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

Aqeel Adel Hasan¹*, Iman Tarik Al-Alawy², Hazim G. Daway²

¹General Directorate of Education for the Holy Karbala, Iraqi Ministry of Education, 56001 Karbala, IRAQ.
²Department of Physics, College of Science, Mustansiriyah University, 10052 Baghdad, IRAQ.

*Correspondent contact: aqeeladi@uommustansiriyah.edu.iq

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.


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 radionuclides 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 NTDs, 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 km², 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 km², latitude of 32°32'13.69"N and 44°13'44.56"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-kamyata 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.

CR-39 Detector
In the present study, a C₁₂H₁₈O₇ polymer with a density of 1.36 gm/cm³ and an area of about 11 cm² 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.
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](image)

**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]:

\[
\text{Tracks density} = \frac{\text{Average number of total pits (tracks)}}{\text{Area of the field view}}
\]  

(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:

\[
C_X(\text{sample})/\rho_X(\text{sample}) = C_S(\text{standard})/\rho_S(\text{standard})
\]

i.e. \(C_X = \rho_X(C_S / \rho_S)\)  

(2)

where: \(C_X\) and \(C_S\) is the radon concentration in the unknown and standard sample, respectively. While, \(\rho_X\) and \(\rho_S\) 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.

\[
\text{AED}(\mu Sv/y) = C_{Rn} \times C_{Rw} \times DCF
\]

(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 \(\mu Sv/y\), using the formula [14]:

\[
\text{AED}(\mu Sv/y) = C_{Rn} \times R_{aw} \times F \times O \times DCF
\]

(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 1Bq.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]:

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

(5)

Where, \(C\) is the integrated Radon exposure (Bq.h. L\(^{-1}\)), \(A\) is the air volume in the cup (L), \(\lambda\) 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 of (Bq.m\(^{-2}\).h\(^{-1}\)) [17]:

\[
C_d (Bq/L) = C_Rn \times hT/L
\]

(6)

where \(C_{Rn}\) is the concentration of radon in the ingested water in unit (Bq. l\(^{-1}\)), \(\lambda\) 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 linear between (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 \(C_d\) (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>
<thead>
<tr>
<th>Monitoring Stations</th>
<th>Track Density (track/mm²)</th>
<th>(C_{Rn}) (Bq/l)</th>
<th>(E_A) (Bq/m².h)</th>
<th>(C_d) (Bq/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hindiyia Bridge</td>
<td>234.197</td>
<td>1.793</td>
<td>6.54</td>
<td>10.12</td>
</tr>
<tr>
<td>Bani-Hasan (Abou Seven)</td>
<td>198.980</td>
<td>1.467</td>
<td>5.35</td>
<td>2.934</td>
</tr>
<tr>
<td>AljadwalAlgharbi (Bhil River)</td>
<td>248.299</td>
<td>1.83</td>
<td>6.67</td>
<td>3.66</td>
</tr>
<tr>
<td>Al-Husseiniya (Salami Site)</td>
<td>178.571</td>
<td>1.316</td>
<td>4.803</td>
<td>2.632</td>
</tr>
<tr>
<td>Al-Hur District (Al-kamalia Site)</td>
<td>221.088</td>
<td>1.629</td>
<td>5.940</td>
<td>3.260</td>
</tr>
<tr>
<td>Al-Hur District (Al-bubyat Site)</td>
<td>214.286</td>
<td>1.58</td>
<td>5.76</td>
<td>3.16</td>
</tr>
<tr>
<td>NorthrenDrainers (Al-Shariea Site)</td>
<td>222.78</td>
<td>1.642</td>
<td>5.99</td>
<td>3.284</td>
</tr>
<tr>
<td>Average</td>
<td>218.171</td>
<td>1.608</td>
<td>5.864</td>
<td>3.216</td>
</tr>
<tr>
<td>±S.D</td>
<td>±24.205</td>
<td>±0.178</td>
<td>±0.649</td>
<td>±0.356</td>
</tr>
<tr>
<td>Maximum</td>
<td>248.299</td>
<td>1.83</td>
<td>6.67</td>
<td>3.66</td>
</tr>
<tr>
<td>Minimum</td>
<td>178.571</td>
<td>1.316</td>
<td>4.803</td>
<td>2.632</td>
</tr>
</tbody>
</table>
In addition, radon exhalation (E_A) in Euphrates River values ranged from the lowest value of 1.204 Bq/m².h in Al-Husseiniya to the highest value of 1.674 Bq/m².h in Al-Jadwal Al-Gharbi, and the average concentration of 1.471 Bq/m².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.

<table>
<thead>
<tr>
<th>Places</th>
<th>C_(Rad)(Bq/l)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iraq/Baghdad</td>
<td>0.930</td>
<td>River water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Amin et al. (2019) [20]</td>
</tr>
<tr>
<td>Jordan/Irbid</td>
<td>4.3-6.3</td>
<td>River water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AL-Bataina et al. (1997) [21]</td>
</tr>
<tr>
<td>Turkey</td>
<td>1.26</td>
<td>River water</td>
</tr>
<tr>
<td>Iraq/Najaf</td>
<td>0.355</td>
<td>River water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A.S. Alaboodi et al. (2020) [23].</td>
</tr>
<tr>
<td>Iraq/Karbala</td>
<td>1.608</td>
<td>River water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Present work (2023)</td>
</tr>
</tbody>
</table>

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.
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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.

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