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Radon Concentration: The cases of study are Shut- Al-Basra, river banks and Basra Sport City, Basra, Iraq

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ABSTRACT

Radon emanated from soil at Shutt- Al-Basrah river-banks and Basrah Sport City have been investigated. The measurements were carried out in 17 points in four depths from the surface, using CR-39 and LR-115 solid state nuclear track detectors and RAD7 instrument. The location of sample points were selected according to mesh map covered the surveyed area, 5x5 km^2 for each mesh area. The results of outdoor radon levels concentrations in these sites were found to vary from 1439±90 Bq m^{-3} to 38765±2432 Bq m^{-3}, with average values of 5292 Bq m^{-3}. The radon annual effective dose ranged from 1.60 mSv y^{-1} to 9.12 mSv y^{-1} . The corresponding mean values of annual effective dose for the sites was 3.02 mSv y^{-1}, indicates that the open area basements, storage areas and tunnels are safe occupancies.

Keywords: Radon, CR-39, LR-115 type II, RAD7, Annual effective dose

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INTRODUCTION

The main source of ionizing radiation in the earth crust, which continuously exposed the human being, is uranium, thorium and their progeny in the environment [1-2]. Researches carried out in recent decades show that, under normal conditions, more than 70% of a total annual radioactive dose received by people originates from natural sources of ionizing radiation, whereby 54% is due to inhalation and ingestion of natural radioactive gas radon ^{222}Rn and its decay products. Long term exposures to radon via inhalation in closed rooms or caves or open air saturated with Radon gas is the cause of about 10% of all deaths from lung cancer [3-6]. Studied also related to Radon in kidney and malignant melanoma cancer have been reported. Radon is a natural inert radioactive tasteless and odorless gas, whose density is 7.5 times higher than that of air. Radon gas and its radioactive isotopes have special attention among the other naturally radioactive materials, because it has the largest amount of total annual effective dose to humane [7-8]. There are three natural occurring isotopes of Radon; Radon ^{222}Rn , a direct product of ^{226}Ra in the 238U groundwater. Because it's relatively long half - life enabling it to migrate quit significant distance before decaying and can be found in the soil gas. While the plastic detector CR39 or LR-115 type II and Gamma Spectroscopy were used to estimate Radon concentration in soil [9-10], the solid state alpha detector RAD7 used in the present investigation to provide the Radon concentration in soil gas data, which Iraq is still suffering the lack of such data. Recently, RAD7 was used in many experimental techniques concerning measurement of Radon concentration in different locations for continuous radon monitor [11-14]. The aim of the present work is to determine the radon concentration in soil gas at a specific depth within the soil at Shutt Al- Basrah river banks and Basrah Sport City. To do this, the air must be removed from the soil and delivered to a RAD7 (radon monitoring system) of Durridge Company (USA), without dilution by outside air. The volume of gas removed depends on the technique used to extract it and the porosity of the soil. decay series with physical half-life 3.825 days, ^{220}Rn, decay products of ^{232}Th, Thoron ^{220}Rn , half-life 55.6s is a radioactive noble gas exists in natural radon gas as well, and ^{119}Rn, a decay product of ^{235}U, with half life of 3.6s. Among the three radioactive isotopes ^{222}Rn is the most significant. To compare the results, the SSNTDs ware also used in the measurements of radon concentrations in the same area. That will be valuable in deterring geological controls on the occurrence and migration of radon in the overburden of Iraq.

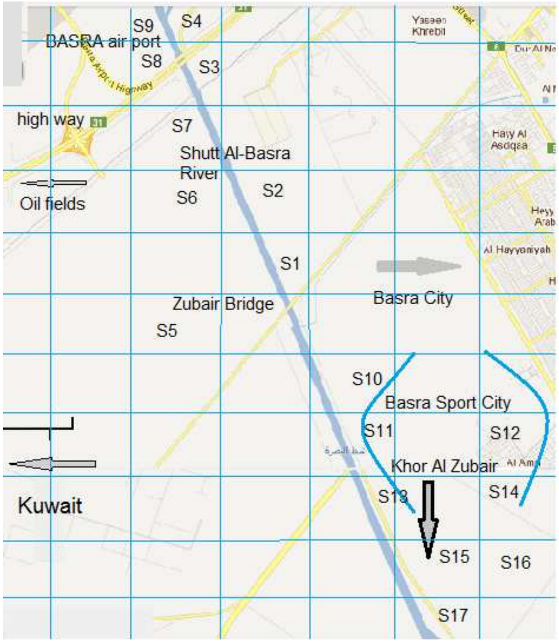

Figure 1. Area of study map, where places of sample points clearly identified

MATERIALS AND METHODS

2.1 The passive method

We used the Solid State Nuclear Track Detectors (SSNTDs), for the measurements of radon concentration in soil. The detectors are CR39 and LR115-II 1.5x1.5cm films, were glued on the bottom of container's cover. The containers then covered, sealed and left for three months to irradiate the films with alpha particles emitted from radon. The cylindrical container is presented in figure 2.

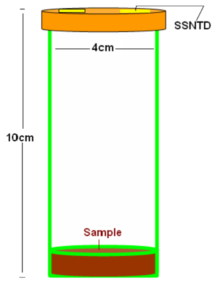

Figure 2. The cylindrical plastic containers used to measure Radon concentration in soil samples

After this time of irradiation the detectors removed carefully from the cover and etched with NaOH solution with conditions 6.25N at 70^o C for 7 hours for CR39 film and 2.5N at 60^o C for 2 hours in the case of LR115-II film. The detectors then washed many times by distilled water and dried with tissue papers. The numbers of tracks due to alpha particles interaction are counted by the means of optical microscope 400X. The tracks number been evaluated as a mean value of tracks in more than 20 areas of field of view. Figure 3 represent a sample of tracks recorder in both types of detector for the same sample.

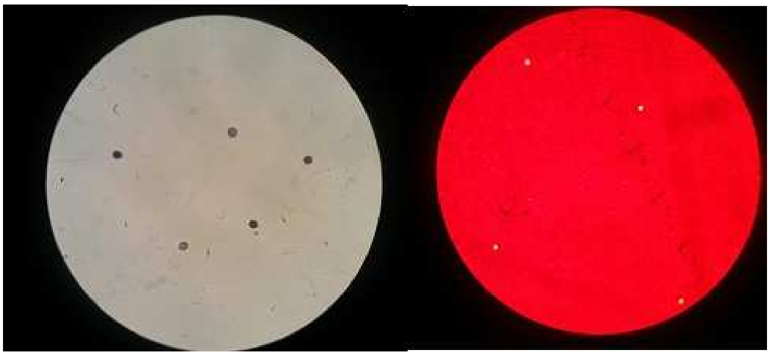

Figure 3. Sample of tracks in CR39 and LR115 type II for the same sample

2.2. Theoretical aspect

The alpha particle densities that registered on CR39 and LR115 written as;

$$\rho_G = \frac{Trak\ number}{Global\ viewarea\,(cm^2)\,x\,Global\ erradiation\ time\,(\sec)} \quad (Tr/cm^2.Sec) \qquad (1)$$

This density can be given by [15-16]

$$\rho_G^{CR} = A_c^{222}(Bq.cm^{-3})\left[\sum_{i=1}^{3} k_i\, P_i^{CR}\, R_i + \frac{A_c^{220}}{A_c^{222}}\sum_{i=1}^{4} k_i\, P_i^{CR}\, R_i\right] \qquad (2)$$

where A^{222} and A^{220} are radon and thoron concentration, P_i^{CR} the probability of alpha-particle of energy E_α (tabulated), R_i is the range of alpha particle in the detector material, and k_i is the branching ratio for alpha decay of radon (tabulated)

$$\rho_G^{LR} = A_c^{222}(Bq.cm^{-3})\left[3P^{LR}\,\Delta R + 4P^{LR}\,\Delta R\,\frac{A_c^{220}}{A_c^{222}}\right] \qquad (3)$$

Dividing equation (2) on (3) we get

$$\frac{\rho_G^{CR}}{\rho_G^{LR}} = \frac{\sum_{i=1}^{3} k_i\, P_i^{CR}\, R_i + \frac{A_c^{220}}{A_c^{222}}\sum_{i=1}^{4} k_i\, P_i^{CR}\, R_i}{3P^{LR}\,\Delta R + 4P^{LR}\,\Delta R\,\frac{A_c^{220}}{A_c^{222}}} \qquad (4)$$

Measuring ρ_G^{CR} , ρ_G^{LR} and making use P_i^{CR}, P_i^{LR} values, one can calculate the $^{220}A/^{222}A$ ratio from the following;

$$\frac{A_c^{220}}{A_c^{222}} = \frac{\sum_{i=1}^{3} k_i\, P_i^{CR}\, R_i - 3P^{LR}\Delta R\,\frac{\rho_G^{CR}}{\rho_G^{LR}}}{4P^{LR}\Delta R\,\frac{\rho_G^{CR}}{\rho_G^{LR}} - \sum_{i=1}^{4} k_i P_i^{CR} R_i} \qquad (5)$$

RESULTS AND DISCUSSION

2.3 Results and discussion of passive method

Using relations (5), (2) and (3) one can calculate the activity concentration of radon ^{222}A and thoron ^{220}A. The results were tabulated in Table 1. The average radon concentrations for all samples is 5292 Bq/m^3, while, the maximum value 38765±2432 Bq/m^3 for sample S2 at depth 60 cm from earth surface and minimum value is 1439±90 Bq/m^3 for sample point S10 at depth 60 cm, in the hotels area.

Table 1. The radon and thoron concentrations in soil of the river banks of Shutt Al-Basrah river and soil samples taken from Basrah Sport City. The measurements were conducted by using SSNTDs.

Sample ID.	No of Tracks. CR39	No. of Tracks LR115	^{222}A in Bq/m^3	^{220}A in Bq/m^3
S1				
1.1	7.7	4.78	6518±409	3423±215
1.2	8.5	5.25	8264±518	2734±171
1.3	5.4	3.33	5444±341	1579±99
1.4	4.55	2.8	5614±352	1115±70
S2				
2.1	16.1	10.0	13372±1072	426±27
2.2	17.0	10.6	12192±765	9287±582
2.3	15.0	9.3	13246±832	9237±392
2.4	38.33	23.66	38765±2432	12068±758
S3				
3.1	8.5	5.3	6163±386	4695±294
3.2	7	4.34	6250±392	2942±184
3.3	5.8	3.575	5978±375	1599±100
4.3	6	3.75	3931±246	3644±228
S4				
4.1	10	6.17	9914±622	2951±185
4.2	9.5	5.86	9486±595	2749±804
4.3	6.5	4.03	5556±348	2616±164
4.4	5.5	3.43	3791±237	2930±183
S5				
5.1	9.5333	5.9583	5355±335	4963±311
5.2	11.7307	7.3316	4613+289	6104±383
5.3	8.4000	5.2500	4718±296	4373±274
5.4	8.2083	5.1301	9592±413	4270±267
S6				
6.1	2.6500	1.6159	3017±189	83±5
6.2	2.4500	1.4939	2791±175	75±4
6.3	3.8695	2.3885	3672±230	1141±71
6.4	4.7391	2.9253	4496±282	1399±87
S7				
7.1	3.9200	2.4198	3532±221	1104±69
7.2	3.6364	2.2447	3278±205	1023±64
7.3	3.7273	2.3008	3361±210	1048±65
7.4	3.8695	2.3885	3672±230	1141±71
S8				
8.1	2.6775	1.6327	2199±138	70±4
8.2	3.1334	1.9342	2535±159	686±43
8.3	2.7037	1.6486	2562±160	69±4
S9				
9.1	6.9584	4.3490	4319±271	4004±251
9.2	6.2500	3.9063	3877±248	3877±248
9.3	11.0371	6.8982	6851±429	3814±239
9.4	8.4783	5.2990	3814±239	6851±429
S10				
10.1	3.3500	2.0679	2232±140	696±43
10.2	3.7878	2.3381	2526±158	786±49
10.3	3.3461	2.0654	2233±140	693±43
10.4	3.3636	2.1022	1439±90	1331±83
10.5	3.4146	2.1077	2233±140	708±44
S11				
11.1	3.1428	1.9400	2044±131	653±41
11.2	3.2692	2.0180	2179±136	679±42
11.3	3.1290	1.9314	2088±131	648±40
11.4	3.3714	2.0811	2247±141	700±43
S12				
12.1	3.9565	2.4422	3916±245	1217±76
12.2	3.8181	2.3568	3778±237	1176±73

12.3	4.0000	2.4691	3822±239	1232±77
12.4	3.8636	2.3849	3957±248	1190±74
S13				
13.1	7.2084	4.5053	4380±274	4046±254
13.2	5.2500	3.2813	3189±200	2960±185
13.3	8.4500	5.2813	3413±214	4764±298
13.4	5.6191	3.5120	5135±322	3169±198
S14				
14.1	7.2917	4.5574	4429±277	4112±258
14.2	6.9131	4.3207	3410±213	3896±244
14.3	5.5834	3.4897	4405±276	3149±197
14.4	6.2174	3.8859	4344±272	3504±219
S15				
15.1	NT	NT		
15.2	4.000	2.4692	3219±202	1185±74
15.3	5.9412	3.7133	3610±226	3350±210
15.4	5.2963	3.3102	3790±237	2985±187
S16				
16.1	9.0572	5.6608	5504±345	5106±320
16.2	9.6191	6.0120	5845±366	5423±340
16.3	9.2258	5.7662	6505±351	5202±326
16.4	7.4118	4.6324	4505±282	4178±262
S17				
17.1	2.9167	1.7785	3321±208	90±5
17.2	2.2500	1.3720	3278±205	70±4
17.3	2.6819	1.6353	3361±210	82±5
17.4	2.6452	1.613	3672±230	83±5

In the case of thoron concentrations, the maximum value was 5423±340 Bq/m^3 and minimum value was 70±4 Bq/m^3, while the average value was 2523 Bq/m^3. The ^{220}Rn/^{222}Rn= 0.477, means that thoron mostly less than radon concentration. The data collected does not give any indications that, the concentration depend on depth up to 60 cm.

2.4 Results and discussion of active method

Measurements of radon concentration soil were carried out using a calibrated alpha spectrometer DURRIDGE *RAD 7 USA*, with special accessories for radon measurement in soil. The detector converts alpha radiation directly to an electric signal and has the possibility of determining electronically the energy of each particle, which allows the identification of the isotopes (^{218}Po, ^{214}Po) produced by radiation, so it is possible to instantaneously distinguish between old and new radon, radon from Thoron, and signal from noise.

Figure 4 Active methods for measuring radon concentration in soil

The selected points taken according to the ability of measurement on the field .Total of 17 positions were tested and in each position, samples from three different depths were taken. These points covered most area of study and the distance between the points approximately 5 km. A stainless steel soil gas probes supplied by Durridge Company (USA), were used in the present experiment. The probe, with a hollow tube and sampling holes near the tip inserted into the soil, and air drawn up the tube, and into the RAD7. In the location, we looked for soil containing few solid stones to avoid cracking the probe. The probe connected to RAD7 by pushing the plug-in hose connector into the probe. Entomb down soil around the probe to prevent the leakage of fresh air into the sample acquisition path or down the outside of the probe to sampling point. Air was circulated in a closed circuit for a period of 5-10 min until the radon was uniformly mixed with the air and the resulting alpha activity was recorded and it directly gives the radon concentration. A half hour counting time in the Grab protocol for all sampling points had been taken. In each sampling location three times measurements of sampling point, the distance between each 10-20cm, then the average reading of RAD7 have been taken.

The results of radon concentrations in sample of soil measured using RAD7 were tabulated in Table-2. In this table one can find both values of RAD7 in comparison with the results of SSNTDs for the same point. The measurements were for three depth (20,40,60) without samples from the soil surface. In comparison one can find that, there is a different between the two measurements (RAD7 values are less than SSNTDs),this is due to the effect of the time shortness of RAd7 measurement (Grab sample approximately 30 min while the SSNTDs is around three months).

Table 2. Radon concentration measured by RAd7 in comparison with SSNTSs measurements for selected points in the studies area.

Sample ID	Depth(cm)	^{222}Rn RAD7 (Bq /m^3)	^{222}RnSSNTD (Bq/m^3)
S1			
	20	2172±323	8264±518
	40	2858±237	5444±341
	60	3126±129	5614±352
S2	20	3050±293	12192±765
	40	5811.±119	13246±832
	60	21400±512	38765±2432
S3	20	1138±320	6250±392
	40	1769±131	5978±375
	60	1972±186	3931±246
S4	20	5280±264	9486±595
	40	2126±50	5556±348
	60	1260±196	3791±237
S5	20	3124±215	4613+289
	40	5443±198	4718±296
	60	12430±452	9592±413
S6	20	2140±983	2791±175
	40	8170±1160	3672±230
	60	10800±581	4496±282
S7	20	1180±19	3278±205
	40	2223±115	3361±210
	60	3240±162	3672±230
S8	20	1120±272	2199±138
	40	2870±168	2535±159
	60	4940±782	2562±160
S9	20	2580±113	3877±248
	40	4109±68	3814±239
	60	8886±71	6851±429
S10	20	1380±150	1439±90
	40	3650±377	2233±140
	60	4810±555	2526±158
S11	20	1620±234	2179±136
	40	6160±567	2088±131
	60	12700±6890	2247±141
S12	20	1060±615	3778±237
	40	1360±366	3822±239
	60	2516±580	3957±248
S13	20	887±144	3189±200
	40	1160±336	3413±214
	60	262±138	5135±322
S14	20	2250±320	3410±213
	40	6020±271	4405±276
	60	7290±579	4344±272
S15	20	1100±266	3219±202
	40	2323±67	3610±226
	60	4000±606	3790±237
S16	20	1126±50	5845±366
	40	1260+126	6505±351
	60	5280±264	4505±282
S17	20	597±53	3278±205
	40	866±212	3361±210
	60	1054±112	3672±230

In the present study, we have found that most of the soil in all regions are nearly similar in content. However, a remarkable increase in Radon concentration is found in sample S2 (21400±512Bq/m^3) at depth 60 cm from the surface of the earth. The average value was 3929 Bq/m^3 and minimum value was 262±138 Bq/$m^3$for sample S13 at depth 60 cm. The correlation between the two types of measurement is show in Figure 4, which show a reasonable correlation R=0.62. Table 6.3 contains the radon concentrations in different places in the world, in comparison with the results of the present work.

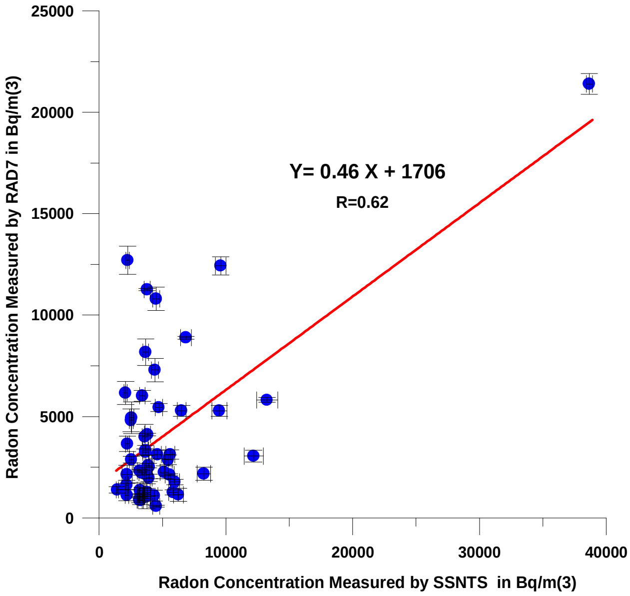

Figure 5. Correlation between two types of radon detector (SSNTD and RAD7)

Table 3 Radon concentrations in soil of different part of the world

Reference No	Mean kBq m^{-3}	Range in kBq m^{-3}	Method used	Place of Study
17	8.05	5.79-9.27	SSNTD	India
18	5.6	0.622-24.855	RAD7 and SSNTDs	Kurdistan Iraq
19	10.446	0.232-104.30	RAD7	Italy
20	1.3	0.076-5.130	Locas cell	Syria
21	6	3-7	Probe+RAD7	India
22	1.66	1.56-16.200	SSNTDs	Surface soil. of Basra, Iraq
23	7.456	1.098-31.776	SSNTDs	Himalaya
24	11.4	1- 56.5	Bore-holes and SSNTD	Japan
25	4.01	0.9-22.9	Alpha Gaurd	Slovenia
26	2.07	1.42-4.55	CR39	Jerash-Jordan
27	5.3	0.3-35.8	Alpha Gaurd	Punjab- India
28	8.05	4.9-13.9	SSNTDs	Karnataka- India
Present work	**4.708**	**1.439-38.765**	**SSNTD and RAD7**	**Basrah- Iraq**

Radon has a good contribution toward the natural absorption radiation dose. The ICRP published in its report 1994 that every 1 Bq/m^3 of radon level contributes about 0.025 mSv y^{-1} [30]. Cross (1992) [29] estimated the probability of getting lung cancer from radon concentration to be equal to 1.65x10^{-3} if the radon concentration was 37 Bq/m^3. If one assumed that 2% of radon in soil emigrate to the atmosphere ,UNSCEAR 2006 [31] then, the average radon concentration in the atmosphere is 94.16 Bq/m^3. So, the average calculated equivalent doses was 2.354 mSv y^{-1} which is in the range of recommended value of WHO [3]. However the maximum radon concentration is 38765±2432 Bq/m^3 at depth 60cm from the surface of the earth. This equivalent to 775.3 Bq/m^3 in the atmosphere, or, the effective dose in contact with point is 19.38 mSv y^{-1}, which is outside the recommended range and need special attention.

CONCLUSION

Two analytical methods (SSNTDs and RAD7) were used to measure radon concentration in soil the results of soil radon concentration and can be considered comparable between two method. No significant differences were observed between points in the field of study except one point sample, where the concentration is high recorded by both types of detectors. It is worth to mentioning that differences can be due to the heterogeneity of uranium and thorium distribution in the soil and local permeability of the soil. Thus, in the long run, it is safe to consider such studied areas for establishing dwelling and buildings for people use. Most of the samples show a low thoron concentration, which indicate that the area has poor thorium and its progeny concentration.

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