



Measurement of Uranium and Radium Concentrations in Sediments of the Arabian Gulf Coast in the Raas Al-Besha Area, Basra- Iraq

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Abstract - The present work investigated the levels of uranium (^{238}U) and radium (^{226}Ra) in sediment samples collected from the coastal region of the Arabian Gulf at Raas Al-Besha, Basrah, Iraq. The main aim was to evaluate whether the detected concentrations comply with internationally accepted safety standards. Thirty-six sediment samples were collected from various sampling points, and measurements were performed using CR-39 solid state nuclear track detectors.

The findings revealed noticeable spatial variability in radionuclide concentrations. Uranium concentrations ranged between 8.587 ppm and 18.340 ppm, while radium concentrations varied from $6.177 \text{ Bq}\cdot\text{kg}^{-1}$ to $13.192 \text{ Bq}\cdot\text{kg}^{-1}$. Results were discussed and compared with the internationally recommended approved values. According to ICRP guidelines, the majority of the measured values were elevated. A significant correlation was observed between uranium and radium concentrations in the studied samples. This work provides the first baseline dataset for uranium and radium distribution in sediments at the investigated sites using CR-39 detection techniques, and the results of the study can serve as a reference for future radiological assessments.

قياس تراكيز اليورانيوم والراديووم في رواسب ساحل الخليج العربي في منطقة رأس البيشة، البصرة-العراق

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المستخلص - تناولت هذه الدراسة الحالية تحليل مستويات اليورانيوم (^{238}U) والراديووم (^{226}Ra) في عينات الرواسب التي جمعت من المنطقة الساحلية للخليج العربي في منطقة رأس البيشة، البصرة، العراق. وكان الهدف الرئيسي هو تقييم مدى توافق التراكيز المقاسة مع المعايير الدولية المعتمدة للسلامة الإشعاعية. تم جمع ستة وثلاثين عينة من الرواسب من مواقع مختلفة، وأجريت القياسات باستخدام كواشف الأثر النووي بالحالة الصلبة من نوع CR-39. أظهرت النتائج وجود تباين مكاني ملحوظ في تراكيز النظائر المشعة، إذ تراوحت تراكيز اليورانيوم بين 8.587 (ppm) و 18.340 (ppm)، في حين تراوحت تراكيز الراديووم بين $6.177 \text{ (Bq}\cdot\text{kg}^{-1})$ و $13.192 \text{ (Bq}\cdot\text{kg}^{-1})$ وقد تم مناقشة النتائج ومقارنتها بالقيم المعتمدة دولياً. ووفقاً لإرشادات اللجنة الدولية للوقاية من الإشعاع (ICRP)، فإن معظم القيم المقاسة كانت مرتفعة. كما لوحظ وجود علاقة ارتباط معنوي بين تراكيز اليورانيوم والراديووم في العينات المدروسة. توفر هذه الدراسة أول قاعدة بيانات مرجعية لتوزيع اليورانيوم والراديووم في رواسب المواقع المدروسة باستخدام تقنية كواشف CR-39، ويمكن أن تُستخدم نتائجها كمرجع للدراسات المستقبلية في مجال التقييم الإشعاعي.

الكلمات المفتاحية: اليورانيوم، الراديووم، الرواسب، رأس البيشة، العراق، البصرة.

Introduction

Naturally Occurring Radioactive Materials (NORM) are unstable isotopes of chemical elements, referred to as radionuclides, that undergo radioactive decay, emitting ionizing radiation in the form of Alpha, beta particles and gamma rays. Despite the fact that there are many radionuclides, many of them are either artificially created or rare in nature (Patel *et al.*, 2023).

Uranium isotopes (U-238 and U-235), thorium-232, potassium-40, carbon-14, and their progeny, including thorium-234, radium-226, polonium-210, lead-210, and radon-222, are the most often found radionuclides in the environment (EleAbiama *et al.*, 2012; Krishnamoorthi *et al.*, 2025).

The ionizing radiation released during radioactive decay may provide serious risks to the environment and human health (Frischknecht *et al.*, 2000), especially by raising the risk of cancer. Certain radionuclides, such as uranium, have chemical toxicity in addition to radiological effects (Hon *et al.*, 2015). By releasing radionuclides into the environment, anthropogenic activities have the potential to significantly increase human exposure to ionizing radiation. Transportation of nuclear materials, nuclear power generation, reprocessing of nuclear waste (Ewing *et al.*, 1995), industrial production and use of fertilizers and coal, oil, and gas extraction (IAEA, 2003; Hilal *et al.*, 2014; Al-nabhani *et al.*, 2017), mining and processing of uranium and thorium ores (Arogunjo *et al.*, 2009), and disposal of spent nuclear fuel (Johnson *et al.*, 2005) are some examples of these activities. Furthermore, without human interference, naturally existing radionuclides can move from geological formations to the atmosphere, soil, water bodies, and living things (Chen *et al.*, 2005; Al-Kharouf *et al.*, 2008; Kiruba *et al.*, 2025; Rasheed *et al.*, 2025; Lapid *et al.*, 2025; Saleh *et al.*, 2016).

Significant health and environmental risks could result from the ionizing radiation released during radioactive decay, especially as it raises the risk of cancer. Ingestion of contaminated food and drinking water (Fisenne *et al.*, 1987; Shiaishi *et al.*, 1997; Kuwahara *et al.*, 1997) and inhalation of airborne particles (Misdaq *et al.*, 2001) are the main ways that radionuclides can enter the human body. Individuals exposed to radioactive sources may have tissue damage from nuclear radiation exposure (alpha, beta, and gamma). People at the coasts may be exposed to radiation directly while performing their duties (Bakr, 2010). The sediment and water may include radioisotopes, which makes them a possible source of radiation exposure for people (Al-nabhani *et al.*, 2017). To determine the radiation dose that people received from it, it is crucial to count the number of radioactive nuclei that are present in these deposits. Recommendations from the International Commission on Radiological Protection (ICRP) regarding acceptable radiation doses must be followed if they are exceeded. People may be more susceptible to cancer if excessive exposure is not controlled.

Alpha and gamma spectrometry (Desideri *et al.*, 2011; Jia *et al.*, 2012; Tzika *et al.*, 2016), radiochemical separation techniques (Chakraborty *et al.*, 2014; Guirguis *et al.*, 2015), extraction chromatography (Wang *et al.*, 2017), and solid-state nuclear track detectors (SSNTDs) (Amin, 2015; Yousef *et al.*, 2016; Omori *et al.*, 2016) are some of the analytical techniques used to determine the concentrations of uranium and other radioactive elements in different materials. The SSNTD technique counts alpha-particle tracks that are released from radioactive elements and recorded on the detector material in order to quantify uranium and other radionuclides.

The quantities of uranium and radium were measured in sediment samples taken from the Arabian Gulf coastline in the Raas Al-Besha area of Basrah, Iraq, for the current study. Track densities in CR-39 detectors generated by alpha particles released from the uranium decay series were calculated using the SSNTD methodology. Radionuclide concentrations were then estimated using these track densities.

Raas Al-Besha location along the Arabian Gulf shoreline in Basrah, Iraq, is scientifically significant for this study due to several factors; it illustrates a dynamic coastal and sedimentary ecosystem influenced by marine processes and terrestrial inputs from the Shatt Al-Arab system. This identifies it as a possible accumulation zone for naturally occurring radioactive materials (NORM), including uranium and radium. The region is ecologically significant as it forms part of Iraq's southern coastal environment, affected by industrial

activities, oil operations, shipping routes, and past environmental stresses. These factors may result in increased radioactive levels in coastal sediments. Additionally, sediments in coastal regions act as lasting reservoirs for radionuclides, allowing them to reflect both current and past contamination levels. Thus, analyzing uranium and radium levels in Raas Al-Besha provides critical baseline information for assessing environmental radioactivity in the northern Arabian Gulf. This site exhibits a lack of previous radiological studies, highlighting the need to rectify data gaps and enable future environmental assessments and radiation risk analyses. This study aims to quantify and evaluate uranium and radium concentrations in the coastal sediments of Raas Al-Besha, Basrah, to determine environmental radioactivity levels and potential radiological hazards. There are important previous studies related to our topic (Al-Imarah *et al.*, 2023; Arneodo *et al.*, 2022; Jaber *et al.*, 2022).

Methodology:

Experimental Procedure:

In October 2024, sediment samples were collected from 36 unique locations in Raas Al-Besha area, as illustrated in Figure 1. Each sample was collected at an approximate depth of one meter beneath the surface. Following three days of air drying, the collected sediments were subjected to oven drying for four hours at 180 °C. To attain a uniform grain size distribution, the samples are processed in a mechanical grinder and subsequently sieved through a mesh with an aperture of 300 µm.

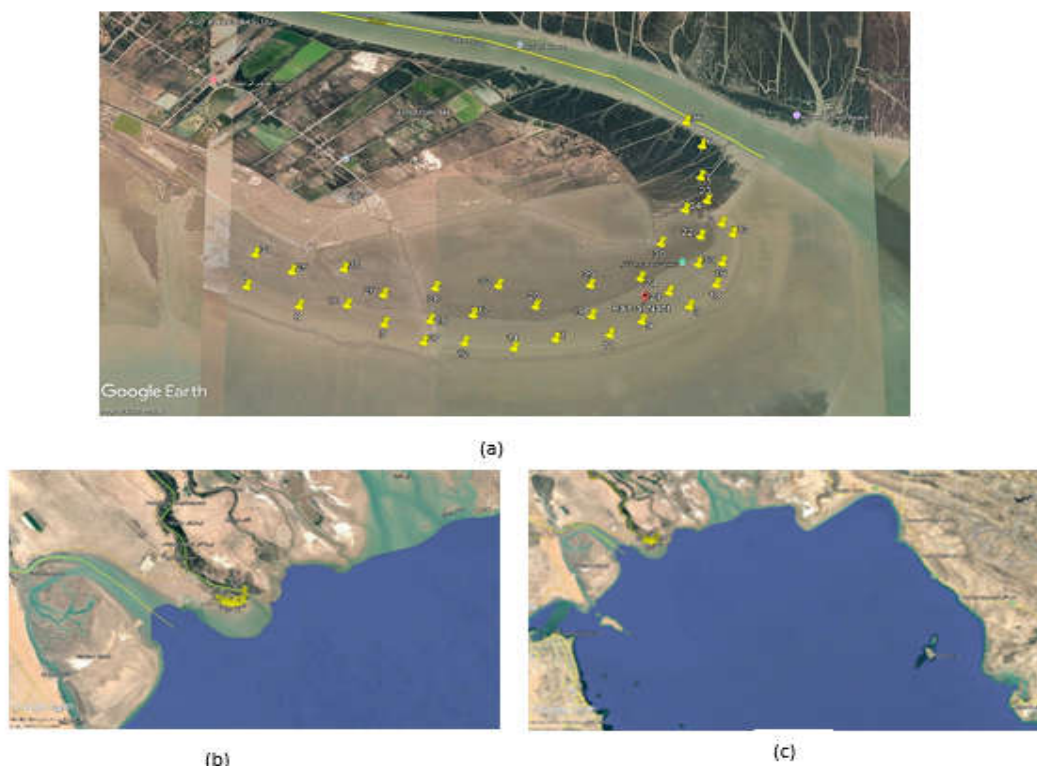


Figure 1. The study area is located along the Arabian Gulf coast at Raas Al-Besha, Basrah, Iraq.

Figure 1-a shows the locations and numbers of the collected samples, whereas figures 1-b and 1-c illustrate deeper layers of the same area.

The cylindrical plastic containers used for the experiment have an inner diameter of 2.1 cm and an inner height of 16.5 cm. As shown in Figure 2, a known mass of the prepared sample was positioned at the bottom of each container up to 8.5 cm, and the container was sealed to

act as an irradiation chamber. A disk-shaped CR-39 solid-state nuclear track detector (SSNTD) measuring 2.1 cm in diameter and 500 μm in thickness was attached to the inside of the container lid and placed 8 cm above the sample surface. To improve measurement accuracy, two identical containers fitted with CR-39 detectors were made for every sample.

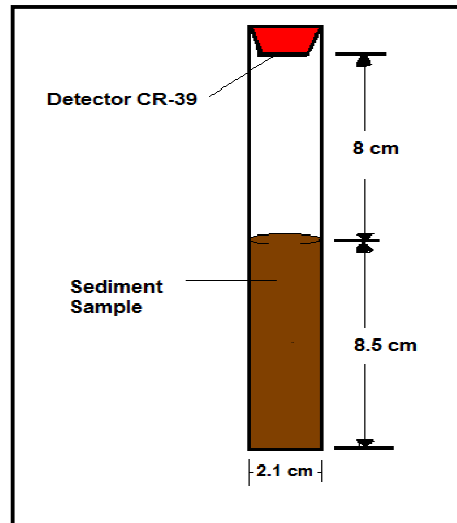


Figure 2. A closed cylindrical plastic container with a 2.1 cm diameter contains CR-39 detector films positioned 8 cm above a sediment sample.

In order to achieve a secular equilibrium between radium (^{226}Ra) and radon (^{222}Rn) of roughly 98%, the samples were first kept in sealed containers for 22 days without detectors. The equilibrium relationship for radioactive decay, as described by (Azam *et al.*, 1995), was used to calculate this equilibrium period.

$$A_{Rn} = A_{Ra} (1 - e^{-\lambda_{Rn} t}) \quad \dots\dots (1)$$

Where, A_{Rn} is radon activity, A_{Ra} is radium activity, λ_{Rn} is the radon decay constant equal to 0.1814 d^{-1} and t is the Decay time.

To avoid air exchange between the interior chamber and the external environment, the cylinder cover was cautiously opened after radioactive equilibrium was achieved. After quickly installing a second pre-made cover with a CR-39 detector film, the cylinder was sealed once more and exposed to radiation for 60 days. In order to gather enough alpha-particle tracks from uranium and its decay products, this extended exposure time was necessary.

At the end of the irradiation period, the detector films were removed and subjected to chemical etching in a sodium hydroxide (NaOH) solution under controlled conditions of 6.25 N concentration at 70 °C for 5 hours. Following the etching process, alpha-particle tracks (i.e.,) were visually counted using an optical microscope with a magnification power of 200×. The total alpha-particle track densities recorded on the CR-39 detector (ρ) were calculated using the following equations:

$$\rho = \frac{N_G^{CR}}{A_G} \quad \dots\dots\dots (2)$$

Where A_G is the global area of view.

The Theoretical Section:

The following relations (Azam *et al.*, 1995) can be used to calculate radon concentration:

$$\rho = K C_{Rna} T \dots\dots(3)$$

Where, ρ is the track density in (Track/cm²), K is the diffusion constant, C_{Rna} is the radon concentration in air space in Bq/m³ and T is the radiated time in day.

The diffusion constant was measured from the following equation (Barillon *et al.*, 1991):

$$K = \frac{1}{4} r(2 \cos \theta_c - r / R_\alpha) \dots\dots(4)$$

Where: r is 1.05 cm, the radius of the cylinder utilized as a radiated chamber, R_α is the alpha particle range in air and θ_c is the detector CR-39's critical angle is equal to 35°.

Thus, by entering these numbers into equation (4), we were able to obtain:

$$K = 0.0312 \text{ Tr.cm}^{-2} \cdot \text{d-1/Bq.}$$

The following formula is used to determine the radon concentrations in soil samples (Al-Bataina *et al.*, 1997):

$$C_{Rns} = \lambda_{Rn} C_{Rna} h T/L \dots\dots (5)$$

Where, C_{Rns} is radon concentration in sediment in Bq/m³. The radon decay constant equals 0.1814 d⁻¹, h is the height of air over the sediment sample in the cylinder, equal to 8 cm, L is the height of the sediment sample in the cylinder, equal to 8.5 cm, T is the radiated time in days, equal to 60 days.

The radiation activity for radon can be determined from the following equation (Al-Bataina *et al.*, 1997):

$$A_{Rns} = C_{Rns} V_s \dots\dots (6)$$

$$V_s = \pi r^2 L$$

V_s is the volume of sample in m³.

To determine the concentration of uranium (²³⁸U) in the sediment samples, it is first necessary to calculate the number of uranium atoms present in the sample N_U . This can be achieved by substituting the number of radon atoms N_{Rn} into the following relationship as reported by Khallil (1994):

$$(\lambda_{Rn} N_{Rn} = \lambda_U N_U \dots\dots(7)$$

Where

λ_{Rn} is radon decay constant equal to $2.1 \times 10^{-6} \text{ S}^{-1}$

λ_U is uranium decay constant equal to $4.9 \times 10^{-18} \text{ S}^{-1}$

The mass of uranium in the sediment sample W_U expressed in grams can be calculated using the following equation, as described by (Khallil, 1994):

$$W_U = \frac{N_U A_U}{N_{av}} \dots\dots\dots (8)$$

Where:

A_U is the uranium atomic number equal to 238.

N_{av} is Avogadro's number equals $6.02 \times 10^{23} \text{ mol}^{-1}$

To determine the uranium concentration C_U in ppm units, use the following relation:

$$C_U (\text{ppm}) = \frac{W_U}{W_s} \times 10^6 \dots\dots(9)$$

Where:

W_s is mass of sample in gm.

The following formula is used to get the radon surface evaporation rate in (Bq.m-2.s-1) (Rehman, 2005).

$$E_R = \frac{C_{Rn}(C_o a + \lambda_{Rn} V_a)}{a(1 - e^{-(\frac{C_o a}{V_a} + \lambda_{Rn})T}}) \dots\dots\dots (10)$$

Where: $C_o = \lambda_{RN} L$, C_o The repeat propagation's correction limit (m.s⁻¹), (a) The sample's surface area (m²), and L sample thickness (m).

$$V_a = \pi r^2 h$$

V_a The size of the air space (m³).

$$C_{Ra} = \frac{E_R}{\rho_s \lambda_{Rn} E L} \dots\dots\dots(11)$$

Where:

$$\rho_s = \frac{W_s}{V_s}$$

ρ_s is sample density in (kg.m⁻³).

E is the radon emanation factor equal to 0.3 (Rehman, 2005).

Results and Discussion:

The values of C_U (ppm) and C_{Ra} (Bq.kg⁻¹) were calculated using equations 9 and 11, respectively. The uncertainty associated with the alpha-particle track density measurements was found to be less than 2% for all analyzed samples. The data in table 1 present, for each sample, the sample number, the total alpha-particle track density recorded on the CR-39 detector ρ_G^{CR} , the mass of the sample in grams, the uranium-238 concentration C_U in parts per million (ppm), and the radium-226 activity concentration C_{Ra} in Bq.kg⁻¹.

Uranium Concentration²³⁸U(C_U):

The results revealed that most measured concentrations of uranium and other naturally occurring radionuclides exceeded the recommended levels reported by the ICRP (ICRP, 1987). Natural uranium concentrations in soils and sediments generally range between 2 and 3 ppm, whereas considerably higher values may indicate enhanced accumulation of naturally occurring radioactive materials (NORM). However, variations in radionuclide levels among different materials reported by the ICRP are influenced by factors such as the type and depth of seawater, reflecting the natural presence of these elements in the Earth's crust. In this study, uranium concentrations were specifically determined in sediment samples. As presented in table 1 and illustrated in figure 3, the uranium concentrations ranged from a minimum of 8.029 ppm to a maximum of 18.34 ppm.

Table 1. Sediment samples in the Raas Al-Besha area, Basrah, Iraq.

Sample Number	Density ρ (kg.m-3)	Mass of sample (g)	C_U (ppm)	C_{Ra} (Bq/Kg)
1	3145.396	51.74	8.587	6.177
2	4419.281	47.77	13.067	9.399
3	4529.370	49.35	12.964	9.325
4	4686.640	47.84	13.838	9.953
5	4340.646	50.11	12.235	8.801
6	4340.646	48.669	12.598	9.062
7	4010.380	51.57	10.984	7.901
8	5268.538	51.43	14.470	10.408
9	3758.748	53.09	10.000	7.193
10	6275.065	48.33	18.340	13.192
11	3947.472	46.82	11.909	8.566
12	4560.824	51.97	12.396	8.917
13	4403.554	46.44	13.394	9.634
14	4702.367	47.67	13.934	10.022
15	5158.449	47.1	15.470	11.128
16	4277.738	43.76	13.808	9.932
17	424.628	48.35	1.241	0.892
18	3774.475	46.33	11.508	8.277
19	4938.272	48.67	14.332	10.309
20	5866.163	46.5	17.819	12.818
21	5001.180	53.16	13.289	9.559
22	4686.640	52.53	12.602	9.065
23	4419.281	50.22	12.430	8.941
24	3680.113	51.71	10.053	7.231
25	4906.818	52.65	13.164	9.469
26	4387.827	43.72	14.176	10.197
27	4466.462	52.18	12.091	8.697
28	4482.189	48.34	13.097	9.421
29	4938.272	49.55	14.077	10.126
30	4387.827	48.39	12.808	9.213
31	3994.653	42.89	13.156	9.463
32	5661.713	51.77	15.448	11.112
33	4859.637	46.56	14.743	10.605
34	5410.081	47.14	16.211	11.661
35	3680.113	49.23	10.559	7.595
36	2830.856	45.44	8.800	6.330

The table includes sample number, density of sample ρ (kg.m-3), mass of sample in (g), uranium concentration C_U measured in parts per million (ppm) and radium concentration C_{Ra} measured in (Bq/Kg).

It is not fully safe for people to be exposed to even relatively low amounts of uranium, especially over an extended period of time. Thus, as shown in Table 1 and Figure 3, the detected uranium levels in these sediments may still present a possible radiological danger in accordance with UNCRP criteria.

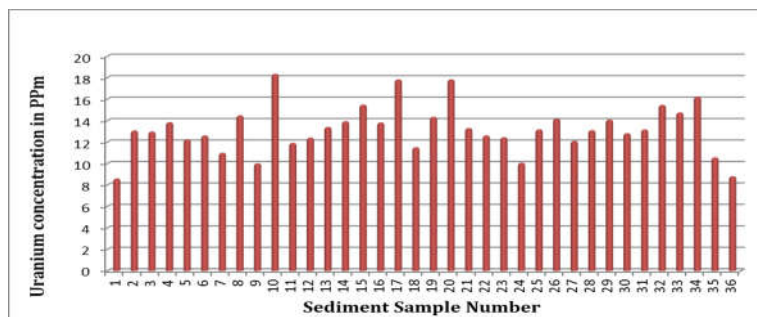


Figure 3. The uranium concentrations in the sediment samples.

Radium concentration ^{226}Ra (C_{Ra}):

The silt samples taken from Raas Al-Besha region were tested for radium content. According to the measurements, the highest reported radium content was $13.192 \text{ Bq}\cdot\text{kg}^{-1}$, while the lowest was $6.17 \text{ Bq}\cdot\text{kg}^{-1}$. The range of radium activity found in the examined sediment samples is represented by these findings, which are compiled in Table 1 and shown in Figure 4.

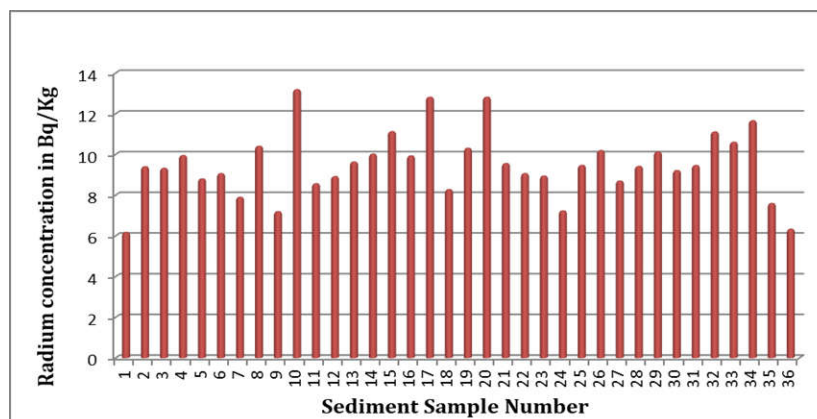


Figure 4. The radium concentration in the sediment samples.

Conclusions:

This study evaluated the amounts of uranium (^{238}U) and radium (^{226}Ra) in sediment deposits from the Arabian Gulf Coast at Raas Al-Besha, Basrah, Iraq. For the first time in this area, CR-39 detectors were used for the measurements, which were carried out inside sealed cylindrical plastic containers. This work is the first attempt to create a local database of radionuclides in this region, including uranium. The equations used to compute the concentrations of uranium and radium are linear and derived from each other; there is an obvious correlation between the two radionuclides.

Factors affect the outcomes that are seen; one of these is the makeup and properties of seawater, which are of important consideration, higher amounts of uranium and radium in seawater typically correlate to higher levels in the sediment samples.

As seen in the preceding tables, sites 10, 15, 32, 33, and 34 have comparatively high quantities of uranium and other radionuclides among the 36 sampling locations. According to the study, radium concentrations are higher at a number of these locations in areas with higher uranium levels. The presence of seawater at considerable subterranean depths and the inherent richness of radioactive materials in the Earth's crust are the primary causes of the greater uranium and radium concentrations in the sediment of the coast.

Upon reviewing previous studies conducted in other regions around the world (Kiruba *et al.*, 2025; Abshire *et al.*, 2022; Wang *et al.*, 2021; Haidong *et al.*, 2024; Krachle *et al.*, 2018), it can be observed that the measured values in this area are relatively high. High concentrations of these radionuclides in sediment could be harmful to local residents' health, increasing their risk of developing cancer. People in the vicinity might be in close proximity to radioactive materials and be exposed to alpha, beta, and gamma radiation.

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