Radioactivity Assessment in the Sediments Samples of Tigris River, Baghdad, Iraq

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Abstract. Seasonal monitoring of the natural radon levels was done for sediment samples picked from particular locations over the Tigris River in Baghdad city area for the whole year 2018. CR-39 passive detector was used for detecting alpha activity in the sediment samples of the 20 g mass. The alpha (α) activities from radon were found to be comparatively higher during the dry season and lower during the rainfalls season. The radium content of the samples was the highest in site4 sediment samples (south Baghdad) is likely because of the outcome of great human activities particularly Al-Dora oil refinery. The variations in radon levels were possibly referred to the type of the collected sediment samples and human activities that influence the river environs. The determining radon levels in the most investigated sediment samples were within the recommended world average values.

Keywords: CR-39, passive detector, radon, sediment, Tigris River.

1. Introduction
The naturally occurring radioactive nuclei (NORM) are found everywhere around us. Its presence depends on many parameters such as; geological and geographical conditions and seasonal and climatic variations. The concentration of radioactive materials in the soil is different in each region in the world [1].

Radon-222, the daughter nuclei of radium-226 which in turn is one of the progenies of uranium-series, is a natural radioactive gas employ to assess the radiological risk by cause of water, soil and sediment [2]. The α-emitter element (radium) is a solid radioactive element with a half-life equal to 1620y, emits alpha under normal circumstances of temperature and pressure. Radium is concerned as a dangerous element because of the continuity of radon production. The migration of radon gas out of the rocks and soil is affected by the quantity and position of the uranium concentration underground, and pathways for the movement of radon to the surface to associate with deep water [2].

The sediments are usually piled up in the bottom of the river, which contain several naturally occurring radioactive elements. These radioactive materials have mostly come from the uranium chain, and generally, their level is expected to be higher than the mean values [3][4]. For that reason, the determination of the radioactive materials distributed in the natural materials enables us to estimate any probable radiation hazard to humans [5].

This research is continuing to our former research on observing radon concentration in the water samples of the Tigris River in Baghdad [6][7] and concerns with the effect of seasonal variations in the presence of primordial radionuclides. The study of primordial radionuclides in the Tigris River is regarded as very sensitive because it is an important source of irrigation, and its importance to a largely arid region. Baghdadi inhabitants depend on the Tigris River to provide drinking water and agricultural irrigation [8]. Furthermore, a study of the natural radioactivity observations of the river sediment samples, the impact of the climatic variations on the primordial radioactive nuclides and their impact on residential health has gained recent attention to many researchers.

In the present study, radon levels and radium content and their variations with seasonal changes have been investigated in the sediment samples collected from four chosen locations along the Tigris River in Baghdad city, Iraq. Besides, the present investigation establishes a guideline map on different
radiological factors of the Tigris River and furthermore is likely to show the effect of seasonal variations on the radioactive nuclide’s accumulation in the sediments in and around the Tigris River in Baghdad.

2. Experimental Work
The study area of the river Tigris is given in our previous article Amin et al [7]. The soil texture of the first three sites is clay loam, while site 4 is silty clay loam. The percentages of their soil compositions are shown in table 1 [9]. Sample collection was done during the one-year period (2018) to study the effect of seasonal changes on the α-emitter radon levels. Accordingly, sediment samples were collected every month. The Four sampling sites were chosen along the Tigris River to cover it from north to the south of Baghdad city. Site 1 is located upstream Al-Rashidya (near Al-Muthana Bridge, which is adjacent to the Baghdad Tourism Island (i.e., intensive humanitarian activities). The second two sites (site 2 and 3) are located in the midstream of the river. The first is near Wazireya (Al-Sarrafi Bridge across the Tigris River from Utaifiya which is near the campus of the University of Baghdad, Baghdad Medical City, in Bab Al-Muadhaham) and the second is near Shawaka (Al-Shuhadaa Bridge opposite to Al-Mutanabi and Al-Rasheed streets (the oldest and best-known streets in Baghdad) and Al-Shorjah (the largest and oldest market in Baghdad city) (i.e. Heavy Human Activities)). Site 4 is located at the downstream Al-Dora (Al-Dora crude oil refinery, Vegetable Oil Factory and Al-Rasheed Gas Power Plant near Al-Dora Bridge). The locations of the sampling sites are illustrated in figure 1.

| Soil texture of sediment samples [9] |
|------------------------------------|
| **Site** | **Clay%** | **Silt%** | **Sand%** |
| Site 1  | 29.0      | 40.4      | 30.6      |
| Site 2  | 27.5      | 37.7      | 34.8      |
| Site 3  | 33.0      | 38.6      | 28.4      |
| Site 4  | 37.0      | 51.6      | 11.4      |

Sediment samples were collected from the river bank at 5 cm depth using Ekman Grab samples. Excess water was removed from the sample. Then the samples were put in glass jars with a sufficient volume of 10% formalin for preservation and transported to Environment Research Center Laboratory. Thereafter, the sediment samples were dried in the oven at 80°C for 16 hours. Afterwards, the samples were crushed and powdered with a grinder and then sieved through (2-mm mesh).

Figure 1. Locations of sampling places over Tigris River in Baghdad city, Iraq.

Alpha particles emitted from radon gas $^{222}$Rn, one of the uranium daughters, were measured by a closed-can technique using solid-state nuclear track detectors CR-39. The weight of 20 gm of each sediment sample was positioned at the base of the can. The samples were then left for 2 months to permit the emission of radon gas from the samples and get a reasonable number of α-particle tracks. At the end
of the exposure period, CR-39 pieces were chemically treated in 6.25N NaOH solution at 70 °C for 4 hrs. Afterwards, alpha particle tracks were counted by an optical microscope with a power of 400x.

Radon concentrations \( C_{\text{Ra}} \) in (Bq.m\(^{-3}\)), effective radium content \( C_{\text{Ra}} \) in (Bq.kg\(^{-1}\)), in the soil samples were given by equations (1) and (2) [10]:

\[
C_{\text{Ra}}(Bq/m^3) = \frac{\rho}{KT}
\]

(1)

\[
C_{\text{Ra}} = C_{\text{Ra}} \frac{V}{M}
\]

(2)

Where, \( \rho \) = The track density (\( \rho \)) in the samples (Tracks/cm\(^2\)), \( T \) = the exposure time (day), \( V \) = volume of the space above the sample (m\(^3\)), \( M \) = weight of the sample (kg), \( K \) = the calibration factor is calculated theoretically and determined by relying on the Eugin et al. model [11], and that of Sarma [12][13], for the parameters; the amount of alpha emitters exists in the air, dimensions of the container and the detector’s type used through etching conditions by using equation (3) [12][14].

\[
K = 0.25R \left[ 2 \cos \theta_e - \frac{R}{R_a} \right]
\]

(3)

where, \( (R) \) the container radius (cm), \( (\theta_e) \) CR-39 critical angle, and \( (R_a) \) \( \alpha \) particles range in CR-39. The calculated value of \( K \) is 0.04891 Track.cm\(^{-2}\).d\(^{-1}\)/Bq.m\(^{-3}\).

3. Results and Discussion

The variations of radon levels depend on the geological parameters and meteorological conditions, such as sand, silt and clay composition as well as the air temperature and pressure, and wind speed [15]; [16]; [17]. As well, the radium and radon concentrations depend on the soil type, the flow of water in the study locations, the geological formation of rocks and the time of sedimentation. Therefore, radon levels in the investigated sediment samples, picked up from choosing locations over the Tigris River in Baghdad city, were monthly determined during 2018. The results are summarized in Figure 2. According to the obtained results, the highest radon levels were observed during the months August, September and October, while the lowest values were during February, March and April. Then, we can classify the results into low radon levels during spring; slightly higher during summer and highest radon levels and vary during autumn and winter. The irregular increased radon level determined in the months mentioned above is regarded to the very hot and dry period of the year, whereas after the first rainfall in November, the radon concentration decreases effectively elucidation that the decrease of the radon level in winter periods could be due to the rainfalls, which generally happen through this period in Baghdad city. The small seasonal fluctuations in the activity of radon indicate that the seasonal variation parameters such as; climate changes, rainfalls and others have a small impact on the alpha activity of radon in the present study area. However, radon concentrations in most sediment samples were less than the world average activity value recommended by the International Commission of Radiation Protection (ICRP) of radon concentration in soil and sediment, which is in the range of 200 to 800 Bq.m\(^{-3}\) [18].

The average radium content in the study sediment samples was also calculated and illustrated in Figure 3. The highest radium content measured value was 7.52 Bq.kg\(^{-1}\) during September while the lowest value was 4.06 Bq.kg\(^{-1}\) during April and the average radium content value was 5.53 Bq.kg\(^{-1}\).

Figure 4 shows the mean alpha activity variation at the four selected sites. The range of alpha activities and mean values for radon concentration (Bq m\(^{-3}\)) in the study sediment samples were given in table 2. The average value of radon concentration in the study area was 753.4 Bq.m\(^{-3}\) and its range were \((553.0-1023.4)\) Bq.m\(^{-3}\). The highest value of the alpha activity, which is higher than the world recommended value given by ICRP [18], is found in the sediment sample collected from Site 4 which is adjacent and very close to the sludge area which leaked to the Tigris River from the Al-Dora oil
refinery process, vegetable oil factory and Al-Rasheed gas power plant. The obtained average values of radon levels of the investigated sediment samples collected from the upstream, midstream and downstream locations over the Tigris River were found to be 661.5, 739.2 and 873.8 Bq m\(^{-3}\), respectively.

![Seasonal variation of radon levels in the investigated sediment samples collected from choosing places over the Tigris River.](image

**Figure 2.** Seasonal variation of radon levels in the investigated sediment samples collected from choosing places over the Tigris River.

![Seasonal variation of the average radium content in the investigated sediment samples collected from choosing places over the Tigris River.](image

**Figure 3.** Seasonal variation of the average radium content in the investigated sediment samples collected from choosing places over the Tigris River.

The measured mean values of radium content, for the above four sites, were 4.86, 5.85, 5.00 and 6.42 Bq kg\(^{-1}\), respectively. These results were compared with the observations of the allocation of several heavy metals in sediment samples in Tigris River [19]. The differences in radon levels may result according to the variance in the type of sediment and various life activities that impact the ecosystem of the Tigris River [20][21]. Moreover, the results show that the radium contents in the sediment samples increases as we go to the south (downstream) of Baghdad city because of the great humanitarian activities that raise the pollutants drainage to the river [22][23][24].

However, the increase in water levels during summer may be an additional key parameter that affects radionuclides concentrations. The high water flow will take off some of the sediments from the river’s bottom, providing that the samples were collected from thickness (0 -10) cm. This mechanism may be
in some ways the reason for the increasing of radionuclides concentration towards downstream of the river.

![Figure 4](#). Average radon levels in the investigated sediment samples collected from choosing places over the Tigris River.

| Site  | Latitude     | Longitude     | Min  | Max  | Mean |
|-------|--------------|---------------|------|------|------|
| Site1 | 33°42'83.22''N | 44°34'55.50''E | 3.58 | 6.85 | 4.86 |
| Site2 | 33°35'37.53''N | 44°37'36.01''E | 3.54 | 9.32 | 5.85 |
| Site3 | 33°33'79.59''N | 44°38'79.03''E | 3.38 | 9.16 | 5.00 |
| Site4 | 33°28'96.82''N | 44°45'02.84''E | 3.70 | 10.04 | 6.42 |
| **Average** | **3.55** | **8.84** | **5.53** |

4. Conclusions
The alpha activity of the investigated sediment samples, pick up from four chosen places over the Tigris River in Baghdad city, was determined using CR-39 SSNTD. From the obtained results of the current study, we conclude the following:
1. Radon levels increased heading downstream of the river because of the effects of several humanitarian activities. As well, this behaviour can be referred to as the kind of sediment samples along the river and humanitarian activities.
2. Higher radium levels were observed during August, September and October. While lower radium levels were observed during rainfalls months of the year.
3. The results of the measured alpha activity were lower than the global mean activity value in most of the sampling sites.
4. The study area poses no significant radiation risk for the inhabitants.
5. A radiological guideline map of the Tigris River in Baghdad city can be drawn out and used as an information reference for the evaluation of any future changes in the radioactivity of the sediments due to any season and climate change.

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