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Estimate the Relationship Between Track Density and Radon Concentration: Hazard Effects in Euphrates River of Karbala-Iraq

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ABSTRACT

Due to the population's health risk, radon has emerged as a major worldwide health problem. 50% of the total eugenic radiation dose is caused by radon and its progenies; therefore, pollution of river water with minerals and radon that cause serious harm to human health. Through the practical results obtained, the theoretical results were linear and a high correlation coefficient. Radon concentrations were measured with CR-39 nuclear track detectors (NTDs). Radon gas concentration and annual effective dose were below the recommended limits. This indicates that the water of the Euphrates River is safe for aquatic life.

KEYWORDS: CR-39 detector, Euphrates River, Karbala.

الخلاصة

نظراً للمخاطر الصحية التي يتعرض لها السكان فقد ظهر الرادون كمشكلة صحية عالمية. ٥٠٪ من إجمالي جرعة الإشعاع هي ناتجة عن الرادون ووليداته لذلك تلوث مياه الأنهر بالرادون مما يسبب ضرراً جسيما لصحة الانسان. من خلال النتائج العملية التي تم الحصول عليها كانت النتائج النظرية خطية وذات معامل ارتباط عالي. تم قياس تراكيز الرادون باستخدام كاشف الأثر النووي (CR-٣٩) وكان تراكيز غاز الرادون والجرعة الفعالة السنوية أقل من الحدود الموصي بها و هذا يدل على أن مياه نهر الفرات صالحة للحياة المائية.

INTRODUCTION

Water is a fundamental natural asset for human existence. It is a significant asset in creating financial aspects and social aspects regarding agribusiness, industry, and different offices. Streams supply water for human utilization as well as get wastewater released from every human movement [1]. Because of the negative effects of pollutants from treated and untreated home wastewater, treated and untreated industrial wastewater, and farming and agricultural pollutants, the Euphrates River is very important to Iraqi environmental researchers. This river's primary sources of water are rain and stored water in lakes and reservoirs. Natural radionuclides are naturally found in varying levels in drinking water. They are released from the rocks and minerals that make up the aquifer in the same way that other cations and anions are: erosion and dissolution bring radioactive elements from the rocks into the water. Some common natural radioelements include those from the uranium-238 chain, which is a naturally radioactive series of numerous radionuclides that descend from one another. Uranium-238, uranium-234, radium-226, and radon-222 are the most important [2]. The aim of this study is to estimate and relationship between track density and radon concentration, annual effective dose (AED) and risk hazard in Euphrates River samples from selected areas in Karbala governorate using the CR-39 NTD$_S$, and assesses the position. Many revised articles studied the water quality in the Different parts along the Euphrates River within the Iraqi border such as Al- Al-Alawy et al., 2018, 2016, 2015 [3-7].

MATERIALS AND METHODS

Study Area

The Euphrates River is the largest river in Southwest Asia, measuring 2786 km in length.

The Euphrates Basin encompasses approximately 440,000 km^2, 47% of which is in Iraq, 22% in Syria, and 28% in Turkey. Basins riparian are Jordan (0.03%) and Saudi Arabia (2.97%). [8]. The Euphrates River travels 72 km south of Ramadi City to reach Fallujah Town, where a network of canals was built along this portion of the river. This area contains a canal that, during dry spells, transports water from Tharthar Lake to the Euphrates River. The Islamic city of Karbala is well-known. It is well-known for its historical and religious significance, which has been implicated in tragic events and has left its mark on some of the most notable martyrdoms in human history. Approximately 108 kilometers southwest of Baghdad, on the edge of the desert, west of the Euphrates River and east of the Al-Husseiniya River, is where you'll find the governorate of Karbala. It is most famous for being the site of the Battle of Karbala in 680 CE. It is also home to the shrines of Imam Husain and Abbas. It has a total area of 52.856 km^2, latitude of 32°36′52″N and a longitude of 44°1′27″E, an elevation of 32m above sea level, and a population of 1,378,000 according to the 2010 census (2013). Figure 1 illustrates its boundaries, which include the governorates of Anbar to the north and northwest, Al-Najaf to the south, Hillah to the east, and the departments of the Baghdad governorate to the north and northwest [9].

Samples Collection

Seven samples were taken from the Euphrates River at various locations inside the governing Karbala Governorate. It is the Bani-Hasan (Abou Seven), Hindiyia Bridge, AljadwalAlgharbi (Bhil River), Al-Husseiniya (Salami Site), Al-Hur Region (Al-kamalia Site), Al-Hur Region (Al-bubyat Site), and Northren Drainge (Al-Shariea Site) as shown in Figure 1. The map in Figure 1 has been drawn with the aid of Google Earth. Table 1 includes the locations of water samples, the Euphrates River's coordinates. After rinsing the containers with dilute HCl, river water samples were taken from the Euphrates River and placed in plastic containers. The acid inhibits the growth of algae by reducing radionuclide absorption by the container's walls. Before the container is filled, the water is filtered using filter paper to get rid of minute particles that have been lingering in the water.

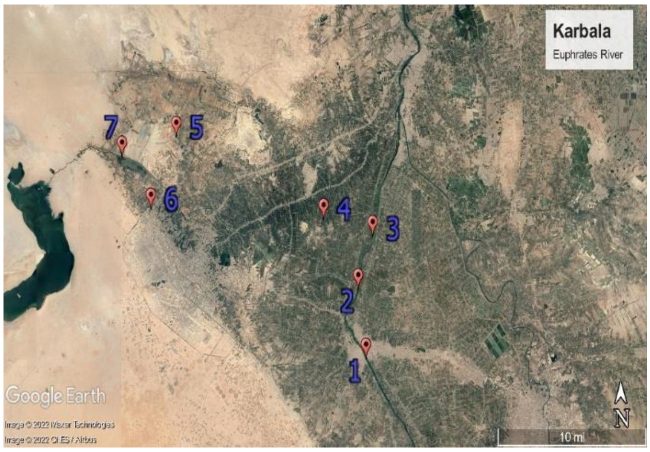

Figure 1. Distribution of the sampling for Karbala by Google earth.

Table 1. Monitoring Stations and coordinates of the Euphrates River.

Code No.	Monitoring Stations	Coordinates
1	Hindiyia Bridge	32°32'13.69"N 44°13'44.56"E
2	Bani-Hasan (Abou Seven)	32°34'58.88"N 44°10'5.92"E
3	AljadwalAlgharbi (Bhil River)	32°30'10.08"N 44°11'53.75"E
4	Al-Husseiniya (Salami Site)	32°38'55.03"N 44°10'48.75"E
5	Al-HurDistrict (Al-kamalia Site)	32°42'51.84"N 44° 0'35.50"E
6	Al-HurDistrict (Al-bubyat Site)	32°39'24.69"N 43°58'50.71"E
7	NorthrenDrainge (Al-Shariea Site)	32°41'54.85"N 43°56'50.00"E

CR-39 Detector

In the present study, a $C_{12}H_{18}O7$ polymer with a density of 1.36 gm/cm^3 and an area of about 11 cm^2 was employed as the CR-39 solid-state nuclear track detector (SSNTD). Up to 40 Mev of energy in the alpha range is detectable by it. It served as a supplementary alpha particle detector for the nuclei of 222Rn and its offspring. The nuclear track detector CR-39 was used to measure the levels of alpha particle emissions from the radioactive element 222Rn in a few chosen samples. The damage that the alpha particle causes when it enters the detector is followed by chemical etching, which makes the damage visible. The etching creates a hole in the detector along the particle route [10]. The CR-39 exposure, using a sealed plastic cup approach, a 0.25 L sample of river water was found, measuring 16 cm in height and 8 cm in diameter.

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A secular equilibrium shown in Figure 2 must be achieved, the sample-detector distance is maintained at 11 cm, and the water sample volume is stored in a plastic container for 30 days prior to measurements.

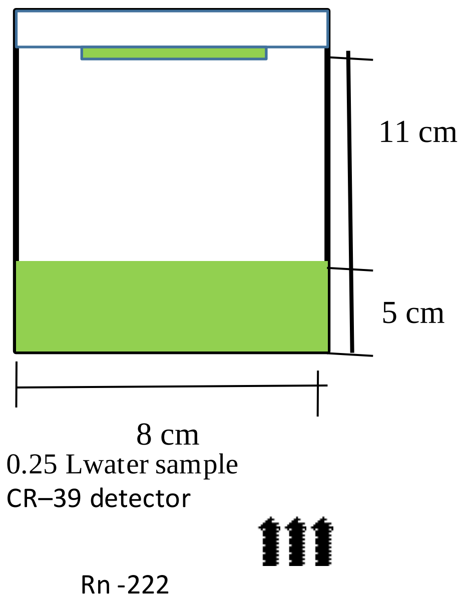

Figure 2. For river water samples, a sealed plastic can technique is used.

Radon Concentration Measurements

The following equation was used to determine the density of the tracks inside the samples: [11]:

$$Tracks\ density = \frac{Average\ number\ of\ total\ pits\ (tracks)}{Area\ of\ the\ field\ view} \quad (1)$$

The following equation [12] was used to compare the track densities made on the detectors of the samples with those of the reference water samples in order to determine the radon concentrations in river water samples:

$C_x(sample)/\rho_x(sample)=C_s(standard)/\rho_s(standard)$

$$\text{i.e. } C_X = \rho_X.(C_S / \rho_S) \quad (2)$$

where: C_X and C_S is the radon concentration in the unknown and standard sample, respectively. While, ρ_X and ρ_S is the track density of the unknown and standard sample, respectively. The relationship between radon concentration and track density in standard water samples, as shown in Figure 3.

Annual Effective Dose

Following the emission of radon gas from river water into indoor air, radon enters the human body through ingestion and inhalation. The basis of the radiation dosage to the stomach and lungs is thus the radon gas in river water. The following table provides the results of the calculation of the annual effective doses for ingestion and inhalation according to the UNSCEAR report 2000 [12]. The following equation was used to calculate the annual effective dose of an individual consumer due to consumption of radon from river water.

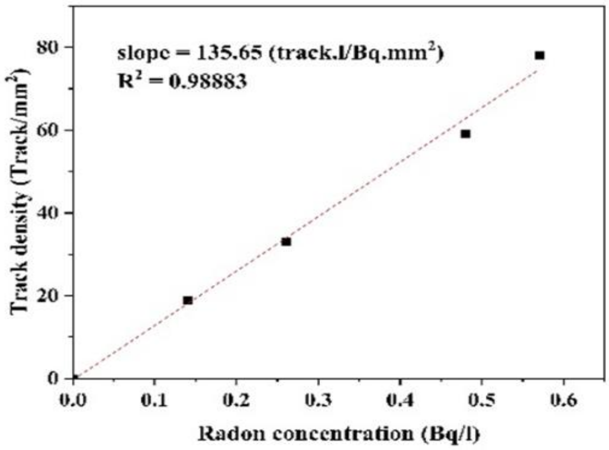

Figure 3. Relation between track density and radon Concentration in standard river water samples.

$$AED(\mu S/y)=C_{Rn}\times C_{Rw}\times DCF \quad (3)$$

where: C_{Rn} is the concentration of radon in the ingestion River water in $Bq.l^{-1}$, C_{Rw} is the consumption rate of river water, and DCF is the dose conversion factor for ingestion [12].In addition, the following may be used to compute the annual effective dose radon in river water in units of µSv/y, using the formula [14]:

$$AED(\mu Sv/y)=C_{Rn}\times R_{aw}\times F\times O\times DCF \quad (4)$$

where C_{Rn} is the concentration of radon in the inhalation river water, R_{aw} is the ratio of radon in air to the radon in River water, F is the equilibrium factor between radon and its progenies, O is the mean residence time of indoor belongs to each individual, and DCF is the dose conversion factor for inhalation [12]. According to the World Health Organization [14] and European Commission Council [15], the effective annual dose from inhalation that corresponded to the content of $1 Bq.l^{-1}$ in tap water was 2.5 μSv/y.

Radon Exhalation Rate

The amount of radon expelled from a material's surface is referred to as the radon exhalation rate (EA) in any sample. The following equation was used to calculate the surface exhalation rate of radon, which is measured in units of $(Bq.m^{-2}.h^{-1})$ [16]:

$$E_A = \frac{CV\lambda}{A[T + \frac{1}{\lambda(e^{-\lambda T} - 1)}]} \quad (5)$$

Where, C: is the integrated Radon exposure $(Bq.h.\ L^{-1})$, A: is the surface area of the sample (m^2), V: is the air volume in the cup (L), λ: is the decay constant for ^{222}Rn (h^{-1}) and T: is the exposure time (hours).

Dissolved Radon Concentration

According to the relationship shown in, the dissolved radon content in river water was calculated in units $(Bq.\ l^{-1})$ [17]:

$$C_d(Bq/L) = C_{Rn}\lambda hT/L \quad (6)$$

where C_{Rn} is the concentration of radon in the ingested water in unit $(Bq.\ l^{-1})$, **λ** is the decay constant for ^{222}Rn (h^{-1}), h is the distance from the water surface to the detector (meter), T is the exposure time (hours), and L is the sample depth (m).

Results and Discussion

We can note from Figures 4, 5, 6, and 7, that the approximation model was linearbetween (X-axis) include track density and (Y-axis) include Radon concentration, annual effective dose, surface exhalation rate and dissolved radon concentration. The slope was positive for the figures, i.e. increasing values (Y-axis) $C_{Rn\ (Bq/l)}$, total (μSv/y), E_A $(Bq/m^2.h)$ and Cd (Bq/l). We also note, from these four forms, that the arrangement is linear between the original and the close data. The highest correlation coefficient was for the annual effective dose (Total) which is equal to 0.990928 while, the lowest correlation coefficient for radon concentrations was 0.990812 as shown in Figures 4, 5, 6 and 7.

Table 2 presented the results of Rn-222 in the river water samples for a few locations in the governorate of Karbala. He found highest value in the Al-Jadwal Al-Gharbi was $1.83\ Bq.l^{-1}$ while, the lowest value of in the Al-Husseiniya was $1.316\ Bq.l^{-1}$ and mean value of $1.608\ Bq.l^{-1}$ characterized by annual effective dose for ingestion and inhalation by the highest value of annual effective dose 6.67 μSv/y, 3.66μSv/y was found in Al-j-Jadwal Al-Gharbi while the lowest value of (AED) was found in Al-Husseiniya which was equal to 4.803μSv/y,2.632 μSv/y with an average value of 5.864 μSv/y, 3.216 μSv/y, respectively.

Table 2. Radon concentration (C_{Rn}), annual effective dose (AED), surface exhalation rate (E_A), and dissolved radon concentration (C_d), in River water samples of Euphrates River.

Monitoring Stations	Track Density (track/mm²)	C_{Rn} (Bq/l)	AED of Adults (μSv/y)			E_A (Bq/m².h)	C_d (Bq/l)
			Ingestion	Inhalation	Total		
Hindiyia Bridge	234.197	1.793	6.54	3.586	10.12	1.64	53.607
Bani-Hasan (Abou Seven)	198.980	1.467	5.35	2.934	8.284	1.342	43.86
AljadwalAlgharbi (Bhil River)	248.299	1.83	6.67	3.66	10.33	1.674	54.713
Al-Husseiniya (Salami Site)	178.571	1.316	4.803	2.632	7.435	1.204	39.346
Al-Hur District (Al-kamalia Site)	221.088	1.629	5.940	3.260	9.200	1.491	48.734
Al-Hur District (Al-bubyat Site)	214.286	1.58	5.76	3.16	8.92	1.445	47.239
NorthrenDrainge (Al-Shariea Site)	222.78	1.642	5.99	3.284	9.274	1.502	49.093
Average	218.171	1.608	5.864	3.216	9.080	1.471	48.084
±S.D	±24.205	±0.178	±0.649	±0.356	±1.005	±0.163	±5.335
Maximum	248.299	1.83	6.67	3.66	10.33	1.674	54.713
Minimum	178.571	1.316	4.803	2.632	7.435	1.204	39.346

Global Limit	-------	11.1 [18]	(1mSv/y) [19]	-----	-------

In addition, radon exhalation (E_A) in Euphrates River values ranged from the lowest value of 1.204 Bq/m^2.h in Al-Husseiniya to the highest value of 1.674 Bq/m^2.h in Al-Jadwal Al-Gharbi, and the average concentration of 1.471 Bq/m^2.h displays the variance in the amount of dissolved radon (C_d) in river water samples. The maximum value was found in Al-Jadwal Al-Gharbi which was equal to 54.713 Bq/l, while the lowest concentration of dissolved radon was found in Al-Husseiniya which was equal to 39.346 Bq/l, with average value of 48.084 Bq/l, prove that the results for the Karbala governorate were below the 300pCi/l recommended upper limit for radon content in drinking water, which is equal to 11.1$Bq.l^{-1}$(USEPA,2012) [18]. The investigated samples' entire annual effective dose was determined to be lower than the EPA's 2000 acceptable value of 1mSv/y [19]. As a result, the radon content in the river water is safe in all examined sites of a Karbala governorate.
Table 3 is an overview of the data those other writers in Iraq's governorates around the Euphrates River have amassed. Some river water samples from the study locations had radon concentrations that were either lower or higher than the maximum value for the amount of contamination.

Table 3. Comparing the Mean Radon concentration of the Euphrates River.

Places	C_{Rn}(Bq/l)	References
Iraq/Baghdad	0.930 River water	Amin *et al.* (2019) [20]
Jordan/Irbid	4.3-6.3 River water	AL-Bataina *et al.* (1997) [21]
Turkey	1.26 River water	Baykara, *et al.*, (2006) [22]
Iraq/Najaf	0.355 River water	A.S. Alaboodi *et al.* (2020) [23].
Iraq/Karbala	1.608 River water	Present work (2023)

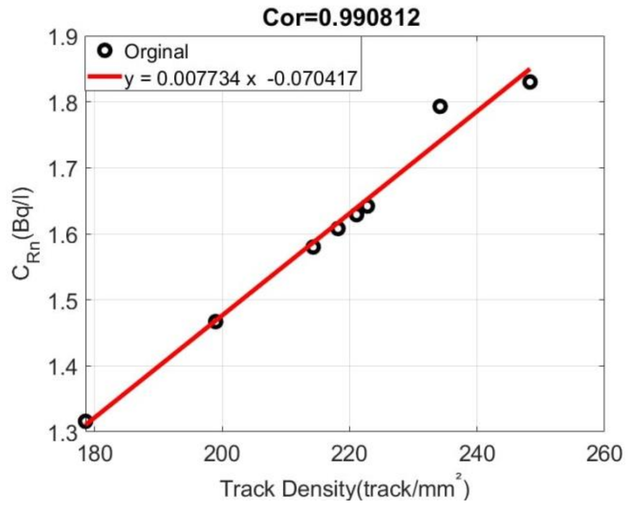

Figure 4. Relationship between track density and Radon concentration for river water.

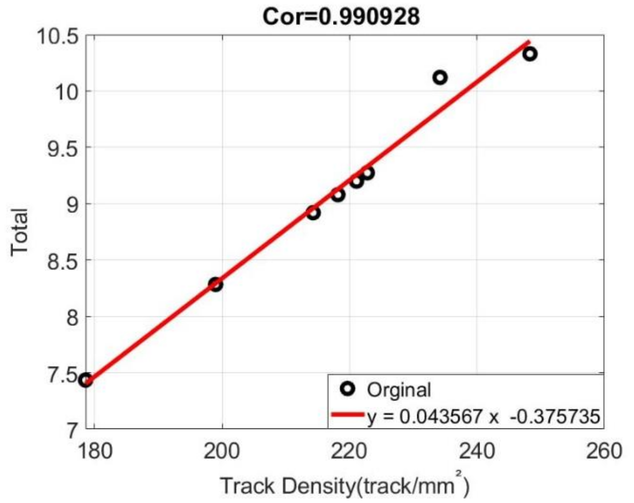

Figure 5. Relationship between track density and annual effective dose for river water.

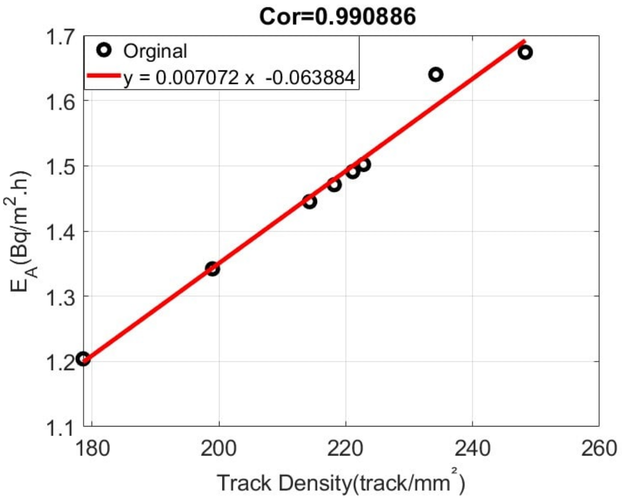

Figure 6. Relationship between track density and surface exhalation rate for river water.

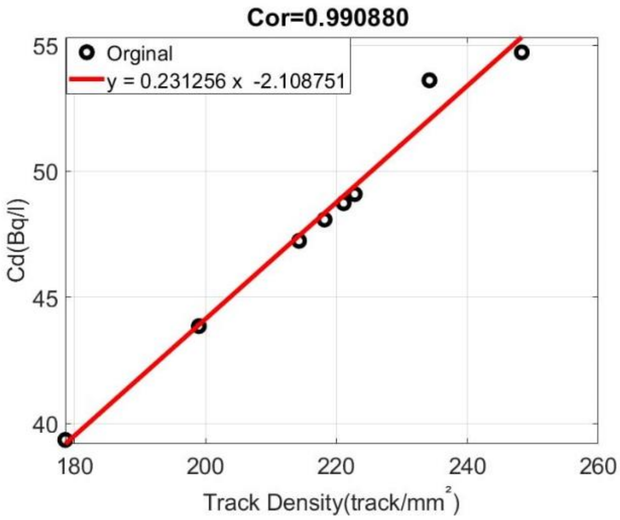

Figure 7. Relationship between track density and dissolved Radon concentration for river water.

CONCLUSIONS

The comprehensive linear depiction of the four variables exhibited an exceptional correlation coefficient of 99%. Assessing radon concentration levels and annual effective dose within Euphrates River water samples traversing Karbala governorate revealed levels well below the prescribed limits outlined by both the USEPA and WHO. Consequently, the water from the Euphrates River can be deemed safe, thereby assuring the populace in Karbala that there are no imminent health risks associated with its consumption.

Disclosure and Conflict of Interest: The authors declare that they have no conflicts of interest.

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