Assessment of Radon Concentrations in Marine Biota of the Iraqi Marine Environment

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Abstract

In this study, samples were collected from three areas of the Iraqi marine environment, where fish are caught to be marketed to local markets for use as food. The study area includes coral reef, Khor Abdallah, as well as Um Qaser Port. Using the closed cylinder technique with Solid State Nuclear Track Detector (SSNTDs) CR-39. The concentration of Radon-222 was measured, as well as the radium equivalent, in addition to the emission per unit area and the emission per unit mass. The results are arranged by region as follows: In the Coral Reef, the lowest value was found in the bivalve Corbicula and was 14.01±4.68 Bq.m^{-3}, while the highest concentration of Radon-222 gas isotope value was in the shrimps; 69.52±19.33 Bq.m^{-3} , with an average value of 28.69±9.1 Bq.m^{-3}. In Kohr Abdallah, the lowest concentration of Radon-222 gas isotope value was found in the Laevicardium sample, it was 16 Bq.m^{-3} , while the highest value was in the Shrimps too, which was 61 Bq.m^{-3}. This value is close to the value of the shrimps in the coral reef area, with the average value 37±11.2 Bq.m^{-3}. In the Um Qaser area, the lowest concentration of Radon-222 9.93±3.76 Bq.m^{-3} was found in Cerithium scabridum whereas the highest value was 29.03±8.84 Bq.m^{-3} and found in the Anemones sample. Based on the measurements taken in this study, in which the concentration of radioactive Radon-222 isotope was calculated, it appears that the measured concentration values are within the acceptable range, and therefore the use of these samples does not pose a risk if used.

Keywords: *Radioactivity, SSNTDs, Radon222, specific activity, risk*

Introduction

Development in all areas of daily life and technology, especially development in the health field and maintaining human health, has led to a significant increase in the population. People began to live in crowded residential complexes, and the large number of people led to an increasing demand for basic needs and foodstuffs for survival. Food was considered the main requirement for the lives of the population. It is known that water covers a wide area of the Earth. These surfaces are considered the main source of food for humans (Kaur *et al*., 2025). Because of the great development in technology, industries, production, and the extraction of energy sources from oil and its derivatives, the waste resulting from these industries has made its way into rivers, lakes, and seas (Ahmed and Haji., 2012). Examples of this are oil and petroleum spills into water. In addition, nuclear and radioactive wastes reach environmental elements through nuclear accidents and the dumping of radioactive waste on the high seas (Al-Wuhaili, 2015; Xiao, 2024). Zooplankton and plants are important to human food, but the wastes may reach humans through the food chain, through interaction between Zooplankton and plant matter with the environment (Barboza *et al*., 2018). On the seas, many types of fish and crustaceans are considered the main source of food for humans. Therefore, it has become necessary to know the percentage of radioactivity in these types of organisms to determine their suitability as food for humans (Biswas *et al*., 2021; Jibiri *et al*., 2023). Through that, it is possible to know whether this environment is suitable to be considered a place from which humans derive their food, as well as to know the safety of the food used in this environment (Botterell *et al*., 2023).

Several previous studies measured the level of Radon gas concentration in samples of marine and river organisms and fish. These studies can be summarized as follows: In 2015, a comparison between Radon concentration in samples collected from local fish in markets close to the study area ranged from 309.4 Bq.m^{-3} to 1600 Bq.m^{-3} and from 507.3 Bq.m^{-3} to 1100 Bq.m^{-3} for imported fish in the study area, respectively (Dawod, 2021). When using the Solid State Nuclear Track Detector (SSNTDs)

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https://ejournal.undip.ac.id/index.php/ijms
DOI: 10.14710/ik.ijms.31.1.1-7
Received : 15-11-2025
Accepted : 11-01-2026

technique to measure the Radon gas concentration, the average value of biota samples analysis was 28.85 $Bq.m^{-3}$ (Girault and Perrier,2012). In 2017, the concentration of Radon gas was measured in some local and imported fish in the city of Karbala when using Solid State Nuclear Track Detectors type CR-39; the results showed that the concentration of these nuclides ranged between 8.163-39.746 $Bq.m^{-3}$ (Ćujić *et al.,* 2021). The comparison between measuring of concentration of Rn222 in the fish from Duhok city and Basrah city ranged 340.917- 98.208 $Bq.m^{-3}$, with an average value of 250,46 $Bq.m^{-3}$. In Basrah city, the range was 1744.23- 898.54 $Bq.m^{-3}$, with an average value of 1300.245 $Bq.m^{-3}$ (Munaf, 2016). The study at 2020, the epidemiological studies on humans pointed out that up to 14% of lung cancers are induced by exposure to low and moderate concentrations of Radon. Animals that breed in ground holes have been exposed to higher doses due to radiation present in soil and air (Khan *et al*., 2011). The level of Radon-222 concentration recorded 15 $Bq.m^{-3}$ in the Ktebban River,2024 (Munaf, 2024).

Material and Methods

The importance of the study area comes from it being Iraq's only sea window to the outside world. The study area is located in the south of the city of Basrah, which overlooks the Arabian Gulf, according to the coordinates (E: 47°47'28", N: 29°55'73"), (E: 48°31'45"

Sample preparation

Samples for the current study were collected through field trips to Iraqi marine waters. The scientific research staff, along with the assistant staff on the boat, belong to the Marine Science Center. The collection of samples was done using several types of nets. One type of these nets is used to catch swimming organisms, and the other type is used to catch benthic organisms as Bottom Trawl Net. These are of certain dimensions commensurate with the size of the organisms to be caught, as in Figure 2. After collecting samples from the nets, they were preserved by cooling and freezing in devices and equipment located on the deck of the boat. Upon arrival at the laboratory, the samples were dried using an oven overnight at a temperature of 50 degrees Celsius. After drying, the samples were crushed with a grinder until they became smooth. The samples were placed in polymeric plastic bottles, as in Figure 3, prepared for them and with specific dimensions, which have a specific calibration factor for this measurement that was calculated in advance through previous practical experiments. An amount of the sample is placed at a height of 5 cm, and a piece of sponge is placed on top of the sample to reduce the access of the thorium to the detector that is placed at the top of the container. Before that, the plastic container was tightly closed and left for 90 days. The reagent is then extracted, and the etching process is performed by using a solution of NaOH or KOH, for example, for a standard 6.25 M NaOH solution, 250 g of NaOH is added into distilled water such that the total volume of the solution becomes one liter and left for 7 h at 70°C.

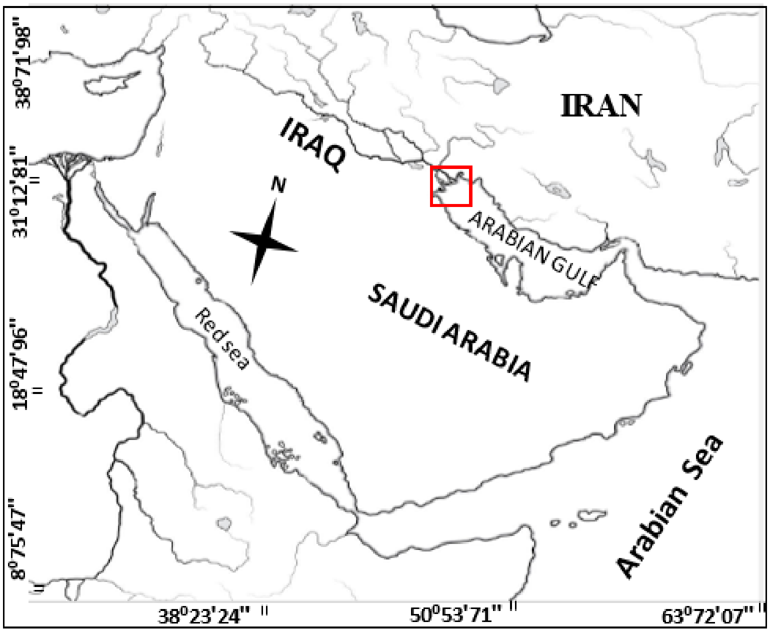

Figure 1. Aera of study. [https://earth.google.com]

Figure 2. Type of net for collection of samples.

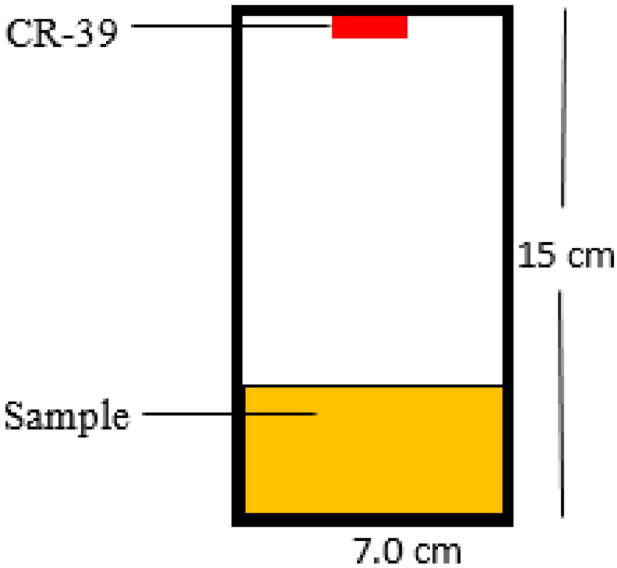

Figure 3. A schematic diagram of the dosimeter used in present work.

Radon measurement

This study used the closed cylinder technique, "Can technique" which is a plastic container with dimensions of 15 cm length and 7.0 cm diameter. The biota samples were put at the bottom of the vessel. The Can is completely sealed for about 27 days or more to allow the ^{238}U,^{226}Ra to reach equilibrium with its progenies (McMahon, 1983). The Solid State Nuclear Track Detector (SSNTDs) is fixed at the inner side of the lid of the Can. The Can is well sealed to let only alpha particles emitted from the samples hit the detector, and the detector is exposed to radon-222 for 90 days.

The numbers of tracks due to alpha particle interaction are counted utilizing an optical microscope 400X. Where Radon concentration $C(t)$ Which is proportional to ρ track density, T is the exposure time in days, therefore:

$$C(t) = \frac{\rho}{K\,T} \qquad (1)$$

K is the calibration factor (Tr.cm^{-2}.day^{-1}/ Bq.m^{-3}), the value of K will depend on the diameter of the Can (Musa, 2017).

The exhalation rate is defined as the rate at which Radon escapes from soil into the surrounding air. This may be measured by either per unit area or per unit mass of the sample. Consider a sealed cylindrical can fitted with a source of Radon and an SSNTD dosimeter fixed at the top of the Can. The surface represents the number of Radon atoms which are present in the air between the sample and SSNTD (Musa, 2003; Regional Training Course, 2014). The Radon exhalation rate in terms of area is calculated from the expression;

$$E_A = \frac{C\,V\,\lambda}{A\,T_{eff}} \qquad (2)$$

where T_{eff} is the effective exposure time, which is related to the actual exposure time T and decay constant λ for ^{222}Rn using the following relation;

$$T_{eff} = T - \frac{1}{\lambda}\,(1 - e^{-\lambda T}) \qquad (3)$$

E_A is the Radon exhalation rate expressed in (Bq.m^{-2}.h^{-1}), C represents the integrated Radon exposure (Bq.m^{-3}. d), V is the effective volume of the Can, T is the exposure time in hours (h), λ is the decay constant for Radon (d^{-1}), and A is the cross-sectional area of the Can (m^2). The Radon exhalation rate in terms of mass is calculated from the expression (Salman and Al-Khalifa, 2013).

$$E_M = \frac{C\ V\ \lambda}{M\ T_{eff}} \qquad (4)$$

where, E_M is the Radon exhalation rate in terms of mass (Bq.kg^{-1}.h^{-1}) and *M* is the mass of the sample.

After closing the Can containing the sample and solid nuclear trace detectors, the detector will record the intensity of the traces. The Radon liberated from the Radium in the sample will reach equilibrium after a period of time estimated at three weeks. The intensity of the effects will increase integrally with time. Thus, the effective Radium is given by the following relationship (Yadav, 2024):

$$C_{Ra} = \frac{\rho\ h\ A}{\mathrm{K\,T_{eff}}\ M} \qquad (5)$$

A, cross-sectional area of the Can in m^2. M, is the mass of the sample in Kg, so that, *h* distance between the detector and the top of the solid sample in meters, and K is the calibration factor for Radon gas in this Can.

Result and Discussion

The concentration of Radon-222 gas in the samples under study, which were collected from the coral reef area, showed the highest value in the shrimp, it was 69.5Bq.m^{-3}, while the lowest value was in Corbicula sample, which reached14Bq.m^{-3}. See Table 1. This can be explained by the fact that shrimp are benthic crustaceans. The shrimp are animals that feed on everything, whether the food is plant or animal. It also eats small living fish and others after preying on them while they are alive or dead. It is known that sediments or soil have a higher concentration of radioactive isotopes than other environmental elements, such as water and air. Their food is in direct contact with the bottom sediments, giving them a higher concentration of radioactive isotopes in their bodies. The Corbicula is a double-shelled animal that feeds on phytoplankton and debris suspended in water with a high filtration rate. Filtering water through the body makes it less likely to store radioactive isotopes because the concentration of isotopes in the water is lower than it is in the soil and sediments (Lomartire *et al*., 2021).

In addition, the shrimp is an animal that moves by swimming over large distances due to the capabilities of movement it possesses. This means that it covers a wide area during its movement in short periods of time, compared to the shelled Corbicula, which is characterized by its slow movement, which means that its movement does not cover large areas during the same period of time compared to the shrimps. As for other neighbourhoods, the Radon concentration values fluctuate between the two values mentioned above. It is possible to arrange the Radon concentration values for the models as follows: Shrimps > Bivalves (mussel) > Crabs > Coral reef (stones) > *Ephippus orbis* > Anemones > *Argyrops spinifer* > *Alepes melanoptera* > *Otolithes ruber* > *Megalaspis cordyla* > *Corbicula fluminalis*

In Khowr Abdallah area, the largest value of Radon-222 gas concentration is found in the shrimps as well, and it is a value close to the Radon concentration level of shrimps in the coral reefs area. The concentration of Radon gas in Khowr Abdallah Shrimp is 61Bq.m^{-3}. While the lowest value of the concentration of Radon 222 in Laevicardium is 16Bq.m^{-3}.

Laevicardium are dioecious animals, and their nutrition consists of filtering the water near their bodies, and the water is naturally less concentrated than the sediments. This amount of concentration is lower than in the coral reef area. Note that the water column in both areas is different, as the water column in Khowr Abdallah reaches between 7 and 10 m, while in the Coral reef area, it is between 20-25 m.

It is known that the shallower the depth of the water column, the more sediments will be stirred up from the bottom as a result of the state of tides and wind speed, and mixing between water and sediment will occur. This will cause the organisms present in an Ocean containing many suspended materials to swim and interact with the organisms in that area. The values for the models are arranged as follows: Shrimps > Bivalves (mussel) > crabs > *Pinna carnea* (Amberpenshell) > *Laevicardium flavum*.

Um Qaser port area is characterized by the fact that it is a navigation channel dug by giant drilling machines for ships anchoring there. There is a continuous drilling and cleaning movement in the port canal basin to make it always suitable for docking ships. Therefore, it is a changing and unstable environment as a result of continuous drilling operations, so life for some organisms is adapted to the prevailing situation as a result of these human operations. There are some species whose life cycle or livelihood is disturbed, which often affects their presence or density. As a result, we see that there are two types of neighbourhoods for which we were able to collect samples due to their wide availability, and they are both *Cerithium scabridum* and Anemones. The Radon concentration in the samples is shown in Table 3, which are 9.93±3.76Bq.m^{-3} , for the first and 29.03±8.84Bq.m^{-3} for the latter. The reason why the concentration of Radon in the bodies of Anemones is high is because of the nature of their nutrition, as they are considered omnivorous animals and feed on Plankton, small fish, and other nutrients that pass through the water currents during the tides (Sebens, 1981). It hunts its prey with its tentacles to release a dose of poison to the prey and control it. The concentration of Radon is lower in the body of *Cerithium scabridum* by analogy with Anemones due to the nature of their nutrition, as they feed on plants in the aquatic environment in which they live. It is known that the source of radioactivity in sediments and soil is greater than in plants and water because the radioactivity in plants comes through the soil and is transmitted to the plants, and through that, the radioactivity is transmitted to the living things through the food chain (UNSCEAR, 2000; Habib *et al*., 2022).

Table 1. Concentration and track density of Rn222 in samples of the Coral Reef.

Position	Samples	ρ (Track .cm^{-2})	Concentration Bq.m^3	E_X (AREA) (Bq.m^{-2}. h^{-1})	E_M (MASS) (Bq.kg^{-1}.h^{-1})	Ra_{eq}
Coral reef:	*Megalaspis cordyla*	393	15.28±5.21	0.01	0.01	9.86E-05
Coral reef:	*Alepes melanoptera*	569	22.16±7.03	0.01	0.01	1.19E-04
Coral reef:	*Otolithes ruber*	412	16.04±5.42	0.01	0.01	1.11E-04
Coral reef:	*Ephippus orbis*	687	26.74±8.24	0.01	0.01	1.74E-04
Coral reef:	*Thunnus albacares*	491	19.10±6.23	0.01	0.01	9.07E-05
Coral reef:	*Argyrops spinifer*	609	23.68±7.44	0.01	0.01	1.31E-04
Coral reef:	Shrimp	1788	69.52±19.33	0.04	0.01	3.09E-04
Coral reef:	Anemones	648	25.21±7.84	0.01	0.01	1.59E-04
Coral reef:	*Corbicula fluminalis*	432	14.01±4.68	0.01	0.01	1.26E-04
Coral reef:	Coral reef (stones)	766	29.80±9.04	0.02	0.01	2.36E-04
Coral reef:	Crab	982	38.20±11.22	0.02	0.01	3.38E-04
Coral reef:	Bivalves (mussel)	1375	44.57±12.65	0.03	0.01	5.18E-04
Minimum		393	14.01±4.68	0.01	0.01	1.11E-04
Maximum		1788	69.52±19.3	0.04	0.01	9.86E-05
Average		762	28.69± 9.1	0.01	0.01	0.0002

Table 2. Concentration and track density of Rn222 in samples of Khowr Abdallah.

Position	Samples	ρ (Trak .cm^{-2})	Concentration Bq.m^{-3}	E_X (AREA) (Bq.m^{-2}.h^{-1})	E_M (MASS) (Bq.kg^{-1}.h^{-1})	Ra_{eq}
Khowr Abd allah:	Shrimp	1572	61.12±17.16	0.03	0.01	4.25E-04
Khowr Abd allah:	*Laevicardium flavum*	412	16.04±5.42	0.01	0.01	1.15E-04
Khowr Abd allah:	Crab	1041	40.49±11.82	0.02	0.01	2.88E-04
Khowr Abd allah:	*Pinna carnea* (Amberpenshell)	417	18.34±6.03	0.01	0.01	1.20E-04
Khowr Abd allah:	Bivalves (mussel)	1513	49.02±13.81	0.03	0.01	4.25E-04
Minimum		412	16.04±5.42	0.01	0.01	1.15E-04
Maximum		1572	49.02±13.81	0.03	0.01	4.25E-04
Average		991	37±11.2	0.02	0.01	0.0075

Table 3. Concentration and track density of Rn222 in samples from Um Qaser

Position	Samples	ρ (Trak .cm-2)	Concentration Bq.m-3	EX (AREA) (Bq.m-2.h-1)	EM (MASS) (Bq.kg-1.h-1)	Ra_{eq}
Um Qaser:	*Cerithium scabridum*	255.50	9.93±3.76	0.02	0.01	1.74E-04
Um Qaser:	Anemones	746.82	29.03±8.84	0.01	0.01	7.13E-05
Minimum		255.50	9.93±3.76	0.02	0.01	7.13E-05
Maximum		746.82	29.03±8.84	0.01	0.01	1.74E-04
Average		501.16	19.48	0.01	0.01	1.2E-04

Table 4. Comparison between the radiation isotopes in fishing around the world.

Country	fishing	Pb210 (Bq.Kg-1)	Po210 (Bq.Kg-1)
Syria	marine	0.05-0.38	0.27-27.48
Syria	river	0.05-0.10	0.61-3.08
Japan	marine	0.040.54	0.6-2.6
Portugal	marine	-----	0.2-11
Austria	marine	------	0.9-44.1
U.S.A	marine	0.1-7	0.4-153.3

For comparison, the radioactive isotope concentrations of Polonium-210 and Lead-210 for marine and river fishing in some countries of the world are shown in Table 4. These countries are distinguished by their different environments from each other as a result of their distance, which is located on different lines of longitude and latitude on the globe comparison From Tables (1,2,3) above, the emanation per unit mass and unit area are arranged: For emanation per unit mass in all samples are 0.01 $Bq.Kg^{-1}.h^{-1}$, but the emanation per unit area with a range between 0.01- 0.04 $Bq.m^{-2}.h^{-1}$. These values are safe for use, when the samples eat or other use.

Conclusion

Through studying the areas from which the samples were collected, it appears that the concentration of the radioactive Radon gas isotope, Radon 222, changes from one animal to another depending on the nature of feeding of the animal, the type of food it is fed on, as well as the method of its physiology. The place where the animal lives does not have a significant impact, but the effect is noticeable without being a major reason for changing the concentrations of radioactive isotopes in the animal's body. Shrimps were the animals with the highest concentration of radioactive isotopes, and the animals with the least concentration of Radon isotopes were *Cerithium scabridum*.

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