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Estimation of Radon Concentration in soil samples and the effective dose rate using SSNDTs in Al-Kebla district of Basrah Governorate

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Abstract

Measurement of radon gas concentrations, area and mass exhalation rate, and effective dose were made for a number of 82 samples of soil taken from selected area in Basrah Governorate (Al-Kebla) in Iraq.In this study; can technique containing LR-115 type II, track detector has been used to estimate the radon concentrations emanated from soil samples. The average value of radon concentration was1067±117 Bq m^{-3} and radium concentration was 6.70±1.02 Bq kg^{-1}. While area and mass radon exhalation rate found to be 0.849±0.099 Bq m^{2} h^{-1}, 0.017±0.002 Bq $kg^{-1}h^{-1}$ respectively. All results were found to be acceptable and well below the permissible levels recommended by ICRP.

Keywords: Radon, Exhalation rate, LR-115 type II, Can technique, Soil.

1. INTRODUCTION

Radon gas product of uranium and thorium decay chains, it is a naturally occurring colourless, odourless, tasteless, inert gas. Soil is the prime source of uranium and thorium and it is structured most of building materials. The internal exposure is caused by radon (^{222}Rn and ^{220}Rn) and its short-lived progenies. Radon is an alpha emitter that may be easily inhaled and its descents may be deposited in tissues of the respiratory tract [1-2]. Most of the isotopes are alpha emitters, so when they are ingested or inhaled, they significantly contribution to the radiation dose that occupancies received [3]. Therefore the exposure of population to high concentration of radon gas and its solid daughters for a long period leads to pathological effects like the respiratory function changes (cancer) [4]. Breathing of low level radon concentration may increase the possibility of lung cancer due to the effect of ventilation [5].

Radon concentration in soil varies greatly from one site to another even in the same geological region[6]. As soil is used in the manufacturing of most building material, thus, it is important to carry out radioactivity in soil [7]. Once the radon atoms are formed by decay of the parent radium, they move inside soil either by diffusion or by transport mechanism or by both [8]. The velocity of radon transport depends on several parameters: soil structure, temperature, wind speed and direction, seasonal variation parameters, barometric pressure, humidity [9]. Radon concentration emitted from soil is in random distribution in most cases, even in the radon chamber, which used to estimate the calibration parameter for SSNTDs [10]. Present investigation used sealed can technique with LR-115 type II plastic track detectors to measure radon concentration in soil samples. Radium concentration, area and mass exhalation rate were also calculated from radon concentration.

2. GEOLOGY OF THE AREA

Basrah soils are transported a Zonal soils, their sediments were contributed from north, north western and western parts of Iraq and other neighbouring countries. The texture of Basrah soils is of fine grained and classified as silt clay and clayey silt, this texture can retained water for long time, so most of Basrah soils are water logged, the subsequent evaporation brought about the deposition of evaporates minerals as surface crust. The wide spectrum of mineral contents reflects the multisource of Basrah soil sediments. Most of clay minerals are detrital in origin, nevertheless; some of them such as playgorskite were formed in place.

Al-Kebla district is located in Southern West of Basrah Governorate, which is southern Iraq as shown in figure 1. It lies between 23^{o} 30’ and 30 11 north latitude and 69 29 and 78 17 east longitude. Figure 1 shows the geographic location of Al-Keblla in Basrah, as well as the location of the sampling sites.

Figure 1: Area of study in Al-Kebla quarter and samples collection zone.

3. EXPERIMENTAL TECHNQUE

The soil of 82 samples were collected from studied area in Basra Governorate (Al-Kebla District), the samples were collected during summer 2014. Most efficient method for the measurement of time integrated radon exhalation rate is to place the sample in the lower part of a closed container (sealed cylindrical can)and 1.5x1.5 sensitive SSNTD on the inner upper surface of the can. In such measurements it is expected that the exhalation rate depends upon the material and its amount as well as on the geometry and dimension of the Can and can be determined with reasonable accuracy. The can dimensions were: 7.5 cm height and7.0 cm diameter. Equal amount of each sample (approximately

100 g) was placed at the base of Can. The Cans were sealed for at least 90 days. Thus the lower sensitive part of the detector was exposed freely to the emanated radon from the sample in the can so that it could record alpha particles resulting from the decay of radon in the remaining volume of the can and from ^{218}Po and ^{214}Po (daughters of radon gas) deposited on the inner walls of the can. Radon and its daughters reach equilibrium in about 4 h and hence the equilibrium activity of emergent radon could be obtained from the geometry of the can and the time of exposure. After the exposure the detectors were etched in 2.5 N NaOH at 60°C for a period of 90 min in a constant temperature water bath for revelation of tracks [11-13]. The resulting alpha tracks on the exposed face of the track detector were counted using an optical microscope at a magnification of 400X.

4. THEORETICAL CONSIDRATION

Radon gas concentration is given by [13,14];

$$A_{Rn} = \frac{\rho}{TK}$$

(1)

whereρ is track density in Tr/cm^2 ,T exposure time in day and K the calibration factor in Tr/cm^2.day / Bq.m^{-3}. The value of K will depend on the height and radius of the measuring can. In the present measurement K=0.056±0.0014 Tr cm^{-2} d^{-1} per Bq. m^{-3}has been used[15]. The experimental error Δ in the value of radon concentration was found according to [16]:

$$\Delta A_{Rn} = A_{Rn}\sqrt{(\frac{\Delta\rho}{\rho})^2 + (\frac{\Delta T}{T})^2 + (\frac{\Delta K}{K})^2}$$

(2)

At the equilibrium state, the surface exhalation rate from the sample inside the can is given by[17];

$$E_{ex} = \frac{A_{Rn}TV\lambda/S}{T+\lambda^{-1}(e^{-\lambda T}-1)}$$

(3)

Where E_{ex} is area exhalation rate in unit Bq m^{-2}.h^{-1}, A is radon concentration measured by RL-115 II detector in unit Bq m^{-3} , λ is radon decay constant, T is the exposure time, V the volume of the can and S is the surface area of the sample.

Selected photographs of tracks emerged on the LR-115 type II detectors are shown in figure 2.

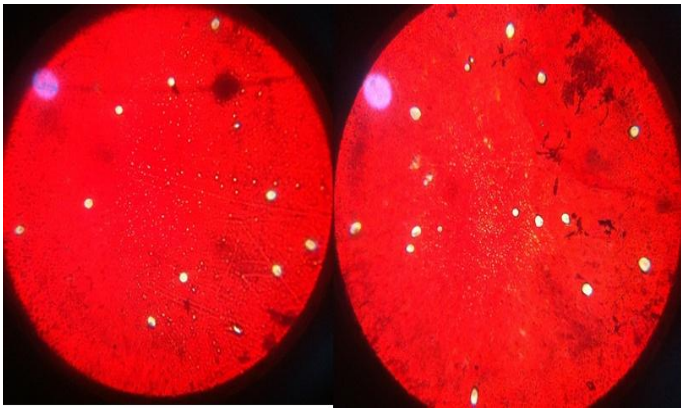

Figure 2: photographs of tracks emerged in LR-115 type II detectors for selected experiments.

The mass radon exhalation rate is calculated from the relation [17];

$$E_M = \frac{ATV\lambda/M}{T+\lambda^{-1}(e^{-\lambda T}-1)}$$

(4)

where E_M expressed in Bq kg^{-1}h^{-1} and M is the mass of the sample.

The effective radium content in the sample could be calculated from [18];

$$A_{Ra} = \frac{\rho hS}{KMT}$$

(5)

whereρ is track density recorder, h distance between the detector and sample, S surface area of sample and T exposure time.

The annual effective dose equivalent to potential alpha energy E_p is given by the following formula:

$$E_p\left(\frac{mSv}{y}\right) = 2.21 \times 10^{-3}\ n\ F\ A_{Rn}$$

(6)

where n is occupation number estimated as n=0.8 indoor and n=0.2, is radon equilibrium factor estimated as F=0.41 and A_{Rn} is the measured radon gas concentration[19]. All experimental errors were calculated in the same manner of equation (2).

5. RESULTS AND DISCUSSION

The results of measurement of radon concentration emitted from soil samples are presented in table 1. From the table one can notice that radon concentration varies from 28 Bq m^{-3} to 3823 Bq m^{-3}, with average value of 1067 Bq m^{-3}. These values are higher than those measured in closed area by references [20,21]and this may be related to the method of measurement or these surface samples have a lot of contaminated fallout from the west part of Basrah.

Table 1 : Results of radon concentration (Rn) in Bq m^{-3}, radium concentration (Ra) in Bq k^{1}, area radon exhalation rate (E_A) in Bq m^{-2} h^{-1}, mass exhalation rate (E_M) in Bq.kg^{-1} h^{-1}

Sample No	Rn Bq/m^3	Ra Bq/kg	E(A) Bq m^{-2} h^{-1}	E(M) Bq.kg^{-1} h^{-1}
1	702±77	4.40±67	0.56±0.06	0.011±0.0016
2	163±18	1.02±0.15	0.13±0.01	0.002±0.0003
3	440±48	2.76±0.42	0.35±0.04	0.006±0.0010
4	1209±133	7.59±1.16	0.96±0.11	0.019±0.0028
5	1023±112	6.42±0.98	0.81±0.09	0.016±0.0024
6	698±77	4.4±0.67	0.55±0.07	0.011±0.001
7	1079±118	6.77±1.031	0.86±0.10	0.017±0.0025
8	1349±148	8.47±1.29	1.07±0.12	0.021±0.0031
9	1339±147	8.41±1.28	1.07±0.12	0.021±0.0031
10	3823±419	24.0±3.67	3.04±0.34	0.060±0.0090
11	713±78	4.47±0.68	0.57±0.06	0.011±0.0016
12	670±73	4.20±0.64	0.53±0.06	0.010±0.06
13	983±108	6.17±0.94	0.78±0.09	0.015±0.0023
14	527±58	3.31±0.50	0.42±0.05	0.008±0.0012
15	279±31	1.75±0.26	0.22±0.03	0.004±0.0006
16	353±39	2.22±0.33	0.28±0.03	0.005±0.0008
17	791±87	4.96±0.76	0.63±0.07	0.012±0.0018
18	93±10	0.58±0.08	0.07±0.01	0.001±0.0002
19	1730±190	10.8±1.66	1.38±0.16	0.027±0.0040
20	1209±133	7.59±1.16	0.96±0.11	0.019±0.0028
21	1268±139	7.96±1.2	1.01±0.1	0.020±0.0030
22	1070±117	6.71±1.02	0.85±0.10	0.017±0.0025
23	874±96	5.49±0.84	0.70±0.08	0.013±0.0020
24	905±99	5.68±0.86	0.72±0.08	0.014±0.0021
25	791±87	4.96±0.76	0.63±0.07	0.012±0.0018
26	1023±112	6.42±0.98	0.81±0.09	0.016±0.0024
27	146±16	0.91±0.14	0.12±0.01	0.0020.0013
28	691±76	4.34±0.66	0.55±0.06	0.010±0.0016
29	28±3	0.17±0.02	0.02±0.00	0.0004±6.6E-05
30	1209±133	7.59±1.16	0.96±0.11	0.0192±0.0028
31	879±96	5.52±0.84	0.70±0.08	0.0139±0.0020
32	1609±176	10.1±1.54	1.28±0.14	0.0256±0.0038
33	1451±159	9.11±1.39	1.15±0.13	0.0230±0.0034
34	1665±183	10.4±1.60	1.32±0.15	0.0264±0.0039
35	1311±144	8.23±1.26	1.04±0.12	0.0208±0.0031
36	2567±281	16.1±2.46	2.04±0.23	0.0408±0.0060
37	1051±115	6.60±1.01	0.84±0.09	0.0167±0.0024
38	2537±278	15.9±2.43	2.02±0.23	0.0403±0.0060
39	1564±171	9.82±1.50	1.24±0.14	0.0248±0.0037

40	1463±160	9.18±1.40	1.16±0.13	0.0232±0.0034
41	818±90	5.14±0.78	0.65±0.07	0.0130±0.0019
42	1649±181	10.3±1.58	1.31±0.15	0.0262±0.0039
43	2156±236	13.5±2.07	1.72±0.19	0.0343±0.0051
44	1826±200	11.4±1.75	1.45±0.16	0.0290±0.0043
45	2537±278	15.9±2.43	2.02±0.23	0.0403±0.0060
46	1615±177	10.1±1.55	1.29±0.14	0.0257±0.0038
47	964±106	6.05±0.92	0.77±0,09	0.0153±0.0022
48	893±98	5.60±0.85	0.71±0.08	0.0142±0.002
49	1339±147	8.41±1.28	1.07±0.12	0.0213±0.0031
50	930±102	5.84±0.89	0.74±0.08	0.0148±0.0022
51	1935±212	12.1±1.85	1.54±0.17	0.0307±0.0045
52	507±56	3.18±0.48	0.40±0.05	0.0080±0.0012
53	986±108	6.19±0.94	0.78±0.09	0.0156±0.0023
54	1014±111	6.36±0.97	0.81±0.09	0.0161±0.0023
55	1144±125	7.18±1.09	0.91±0.10	0.0182±0.0027
56	70±8	0.43±0.06	0.06±0.01	0.0011±0.0001
57	567±62	3.56±0.54	0.45±0.05	0.0090±0.0013
58	121±13	0.75±0.11	0.10±0.01	0.0019±0.0002
59	1349±148	8.47±1.29	1.07±0.12	0.0214±0.0031
60	707±77	4.44±0.67	0.56±0.06	0.0112±0.0010
61	1752±192	11.0±1.68	1.39±0.16	0.0278±0.0041
62	1693±186	10.6±1.62	1.35±0.15	0.0269±0.0040
63	2130±234	13.3±2.04	1.69±0.19	0.0338±0.0050
64	1674±184	10.5±1.60	1.33±0.15	0.0266±0.0039
65	1404±154	8.82±1.35	1.12±0.13	0.0223±0.0033
66	388±42	2.43±0.37	0.31±0.03	0.0061±0.0009
67	1006±110	6.32±0.96	0.80±0.09	0.0160±0.0023
68	1479±162	9.29±1.42	1.18±0.13	0.0235±0.0034
69	1353±148	8.49±1.30	1.08±0.12	0.0215±0.0032
70	670±73	4.20±0.64	0.53±0.06	0.0106±0.0015
71	112±12	0.70±0.10	0.09±0.01	0.0017±0.0002
72	786±86	4.94±0.75	0.63±0.07	0.0125±0.0018
73	1190±131	7.47±1.14	0.95±0.11	0.0189±0.0028
74	1581±173	9.93±1.52	1.26±0.14	0.0251±0.0037
75	93±10	0.58±0.08	0.07±0.01	0.0014±0.0002
76	983±108	6.17±0.94	0.78±0.09	0.0156±0.0023
77	465±51	2.92±0.44	0.37±0.04	0.0074±0.0011
78	493±54	3.09±0.47	0.39±0.04	0.0078±0.0011
79	670±73	4.20±0.64	0.53±0.06	0.0106±0.0015
80	279±31	1.75±0.26	0.22±0.03	0.0044±0.0006
81	735±81	4.61±0.70	0.58±0.07	0.0116±0.0017
82	186±20	1.16±0.17	0.15±0.02	0.0029±0.0004
Max	3823±419	24.0±3.67	3.04±0.34	0.06±0.0090
Min	28±3	0.17±0.02	0.02±0.01	0.0004±0.0001
Av.	1067±117	6.7±1.02	0.849±0.09	0.017±0.0020

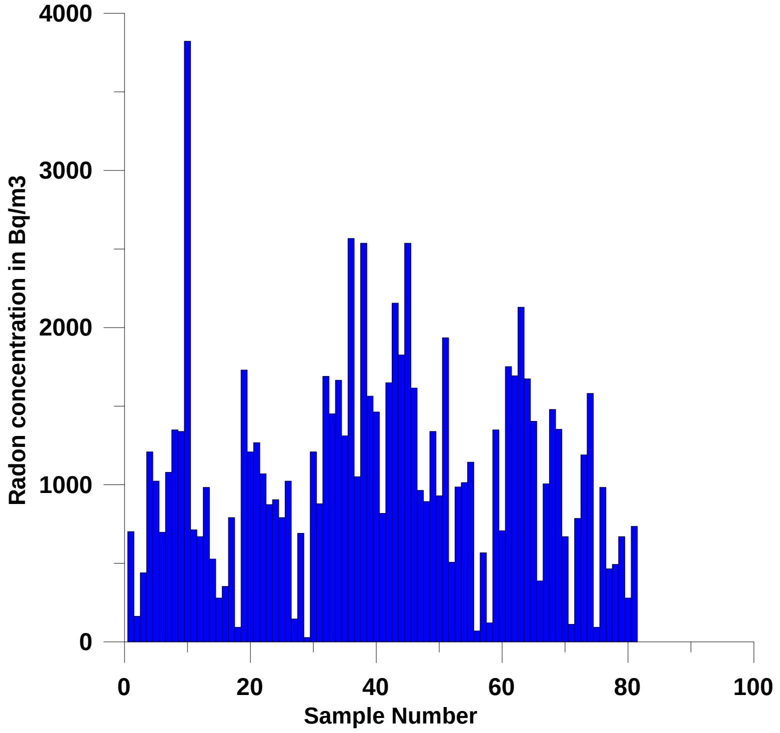

Figure 3: bar chart of radon concentration with the sample number.

The 4th column in the above table shows the radium concentration, which responsible of the amount of radon emanated from soil samples, varies from 0.17 Bq kg^{-1} to 24.0 Bq kg^{-1} with an average value of 6.7 Bq kg^{-1}. The observed values of radium concentration in soil samples in present study are less than the recommended permissible level 370 Bq/kg and also lower than the average worldwide value 50 Bq/kg. The values of area and mass exhalation rates were also presented in the table and their values are; 3.67, 0.02, 1.02 $Bq.m^2h^{-1}$ and 0.01, 0.0004, 0.17 Bq $kg^{-1}h^{-1}$ respectively. According to these results one can say that, the soil in this area is advisable to use in brick manufacturing for building construction. Also, all the calculated parameters related to radon measurement must be correlated with radon concentration in soil. Equation (6) was used to estimate the annual effective dose equivalent to potential alpha energy E_p for outdoor and indoor exposures and present them in figures 4 and 5. From the average value of radon concentrations it is found that $E_p=0.773\ \frac{mSv}{y}$. This value indicates that the annual exposure from radon is less than 2.5 $\frac{mSv}{y}$, the annual background of the total radiation in the natural environment.

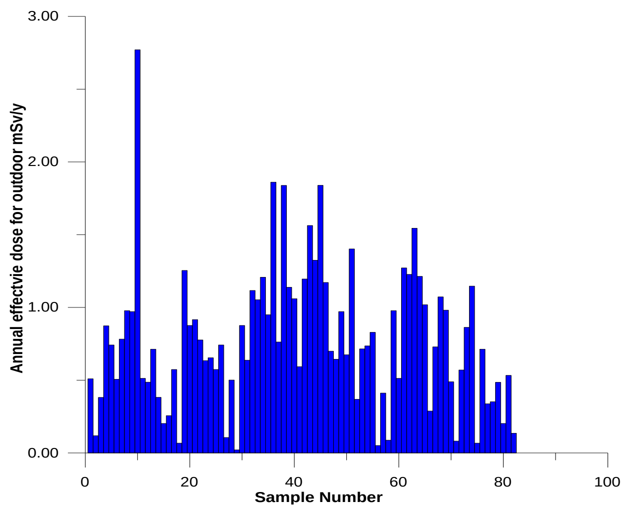

Figure 4: the outdoor annual effective dose for radon emanated from soil samples

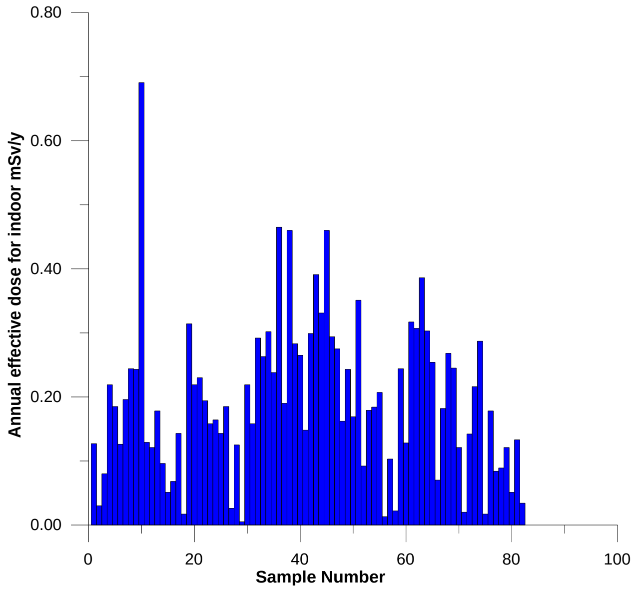

Figure 5: the indoor annual effective dose for radon emanated from soil samples.

6. CONCLUSION

The present measurements show average radon concentration in soil is higher than nearby region, but less than the action level of ICRP. The average values of radium in soil response for such radon are below the global average. The calculated results of radon exhalation rates are quit lower than the safe international limit and therefore, the use of soil of this location as ore in building construction is consider to be safe according to this results. A strong positive correlation between radon concentrations and other calculated parameter were observed.

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تقدير مستوى تركيز غاز الرادون والجرعة المؤثرة بأستخدام كواشف الاثر النووي في منطقة مختارة من محافظة البصره – منطقة القبلة

جبار حافظ جبر

قسم الفيزياء/ كلية التربية للعلوم الصرفة/ جامعة البصره / البصره / عراق

الخلاصة:

تم قياس تركيز غاز الرادون والانبعاث المساحي والكتلي والجرعة المؤثرة لعدد 82 انموذج من التربة مأخوذه من مناطق مختارة في محافظة البصره (القبلة) في العراق. في هذه الدراسة استخدمت تقنية العلبة المغلقة والتي تحتوي كاشف الاثر نوع LR−115 type II لعملية القياس. ان معدل قيمة تركيز الرادون المنبعث من الأتربة كان 1067 ± 117 Bq m^{-3} ومعدل تركيز عنصر الراديوم بلغ 6.70 ± 1.02 Bq kg^{-1} بينما كان معدل الانبعاث المساحي والكتلي هو 0.849 ± 0.099 Bq m^{2} h^{-1}, 0.017 ± 0.002 Bq $kg^{-1}h^{-1}$ على الترتيب. وجد ان جميع النتائج مقبولة وهي اقل من القيم المحدد من قبل منظمة ICRP

الكلمات المفتاحية: رادون ، معدل الانبعاث ، كاشف LR−115 type II ، تقنية العلبة ، تربة