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Radionuclides and heavy elements in a water deposits of Reverse Osmosis system filters in Iraqi houses

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ABSTRACT

Introduction: In this study, we investigated contaminants in sediments of reverse osmosis water systems in Iraqi households. These filters are imported from the US and Taiwan and are available in the Iraqi market. The rate of environmental pollutions in residues of the water filters was examined by measuring alpha particles emission rates and the concentration of heavy metals.

Material and Methods: In this study, we measured the rate of alpha particles emission using CR-39 detector. Heavy elements were measured using an atomic absorption spectrometer.

Results: The highest value of cadmium was found in Ghadeer district and the lowest cadmium value in Alswag district. The highest value of lead was found in Ghadeer district and the lowest in Aljameha. The emission rates of alpha particles were found to be the lowest in the sediments of Ghadeer district, and the highest values were found in Khan Almkhdhar.

Conclusion: The average concentrations of dissolved Cd and Pb were higher than the safe limits for Iraq specifications and the world standard limit.

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Introduction

Radionuclides in drinking water have turned into a significant issue [1]. Contamination with radionuclides exists throughout the city because medical facility and nuclear power wastes are released in water [2]. Radionuclides occur naturally as elements in water, air, soils, and rocks as a consequence of the radioactive decay of ^{238}U and ^{232}Th. This decay occurs as a result of radiation energy. Radon and radium isotopes of the ^{238}U and ^{232}Th series exist in groundwater. Ionizing radiation strikes living organism cells.

Reverse-osmosis (RO) is a pressure-driven membrane separation process, which was introduced by The Environmental Protection Agency (EPA) as a system compliance technology for radionuclides. It can remove 99% of these radionuclides and other contaminants such as arsenic, nitrate, and microbial contaminants [3]. RO unit can be automated and compact, which make the system more appropriate. Membrane failure, which can allow contaminants to pass through to the finished water, is a key concern. Colloids and bacteria can foul a membrane. The product water needs the addition of corrosion inhibitors, as well as pH and alkalinity adjustment upwards by the addition of alkalinity. These actions prevent compliance issues in the distribution system like elevated level of Pb and Cu. Radionuclides in the liquid residual impact disposal option due to the high level of contaminants of water. RO effectively removes inorganic contaminants, including heavy metals and radionuclides (Ra and U). RO can remove about 87-98% of Ra from water and similar elimination can be achieved for alpha particles [4]. Using an RO to remove radionuclides, performance depends on factors such as pH, iron/manganese content, turbidity, and membrane type.

Radioactive particles will necessarily affect ground water, which is to become drinking water. PurePro delivers RO to remove particles with the size of about 0.0001 μ. The Environmental Protection Agency's acceptable standard for radioactive contaminants is about 0.555 Bq l^{-1} in public drinking water supplies. When radioactive particles are ingested, the digestive system is affected [5]. Radioactive particles from Chernobyl and other sources such as ongoing local farming, manufacturing and more, are probably already in the ground water from which most drinking water is attained. The atomic diameters of uranium and radium are about 0.000350 × 10^{-6} m and 0.000430 × 10^{-6} m, respectively. Radioactive particles are larger than 0.0002 × 10^{-6} m. RO removes particles larger than 0.0001 × 10^{-6} m. RO is a deployable

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technology to effectively deal with radioactive contaminants. The process removes chlorine and nuclear elements like radioactive plutonium or strontium from drinking water. RO with activated carbon seems to be the most advanced water purification method developed so far. Nutritional supplements developed for the purpose of detoxifying heavy metals contain plant fibers and algae. EPA regulates radionuclides in water to protect public health [6]. Radionuclides at amounts greater than the drinking water standards cause health problems. The new rule revised the radionuclides regulation that had been in effect. The revisions set new monitoring requirements for community water system. This ensured customers receive water meeting maximum contaminant levels for radionuclides in water. EPA issued a standard for U, as required by the Safe Drinking Water Act Amendments of 1986. The current standards are: combined radium of 0.185 Bq l^{-1}, the gross alpha standard of about 0.555 Bq l^{-1}, and a combined standard of 0.04 mSv.y^{-1} for beta emitters.

RO system removes fallout contamination. The levels of these radioactive contaminants are below the maximum concentration level, but long-term ingestion may not be safe. Drinking unhealthy water affects children more than adults, which causes concern for the health of children drinking tap water [7].

Pollutants come from untreated sewage, factories, and fertilizers. The major source of metal pollution in rivers is the industrial effluents near rivers. The transport of sediment downstream due to the river velocity contributes to the deposition of heavy metals in below the surface [8].

In this study, we aimed to determine the rate of alpha particles emission and heavy elements in household filters used in different areas of Najaf Governorate, Iraq. We also compared our results with global findings to determine the level of environmental pollution resulting from alpha particles and heavy elements. RO is used to remove lead, mercury, fluoride, chlorine, and many other contaminants through various pre- and post-filters that make up a RO filter system.

Materials and Methods

Twelve water filters were collected from houses in different regions of Najaf, Iraq. The filters were selected from houses where 900 liters per month of water was consumed. These samples were transferred to an environmental laboratory for conducting the necessary tests and analysis of the samples. Then, sediments were extracted from the filters. Sediments were placed in airtight polyethylene bags and detailed information such as sample name, area, and date were written on them. The samples were dried by oven for 1 h at a temperature of 120ºC.

The samples were weighed and then placed on α-detector sheets with an area of about 2 × 2 cm^2. Then, it was put in vacuum-sealed, high-density polyethylene bags and clamped in position. An alpha particle, while not penetrating far, deposits considerable energy in a short-range distance. The samples were prepared for examining heavy metals through the extraction of sediments using the evaporation process. The samples were then manually ground by mortar for obtaining homogeneous samples. The studied samples were weighed by a sensitive balance.

Water deposit samples (powder) were placed in contact with the CR-39 detector (α-sensitive detector, PADC-TASTRACK, UK, $C_{12}H_{18}O_7$). The CR-39 has the ability to record the tracks of alpha, proton, and fission fragments because it has carbon bonds that break when exposed to radiation. Nuclear track technology is a technique for determining radionuclides due to availability, accuracy, and not requiring complex electrical devices [9]. The CR-39 detectors and samples were placed together in a freezer at -20ºC for 90-120 days to allow alpha particle tracks to accumulate on CR-39. The samples were then extracted from the detector. The CR-39 detectors were washed using distilled water and dried. Alpha particles were measured without any chemical treatments. CR-39 detectors were etched using NaOH solution as reported in former studies [10-13]. The detectors were etched for calculating the effects of alpha particles as displayed in Figure 1.

Figure 1. CR-39 with a NaOH solution

Alpha tracks were counted using a microscope (A. Kruss. Optronic, Germany) with MDCE-5C camera at 10 × magnification as shown in Figure 2.

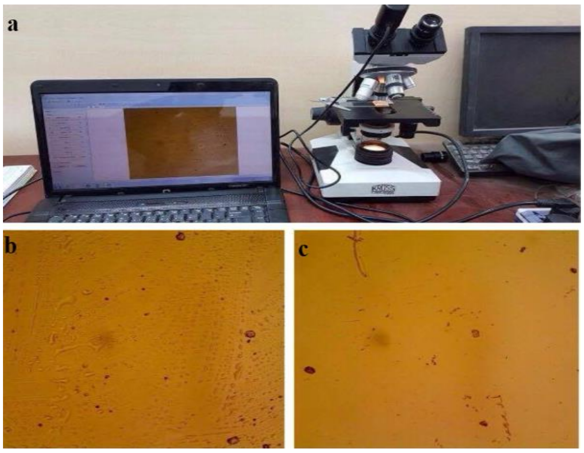

Figure 2. a. Optical microscope connected to the computer; b, c. Alpha particles track

The CR-39 efficiency in this study was calculated [14]. The alpha emission rate (E_α) was calculated [14]:

$$E_{\alpha}(mBq\ cm^{-2}) = \varepsilon\% \frac{(\rho_s - \rho_b)}{T}, \quad (1)$$

Where T is exposure time (s), ρ_S denotes the number of tracks of samples (Track.cm^{-2}), and ρ_b shows background tracks in the detector (Track.cm^{-2}).

About 100 ml of distilled water was added to the sediment samples (0.5 g) at 180ºC for half an hour using VELP Scientifica, which offers a wide range of heating magnetic stirrers. Then, the mixture was heated until it diminished to about 10 ml, and afterwards, this solution was filtered for the separation of solid particles to prepare for the measurement of Cd and Pb using atomic absorption spectrophotometer. The heavy metals in water sediments were determined using a Flame Atomic Absorption Spectrophotometer-6300 AA, Shimadzu, Japan.

Results

Table 1 shows the concentrations of cadmium in the studied samples. The highest value of cadmium was found in Ghadeer water deposits (0.0224 ppm) and the lowest cadmium was in Alswag district water deposits (0.0022 ppm), while the global maximum allowable amount is 0.005 ppm. The concentrations of the lead element are presented in Table 1. This table shows that the highest value of lead was found in Almutanaby water deposits (1.5459 ppm) and the lowest value was observed in Aljameha water deposits (0.4705 ppm).

The emission rates were the lowest for alpha particles (the standard errors were very near to emission rate of alpha) in the sediments of Ghadeer district (0.0009±0.0002 mBq.cm^{-2}) and the highest values were in the sediments of Khan Almkhdhar (0.0482±0.0093 mBq.cm^{-2}) as displayed in Table 2. The standard error was calculated using formula: Standard error $= \frac{\text{STDEV}}{\sqrt{n}}$, where STDEV denotes standard deviation and n shows the number of readings.

Table 1. Heavy metals concentration (ppm) in the samples

Sample Location	Lead	Cadmium
Askary	0.7393	0.0142
Mohandesen	0.6049	0.0112
Ansar	1.1426	0.0097
Alswag	0.9410	0.0022
Aljameha	0.4705	0.0149
Almelad	0.8738	0.0119
Alfurat	1.2098	0.0149
Aljazerah	0.6049	0.0075
Alhindeah	0.6049	0.0157
Ghadeer	0.8066	0.0224
Almutanaby	1.5459	0.0127
Khan Almkhdhar	1.4787	0.0171
Average	0.9186±0.1024	0.0129±0.0014
PTWI*	0.0250	0.0070

*Provisional tolerable weekly intake (PTWI)

Table 2. Information and the emission rates of alpha particles in the sediments of filters from Najaf city, Iraq

Sample Location	Tracks.cm^{-2}d^{-1}	$E\alpha$ (mBq cm^{-2})	±SE of Mean
Askary	0.426	0.0042	0.0004
Mohandesen	1.704	0.0168	0.0036
Ansar	0.169	0.0017	0.0001
Alswag	1.171	0.0115	0.0016
Aljameha	0.339	0.0033	0.0012
Almelad	0.185	0.0018	0.0002
Alfurat	0.195	0.0019	0.0005
Aljazerah	0.392	0.0039	0.0006
Alhindeah	1.504	0.0148	0.0005
Ghadeer	0.087	0.0009	0.0002
Almutanaby	0.610	0.0060	0.0001
Khan Almkhdhar	4.898	0.0482	0.0093
Average	0.973	0.0095	0.0015

Discussion

The global maximum allowable amount of lead in drinking water is 0.05 ppm. Nature concentration of marine water shows that the concentrations of Cd and Pb were 0.11 ppm and 0.3 ppm, respectively [15]. Based on the result of this study, Levels of Pb and Cd in water from Najaf exceeded the World Health Organization (WHO) stipulated limits of Pb and Cd for drinking water [16]. The mean number of recorded alpha tracks per cm^2 per day was 0.952, with the lowest and highest values of 0.087 and 4.898, respectively. The main sources of this waste are factory wastes, smelting of metals, burning of coal, car exhaust, and pesticides. In the present study, the average concentrations of dissolved Cd and Pb were not within the safe limits for each Iraqi specification (Cd=0.005 ppm and Pb=0.05 ppm) and the world standard limits.

There was some spatial variation in concentrations of the studied heavy metals among different sites, which may due to the distribution of elements that is affected by many important spatial factors such as human population, density along the river banks, hydrological conditions of the bed, discharges by local industries, and sewage discharges [17]. Levels of Pb and Cd in water exceeded the WHO stipulated limits of 0.010 for Pb and 0.003 for Cd. Gross-alpha activities of water sediments were lower than those reported by other studies [18, 19]. Thus, it does not affect the human body.

Conclusion

The variation in alpha radioactivity in the sediment-water suspension collected from Najaf households may depend on the transfer of radionuclides from air and soil to water. All heavy metals exceeded the recommended limit. Pb and Cd levels were as follows: Pb > Cd. The mean levels (ppm) of these heavy metals in the suspended sediment samples from Najaf households were 0.9186 and 0.0129, respectively. Generally, the levels of Pb and Cd in water exceeded the WHO stipulated limits of Pb and Cd. Overall, gross-alpha activity of water was low, and thus, it does not impact the human body. That is to say, water sediments in this study were free of environmental pollution of the alpha particles**.**

The present work is useful in determining the exposure and intake rates of alpha particles and heavy metals. RO filters can be employed for the removal of heavy metals from tap water. These filter systems feature more than one type of filter media.

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