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Estimation of Radon Released from Ktebban River, North Basrah City, by Using CR-39

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Abstract. In this work, closed can technique is used to estimate the radon and radium content in solid samples collected from Ktebban River, north Basrah City. The radon concentration in the studied solid samples was between 9.46±2.29 Bq.m^{-3} to 29.83±4.81 Bq.m^{-3}, so that the effective radium variation could be about 0.001 Bq.kg^{-1} to 0.004571 Bq.kg^{-1} since it was responsible for radon emanation in the air. These values considered as acceptable values when comparing worldwide and neighbors countries. The flux and exhalation per unit area and per unit mass arranged between 0.13Bq m^{-2} h^{-1} to 0.54Bq m^{-2} h^{-1} and 0.003Bq m^{-2} h^{-1} to 0.015Bq m^{-2} h^{-1}, respectively. These values are also lower than the reported worldwide limit. This could suggest that it is likely safe to use such sediments for building materials and other uses.

Keywords: Radon concentration, SSNTDs, effective Radium.

1. Introduction

Everything on the Earth's surface is constantly exposed to the effects of radiation from naturally radioactive materials, such as the eternal Earth's radioactive isotopes and what produce from them. Life arose and developed in ocean, humans were exposed to these radiations, whose level has remained almost constant since ancient times (Wilkenning *et al*., 1990).

Environmental radioactive pollution with radioactive materials occurs naturally, while concentrations increase above the natural conditions by nuclear or non-nuclear industries such as the phosphate oil and gas industries and throwing them as wastes into the environment without treatment (Regional training course *et al.*, 2014). One of these isotopes is radon. In general there are three of radon isotopes as a result of differences in radioactivity series. The one of these differences is in their half life times. The ^{219}Rn isotope has a half-life of $T_{1/2}$ = 3.96s, ^{220}Rn has $T_{1/2}$ = 55.6 s and ^{222}Rn has a relatively long-lived half-life of $T_{1/2}$ = 3.82 days (Shikha Pervin *et al*., 2022). The concentration of radon gas follows the concentration of uranium and thorium in soil and rocks. This is because it results from the decomposition of these isotopes. Radon gas is dissolved in water, which is one of the products of Radium-226 (Alexandra *et al*., 2022), and its concentration changes depending on the source of the water, whether surface or underground, and according to its content of mineral salts and the nature of the water basin (Munaf *et al*., 2015). The concentration of radon is approximately of 0-185 Bq/l in surface waters such as lakes. Whereas in rivers and wells is about 185-3703 Bq/l, but in springs it reaches 37 Bq/l. Its concentrations may be high in the old groundwater, because of the accumulation of radon gas (Regional training course *et al*., 2000). The concentration of radon is related to the porosity of rocks, as well as to water-rich sandy interlayers in the sedimentary sequence (Xue Biying *et al.*, 2021). Areas in which intermediate or acidic volcanic and plutonic rocks predominate are characterized by greater radon activity concentration in soils, rendering them radon-prone (Alonso, *et al*.,2019).

1.1 Aim of the Study

The aim of the study was to know the concentration of radon gas in the sediments of the Ktebban River, which branches off the Shatt Al-Arab River. The area is considered one of the areas of the food basket of the city of Basrah, and is inhabited by a large number of people spread across both banks of the river. The region is distinguished by the production of dates, as well as the cultivation of vegetables and dairy products, and these materials are considered a source of food for the people. The presence of a large power plant very close to the study area that operates with Oil products makes it important to know its impact through the waste it produces as a result of the work.

1.2 Study Area

The city of Basrah, located in southern Iraq, is considered the gateway into Iraq and to the word. It is considered the only city that contains Iraqi ports. In the past, the discharge that come to the Shatt al-Arab river was very high, which led to the flooding of agricultural lands on both sides of the river and get rid of its salts, making it a fertile agricultural land. One of these areas is the Ktebban River area within the coordinates of N:30º30″42´, E:47º45″35´ and N:30º30″43´, E:47º47″01´. Fig. 1. Stefan Röttger *et al*., (2022) mentioned that the Ktebban River area is one of the areas of food baskets in the city of Basrah. The length of the river is approximately 7km and connects directly to the Shatt al-Arab river. It heads east through the agricultural lands and most of the residents of this area work in agriculture and animal husbandry so palm gardens are spread on both sides of the river. It connects the life's of the residents of Basrah City with the surrounding areas. On other side, the presence of vital facilities near the area about 5 km such as the oil production fields in the Bin Omar oil fields about 5 km approximately and business accompanying production and operating conditions. Some conditions in the crude oil production field may cause a certain amount of oil spills to be transferred into the environment and cause pollution. Therefore, it is important to monitor the area and create a basic data base in it.

2. Methodology

Most of the radon produced from marine sediment remains within the sediment grains in the bottom water. Many of fractions of radon escapes to the pore spaces, water and porosity (Hallvard *et al*., 2022). It dissolves through the water, depending on the grain size and location of its parent in grain (Duenas *et al*., 1997). The radon, ^{222}Rn, is produced by radioactivity of radium, ^{226}Ra. The ^{226}Ra decays to ^{222}Rn by emitting an Alpha particle (Florian Jorg A. *et al.*, 2022). The main mechanism of escape turns back energy of its atoms during the α decay of ^{226}Ra and diffusion through grain or water as shown in Fig. 2.

In this study, we use closed cylinder technique (Can technique) which is a plastic container vessels of volume (576.97cm3) with cross sectional area of 38.465 cm^2 (Fig. 3). The sediment samples were placed at the bottom of these vessels. The Can is completely sealed for about 27 to 28 days to allow the 238U and 226Ra to reach equilibrium between them (Ahmed *et al*., 2012). The radon gas concentration is given by equation 1.

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

Where: ρ is track density in Tr/cm^2, T is exposure time in day. K is the calibration factor in Tr. cm^{-2}.day^{-1}/Bq.m^{-3}. The radon concentration growth with the time (Musa *et al.*, 2003). The exhalation rate is defined as the rate at which radon escapes from soil into the surrounding air, either per unit area or per unit mass of sample. The radon exhalation rate in terms of area is calculate from equation 2.

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

Where, T_{eff} is the effective exposure time, which is related to the actual exposure time T and decay constant λ for ^{222}Rn, *A* is the area, *v is* a volume over sample and *c* is concentration. The radon exhalation rate in terms of mass is calculate from the expression equation 3.

$$E_M = \frac{C\ V\ \lambda}{M\ T_{eff}} \text{(Jabbar H. Jebur } et\ al., 2015) \quad (3)$$

Where, E_M is the radon exhalation rate in term of mass ($Bq.kg^{-1}.h^{-1}$) and M is the mass of sample, *v* represented the volume over sample in Can.

The concentration of effective radium content in the sample could be calculated from:

$$C_{Ra} = \frac{\rho\ h\ A}{K\,T_{eff}\ M} \text{ (Munaf } et\ al., 2015) \quad (4)$$

Where, T_{eff} is the effective exposure time, M is the mass of the sample in kg, *A* is the area of cross-section of the can in m^2, h is the distance between the detector and top the solid sample in meter, and K is the calibration factor for radon gas.

2.1 Sample Collection

The tools used in collecting samples differ depending on the areas from which samples were collected and on the nature of the area, whether it is a marine (or river) with shallow or deeper depths or land area. In the marine places, the speed of sea/river water currents (high or weak) was taken into account when retriving the samples. All of these conditions allowed us to use the appropriate tools for each area/sample of the study for later analysis. In the study area, the average water depths in the river are about 3-4 m, and the speed of the river currents is weak. Therefore, the sediment samples were collected using the Van Veen Grab Sampler (Fig. 4). This grab sampler allowed us to take surface sediment samples from the bottom of the river or the sea, which it is different in dimensions and weights. The grab sampler has the ability to collect bottom sediment samples with a penetration depth of approximately 10-20 cm.

Immediately after collection the samples were placed in 2 kg polymer bags, transported to the laboratory, and left at normal air temperature for several days to dry, after removal from the polymer bag. Then, samples were crushed to fine powders with sizes of 0.2 mm. Then it is placed in a special measuring box for the purpose of irradiation. The height of the sample in the can is about 5 cm and insure that the tightness of the canister. Samples in the closed canisters were left for 100 days to release radon gas and record emissions from the model via the detector located in the canister installed at a height of 10 cm from the base.

2.2 Chemical Etching

This is the most effective method for laying the size of the latent tracks produced by heavily ionized particles. Chemical etching is usually carried out in a thermostatically controlled bath at 70 °C. The etching time is every 7 hours for CR-39 detector (Loffredo, *et al.*, 2022). The etching, which has been most commonly used for plastic detectors, is aqueous alkaline NaOH or KOH solution with concentration of 6.25 N in order to etch the CR-39 detectors, on metal container (holding many detectors) and attached to a wire and immersed into the etching solution within a beaker (Sahooa *et al.*, 2015). The beaker is then placed in a temperature-controlled water path. At the end of the etching, the detectors are removed and washed under running tap water, to remove the etching residue from the etched pits. After drying, the detectors are counted under an optical microscope. The etched track diameters are typically a few μm in size and grow larger in size after prolonged etching (Dwived *et al.*, 1997). The normality (N) of NaOH solution is calculated by using the following equation 4 (Alharbi *et al.*, 2011).

$$N = \frac{m(g)}{V} \times \frac{1000}{M_W} \tag{5}$$

Where: $m(g)$ is a mass of solid NaOH in grams. V is the volume weight in ml. M_W is the molecular weight of NaOH which is equal to 40. The track samples are shown in Fig. 5.

3. Results and Discussions

The importance of the study area of the Ktebban River with respect of its natural radioactivity is a vital subject for the present study, because it is located in a vital area crowded by the industrial facilities, such as production of electric power. As well as its proximity to the irrigation channel carrying fresh water from the same area to the city of Faw through the city of Basrah. Also, this area is considered a food basket for the city of Basrah, and there are a number of people and villages who live in the area. In the Table 1 which explained the results of radon concentrations in the study area, the results showed that radon concentrations varied from 9.46±2.29 Bq m^{-3} to 29.83±4.81 Bq m^{-3}. Radon flux per unit area in Bq m^{-2} h^{-1} ranged from 0.13 Bq m^{-2} h^{-1} to 0.54 Bq m^{-2} h^{-1}. The mass exhalation rate in the sediment samples of this study ranged from 0.003 m Bq kg^{-1} h^{-1} to 0.015 m Bq kg^{-1} h^{-1}. The effective radium variation varied from 0.001 Bqkg-1 to 0.004571 Bqkg-1, and it is responsible for radon emanation into the air.

The distribution of radon concentration and effective radium in the study area along the river showed that the sample 15 has a higher concentration than in the other samples (Fig. 6-7). This place witnesses human activity in addition to agricultural activity, while in the other models they are less effective and the distribution of values is fluctuating. The positive correlation between Rn-222 and effective Radium Ra_{eff} was 87% as it is explained in Fig. 8. The exhalation rate per unit area and per unit mass of radon concentration in the collected sediment samples is quite lower than those of the international limit. While the recorded effective radium values content in sediment samples taken from the same locations and with comparable to the global average value of radium in soil, we can recommend that the sediments of the study area may be safely used as building materials.

From this study, we can also recommend that the area is safe, as far the health hazard effects of radium and radon flux are concerned. These results could give a clear picture of the radon values through which they contribute to drawing the radiological map of the city of Basrah. From Table 2, comparison between the levels of radon concentrations recorded from sediments and soils in the study area and in many locations worldwide showed the study area has lower values than those recorded worldwide.

Fig. 1. Numbers represented distribution of the samples in the study area.

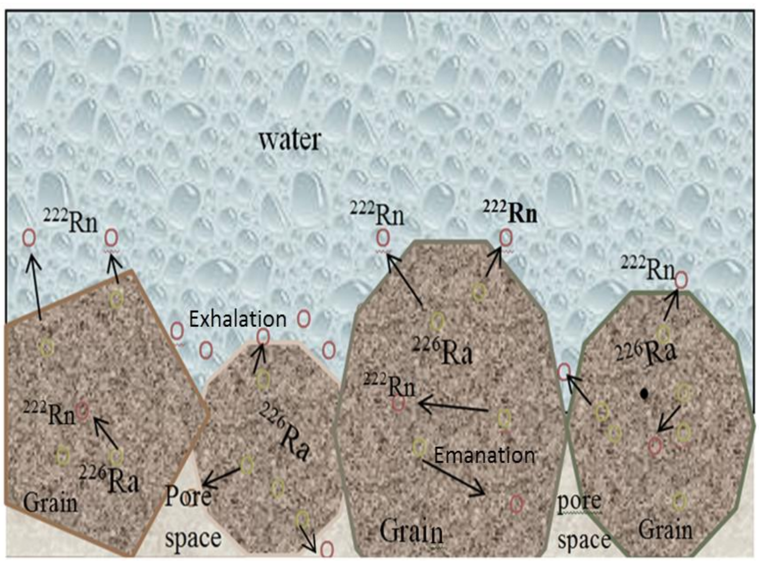

Fig. 2. Sketch of emanation and exhalation processes of 222Rn, depending on location of 226Ra atoms and soil moisture contents.

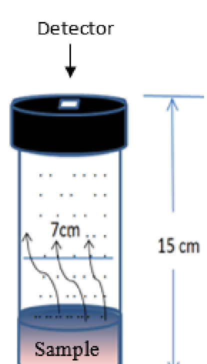

Fig. 3. Schematic diagram showing a closed can cylinder container used in this study.

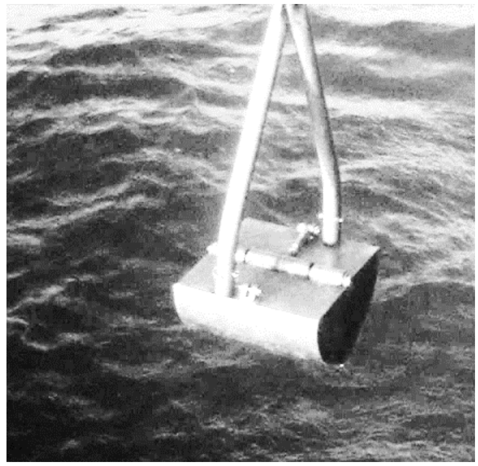

Fig. 4. The Van Veen Grab Sampler for collecting samples.

Table 1. Concentration of effective of Rn-222 and its emanation per unit mass and area.

NO.	**Rn-222 concentration in Bq/m^3 by SSNTDs**	**E_A in Bq/ m^2 .h**	**E_M in Bq/kg. h**	**Effective Ra in Bq/kg**
1	18.91±3.81	0.34	0.008	0.003181
2	15.45±5.22	0.28	0.008	0.00300
3	12.36±3.56	0.22	0.007	0.001711
4	12.74±4.56	0.23	0.007	0.0019
5	13.09±2.78	0.24	0.007	0.001837
6	14.84±6.11	0.27	0.008	0.0019
7	16.73±3.23	0.30	0.009	0.002281
8	13.56±4.23	0.25	0.007	0.0020
9	10.91±3.83	0.20	0.005	0.001727
10	9.94±3.58	0.19	0.005	0.001
11	9.46±3.38	0.17	0.005	0.00144
12	12.34±4.29	0.22	0.007	0.0018
13	14.55±2.15	0.26	0.008	0.001984
14	21.98±8.11	0.32	0.009	0.0030
15	29.83±4.81	0.54	0.015	0.004571
16	23.45±9.21	0.43	0.009	0.0040
17	17.46±3.65	0.32	0.010	0.002224
18	16.89±6.34	0.31	0.008	0.0020
19	16.73±4.23	0.30	0.008	0.002481
20	17.34±6.21	0.33	0.008	0.0026
21	19.64±2.42	0.36	0.010	0.00301
22	17.78±5.91	0.32	0.008	0.0027
23	16.01±3.16	0.29	0.008	0.002325
24	13.77±4.23	0.25	0.007	0.0020
25	11.64±3.42	0.21	0.005	0.001934
26	14.21±5.28	0.26	0.007	0.0020
27	17.46±3.58	0.32	0.009	0.002571
28	13.37±3.98	0.26	0.007	0.0021
29	9.46±2.29	0.17	0.004	0.001496
30	15.55±5.82	0.23	0.005	0.0021
31	19.6459±4.26	0.36	0.010	0.002854
32	19.11±6.21	0.34	0.008	0.0027
33	18.19±1.27	0.33	0.008	0.002986
34	12.32±4.95	0.27	0.007	0.0022
35	7.27±3.23	0.13	0.003	0.001144
36	11.45±4.48	0.21	0.007	0.0021

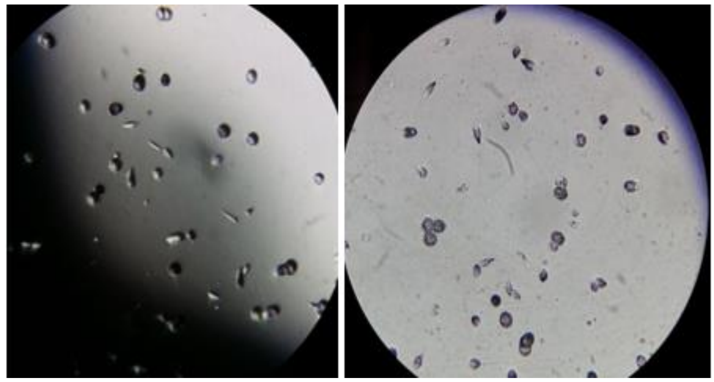

Fig. 5. Image showing the tracks of Alpha particles on detector.

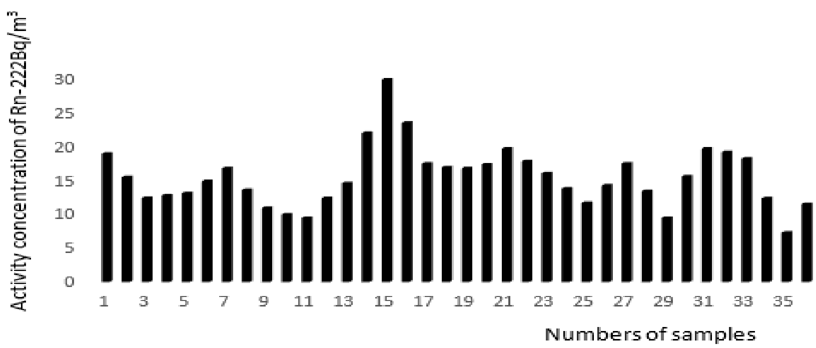

Fig. 6. Distribution of activity concentration of Rn-222 (Bq/m^3) in the studied samples.

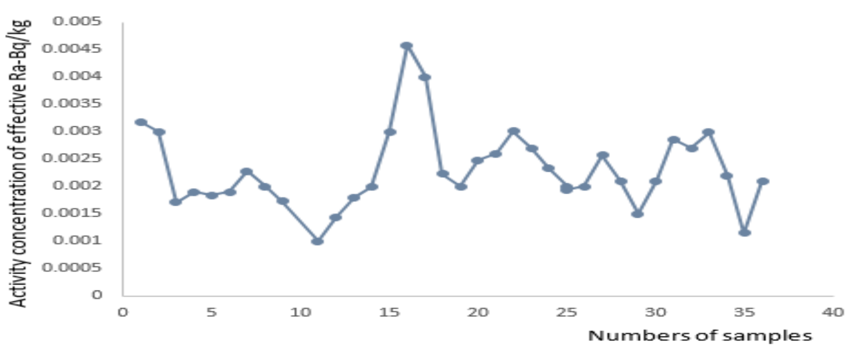

Fig. 7. Distribution of activity concentration of effective Ra (Bq/kg) in the studied samples.

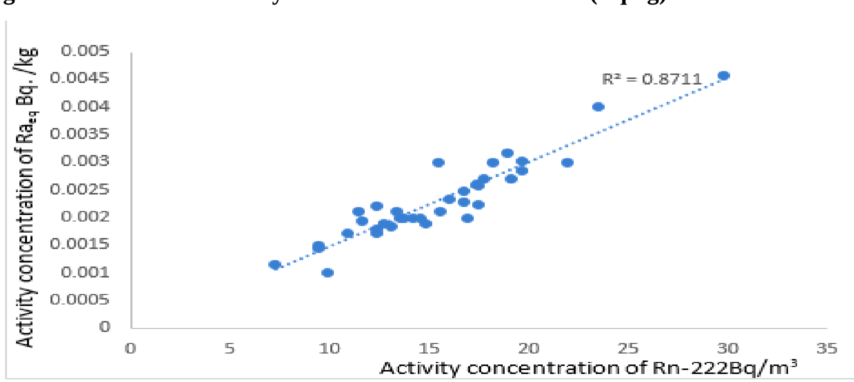

Fig. 8. Scatter plot showing the relation between Rn-222 and Raeff in the studied samples.

Table 2. Comparison between levels of radon concentrations recorded or estimated in many locations worldwide.

Location	^{222}Rn in Bq/m^3	Reference
Pakistan	376	Munza *et al*., (2008)a
Turkey	3.4 – 138	Muslim *et al*., (2011)a
Southern Lebanon	1774.291	Kobaissi *et al.*, (2008)a
Baghdad	7. 11	Saeed (1998)a
Central and Northern Iraq	33-100	Al-Ani (2000)a
Southern Iraq, Karmat Bani Said	1146.227	Mahsur (2009)a
Kut Eastern Iraq	583.594	Jabar (2001)a
Nasiriayh	1386.236	Kadhim (2014)
Ras Tanurah/Saudi Arabia	120	Al-Shari *et al*., (2017)
Khor Abdullah/Iraq	606	Jaber *et al*., (2015).
Marine sediments Iraq	288	Munaf *et al*., (2018)
Standard	800	WHO
Ktibban- Basrah /Iraq	15	current study

4. Conclusion

The radon concentration values obtained from the present study and effective radium concentration showed that they are within the safe and universally permissible limits. They are safe, when their host sediments are used for building materials and any other applications associated with them. The values obtained for the exhalation values per unit volume and unit area also show that they are within the internationally accepted limits and there is no danger in their use. There is a very good correlation between the values of effective radium and the concentration of radon gas. These results help us complete the radiological map of the city of Basrah and its environs.

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تقدير غاز الرادون المنطلق من نهر كتبان شمال مدينة البصرة باستخدام CR-39

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المستخلص. في هذا العمل، تم استخدام تقنية العلبة المغلقة لتقدير محتوى الرادون والراديوم في العينات الصلبة التي تم جمعها من نهر كتبان، شمال مدينة البصرة. كان تركيز الرادون في العينات الصلبة المدروسة بين ٩,٤٦±٢,٢٩ $Bq.m^{-3}$ إلى ٢٩,٨٣ ± ٤,٨١ $Bq.m^{-3}$، بحيث يمكن أن يكون تباين الراديوم الفعال حوالي ٠,٠٠١ $Bq.kg^{-1}$ إلى ٠,٠٠٤٥٧١ $Bq.kg^{-1}$ لأنه كان مسؤولاً عن انبعاث غاز الرادون في الهواء. وتعتبر هذه القيم قيماً مقبولة عند المقارنة على مستوى العالم والدول المجاورة. التدفق والزفير لكل وحدة مساحة ولكل وحدة كتلة مرتبة بين ٠,١٣ $Bq\ m^{-2}\ h^{-1}$ إلى ٠,٥٤ $Bq\ m^{-2}\ h^{-1}$ و٠,٠٠٣ $Bq\ m^{-2}\ h^{-1}$ إلى ٠,٠١٥ $Bq\ m^{-2}\ h^{-1}$ على التوالي. هذه القيم أيضًا أقل من الحد العالمي المُبلغ عنه. قد يشير هذا إلى أنه من المحتمل أن يكون استخدام هذه الرواسب في مواد البناء والاستخدامات الأخرى آمنًا.

الكلمات المفتاحية: تركيز الرادون، SSNTDs، الراديوم الفعال.