dialysate preparation. Samples were systematically drawn from designated points post-treatment **(Figures** 1 and 2).

Data collection and instrumentation: Sterile plastic containers were used to collect the RO water samples, ensuring no external contamination occurred during extraction and transport (January, 2026. The chemical variables measured included Lead, Cadmium, Copper, Zinc, Chromium, and Aluminum. The laboratory analyses were executed utilizing an atomic absorption spectrophotometer, a highly accurate instrument for detecting trace heavy metal concentrations. Official administrative approvals were secured before sampling, and the procedures were strictly for scientific evaluation. The researchers declare that the analytical instruments and standard procedures are commercially and scientifically available, adhering to standard laboratory protocols.

Figure 1: Water treatment system used in the dialysis unit

Figure 2: Post-treatment water sampling point in the dialysis unit

Results

The laboratory analysis focused on measuring specific heavy metals in the treated hemodialysis water. The results were tabulated and compared against AAMI international standards to ensure safety for medical use (**Table 1**). Data demonstrates variations in chemical concentrations. Zinc and cadmium levels were notably high, suggesting a potential deficiency in the treatment system's efficiency or contamination in the supply lines. However, Chromium levels remained within globally acceptable limits, and both Lead and Aluminum were undetectable.

Table 1: Heavy metal concentrations in treated water used in the hemodialysis unit at Nalut Central Hospital

Element	Concentration (mg/L)	Element	Concentration (mg/L)
Zinc	0.93	Lead	Not detected
Cadmium	0.16	Copper	0.57
Chromium	0.002	Aluminum	Not detected

Indicating values below the detection limit of the AAS device

Discussion

Worldwide, hemodialysis is a technological marvel that sustains several million people. This success comes with a hidden environmental price tag. Present-day estimates suggest that a standard hemodialysis treatment is highly resource intensive: depending on the system configuration, a single session may require roughly 300-500 L of water, and total water use may approach about 500 L when RO rejection is included [8]. HD also consumes substantial electricity and relies heavily on single-use consumables and plastics [9]. The study's findings reveal a noticeable elevation in specific heavy metals. Zinc concentration reached 0.93 mg/L, exceeding the AAMI maximum allowable limit of 0.1 mg/L. This spike may be attributed to a degraded RO membrane or corrosion within the distribution pipes. These findings have repeatedly been reported in several studies all over the world [10-13]. Continuous exposure to high zinc levels can cause immune system disruption in dialysis patients. Critically, Cadmium levels were recorded at 0.16 mg/L, far surpassing the strict AAMI limit of 0.001 mg/L. Cadmium is highly toxic and bioaccumulative, particularly damaging to the kidneys. Copper also exceeded permissible limits (0.1 mg/L), recording 0.57 mg/L, which can lead to hepatic complications upon chronic exposure. Conversely, the treatment system successfully managed Chromium, maintaining it at a safe 0.002 mg/L (limit: 0.014 mg/L). The absence of detectable Lead and Aluminum aligns perfectly with global safety standards, indicating partial systemic efficiency. Ultimately, the primary hypothesis-that the water entirely conforms to international standards-was rejected due to the dangerous levels of Cadmium, Zinc, and Copper. Potable water is a limited global resource, and its consumption impacts future availability. In 2010, the United Nations General Assembly recognized access to safe drinking water as a human right. Consequently, governments must create conditions to ensure universal access to water and sanitation without discrimination, prioritizing vulnerable populations. Recognizing the need to prevent water waste, several “green dialysis” initiatives have proposed strategies to reduce, reuse, and recycle water [9].

Conclusion: This study concludes that treated water does not fully comply with the stringent international AAMI standards. While the system effectively eliminated Aluminum and Lead, it failed to appropriately filter out Zinc, Cadmium, and Copper. Because hemodialysis patients lack natural filtration capabilities, this discrepancy poses a severe, cumulative health risk. To rectify this, immediate and structured maintenance of the RO system is required, specifically the regular replacement of membranes and filters. It is imperative to enforce a continuous monitoring protocol for water quality, upgrade aging infrastructure within the water distribution network, and adhere strictly to AAMI and WHO guidelines to guarantee patient safety.

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