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Determination of Radon and Thoron Activity in the Soil By using Solid State Nuclear Track Detectors (SSNTDs), Passive Technique

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ABSTRACT

Radon and thoron activity concentration levels have been determined in the soil of Basra Governorate, Iraq. The area of the study included three districts, they are Hayy-Alabas, Hayy-Aljameeat and Almuaficia.. In this investigation CR-39 and LR-115 type2 solid state nuclear track detectors and a cylindrical plastic container technique are used. The samples are taken from the surface and the depth 1m for each location. Maximum activity of radon levels observed is (16200 Bq.m^{-3}) in Hayy-Alabas station number 10 for soil from the surface and minimum levels is (1560 Bq.m^{-3}) were observed in Almuaficia station number 54 for soil from the surface. The activity of radon were measured in Hayy-Aljameeat and Almuaficia which are with in normal limits according to International Commission on Radiological Protection (ICRP). The high values of radon activity are measured in many locations in Hayy-Alabas and Hayy-Aljameeat. There are many anomalous values of radon activity in the soil in some stations of Hayy-Alabas has been observed in this study. The reasons of this anomalous has been discussed. The activity concentration of thoron is smaller than the activity concentration for radon ((A_c^{220} / A_c^{222}) <1) over all study area. The reason of this result has been discussed. The average value of the activity of thoron concentration A_c^{220} in the soil samples from the surface equal 2073.33 Bq.m^{-3}, 1893.75 Bq.m^{-3} and 1822.22 Bq.m^{-3} for Hayy-Alabas, Hayy-Aljameeat and Almuaficia respectively and the average value for the soil samples from the depth 1m equal 1666.66 Bq.m^{-3} , 906.25 Bq.m^{-3} and 1103.333 Bq.m^{-3} for Hayy-Alabas, Hayy-Aljameeat and Almuaficia respectively.

Keywords: Radon, Thoron, CR-39, LR-115 type 2, soil , Activity (Bq m^{-3}).

INTRODUCTION

Radon is a fascinating type of element in which it is only massive inert gas found every where in different proportions. This special property of radon make it to unique and have characteristics which are unusual in their combination [1]. Radon, thoron and their decay products are alpha-, beta- and gamma-emitting nuclei. Inhalation of these radionuclides represents the main source of exposure to ionizing radiation for population in most countries [2-5].

Figure(1): Basrah Governorate, numbering in station number (s), represent the places where samples taken from, (the two maps are from Google Earth)

Measurements of radon are importance because the radiation dose to human population due to inhalation of radon and its daughters contributes more than 50% of the total dose from natural sources [6]. The dose which deriving from the presence in the air of ^{222}Rn is linked to the inhalation of its short–lived daughters, which are deposited in the respiratory organs, if deeply inhaled, emit alpha-particles in direct contact with the bronchial and pulmonary epithelium. For these reasons, the dose deriving from the exposure to ^{222}Rn in closed spaces has been placed in direct relation to the risk of lung cancer [7]. It seems that radon accepted the idea and implementation of globalization of the world by making available itself everywhere. Its existences is strongly tied with the presence of other elements. Outside air typically contains very low levels of radon, however, it may build up to higher concentrations indoors when it is unable to disperse [8].

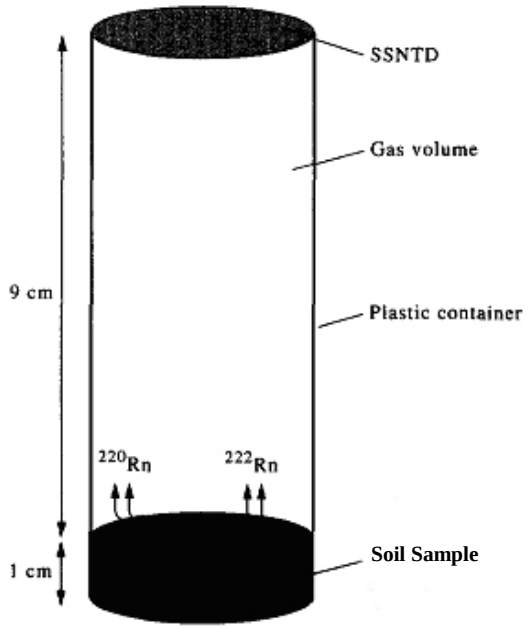
The main source of indoor radon is the soil, the activity concentration of radon coming from the soil can reach higher and higher values due to the better and better insulation techniques of dwellings. The epidemiological researches show the relative risk of lung cancer is 1.33 above 200 Bq m^{-3} [9] and the relative risk increases by 0.15-0.2 per 100 Bq m^{-3} [10]. Solid state nuclear track detectors (SSNTD) have been extensively used in this regard and almost all branches of science and technology [11-14].

In this study, we use a SSNTD technique based on determining detection efficiencies of the CR-39 and LR-115 type II solid state nuclear track detectors for measuring α - particles due to the radon and thoron series. The relevant ranges of the emitted α -particles in air and SSNTD utilized, were calculated by means of a TRIM program [15]. In this work we used (SSNTDs) to evaluate radon and thoron concentrations in various soil samples are brought from different places from Hayy-alabaas district and the area around it in Basra governorate, In order to set a baseline data for these areas which would be of great help for radiological database of Iraq.

MATERIALS AND METHODS

METHOD OF STUDY

The soil samples were collected from 55 locations in Basrah city during October 2011. The area of study included three districts Hayy-Alabas, Hayy-Aljameeat and Almuaficia as shown in figure(1). The soil samples where taken from the surface and depth 1m from each location. The number of soil samples is 110. Each one of these soil samples is dried in the oven at 120 ^{o}C and milled in the grinder. Finally, all samples are sieved (riddled) in sieve with 300 μm pores. Each sample of soil of 1cm height is placed in the bottom of the closed cylindrical plastic container as shown in the Fig.(2) [16].



Figure(2):Arrangement of the solid state nuclear track detector films placed at a distance of 9 cm above a soil sample in a cylindrical plastic container of 2 cm radius.

Identical disks of radius 2 cm of CR-39 and LR-115 type II SSNTDs have been separately placed at a distance of 9 cm above the sample for one month. Two identical films of CR-39 and the same from LR-115 type II are used for

each sample to achieve a high accuracy. This long time of irradiation is necessary for secular equilibrium and to accumulate considerable number of tracks of α -particles that emitted from radon, thoron and their progenies.

After the irradiation, the exposed films were developed in an NaOH solution with chemical etching conditions 2.5 N at 60 ^{o}C for 120 minutes for LR-115 type II films and 6.25 N at 70 ^{o}C for 7 hours for CR-39 films [17]. After the chemical treatment of the CR-39 and LR-115 type II detectors the visual counting of alpha particles tracks (i.e. N_G^{CR}, N_G^{LR}) are carried out by means of an optical microscope.

The global alpha particle track densities that registered on CR-39 and LR-115 detectors (i.e. ρ_G^{CR} and ρ_G^{LR}) are calculated according to the following equations

$$\rho_G^{CR} = \frac{N_G^{CR}}{A_G \times t_G} \qquad \text{---------- (1)}$$

And

$$\rho_G^{LR} = \frac{N_G^{LR}}{A_G \times t_G} \qquad \text{---------- (2)}$$

Where A_G is the global area of view and t_G is the global time of irradiation, N_G^{CR} and N_G^{LR} are the average values of the number of tracks registered on the CR-39 and LR-115 detectors respectively .

Hence, the global density of tracks due to the α -particles emitted by radon, thoron and their daughters, registered on the CR-39 SSNTD is then

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

The global density of tracks per unit time (tracks.cm^{-2}.s^{-1}) due to the α -particles of the radon and thoron groups registered on the LR-115 type II SSNTD is then equal to:

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

Combining eqs.(3) and (4), the following relationship between track densities and thoron to radon ratio is [17]:

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

Where, P_i^{CR} represents the probability for an alpha-particle of energy $E_{\alpha i}$ and index i emitted at a distance x from the detector to reach and be registered on the CR-39 SSNTD [17].

The values of P_i^{CR} for each index i are shown in Table (1) and the values of P^{LR} for each residual thickness are shown in Table (2).

Knowing ρ_G^{CR} , ρ_G^{LR} , P_i^{CR} and P^{LR} one can determine the A_c^{220}/A_c^{222} ratio and consequently the A_c^{220} and A_c^{222} activities of the studied soil samples have been evaluated.

Table (1): Data obtained for the probability (P_i^{CR}) for radon group α -particles and thoron group α -particles to be registered on the CR-39 SSNTD for the gas volume of the α -particles of energy Eα_i and index i in the gas volume [17].

Nuclide	$E\alpha_i$, MeV	R_i , cm	$P_i^{CR}\times10^{-3}$
Radon group α -particles			
^{222}Rn	5.49	3.90	2.871
^{218}Po	6.00	4.65	3.383
^{214}Po	7.68	6.65	4.440
Thoron group α -particles			
^{220}Rn	6.28	4.80	3.391
^{216}Po	6.78	5.45	3.433
^{212}Bi	6.08	4.75	3.527
^{212}Po	8.78	8.36	5.711

Table (2): Values of the probability (P^{LR}) for the α -particles of the radon and thoron groups to be registered on the LR-115 SSNTD for different residual thickness for (LR-115 films) for the gas volume of the water samples. R_{min} and R_{max} are the α -particles ranges in the gas volume which correspond to the lower and upper ends of the energy window [17].

Residual thickness, μ m	R_{min} , cm	R_{max} , cm	$P^{LR}\times10^{-3}$
3	0.46	3.83	203.299
4	0.61	3.52	11.302
5	0.80	3.44	4.329
6	0.98	2.71	1.536
7	1.07	2.66	1.405
8	1.29	2.53	1.336
9	1.42	2.31	0.267
10	1.60	2.02	0.191

RESULTS AND DISCUSSION

The A_c^{220}/A_c^{222} ratios and the radon and thoron activity per unit volume for the samples studied have been determined by using Equations (5) and (4) respectively . The error on track density counting is smaller than 7% for samples studied. The area of study included Hayy-Alabas, Hayy-Aljameeat and Almuaficia districts in Basrah Governorate, each location of the study called station. From table(3) to table(8) shows the number of station, the global track density of LR-115 type II (ρ_G^{LR}), the global track density of CR-39 (ρ_G^{CR}), the ratio of A_c^{220}/A_c^{222} , the activity of ^{222}Rn (A_c^{222}) and the activity of ^{220}Rn(A_c^{220}) for the soil samples. Table(3), table(5) and table(7) are concerned with the soil samples from the surface. Table(4), table(6) and table(8) are concerned with the soil samples from the depth 1m .

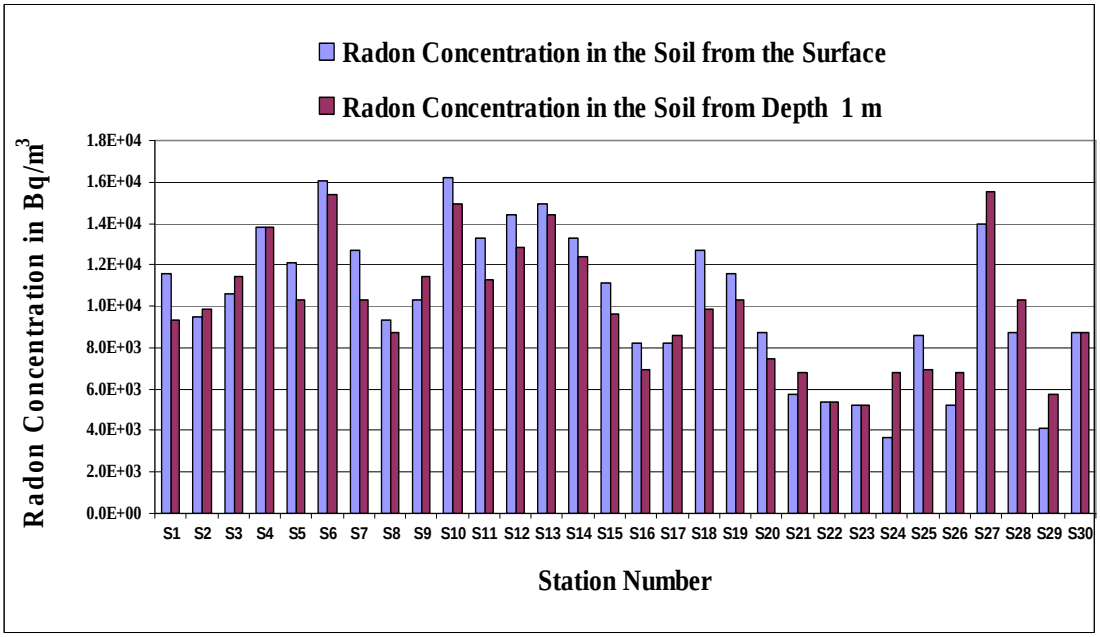
From Table(3) and table (4) it is clear that the observed radon concentrations for the soil from the surface and depth 1m in allot of stations in Hayy Alabas district are high than the natural limits [7].

The high levels of radon concentrations in the soil means clearly there are high uranium and radium concentrations in this soil [18], therefore, the high levels of radon concentrations in many stations in Hayy-Alabas district may be refer to high concentration of uranium and radium, which need more investigation.

When we lock carefully to the data in table(3) and table(4) we notice the radon concentrations for the soil which got from the surface of almost stations of study is greater than for soil which got from the depth 1m, this mean there are external pollution of uranium in the soil of this stations because of in natural case the concentration of uranium is increase with increasing in depth [19]. The data in table(3) and table(4) is shown in figure(3) and figure(4).

Table (3): The radon and thoron concentration in the soil samples from the surface in Hayy-Alabas in Basrah governorate

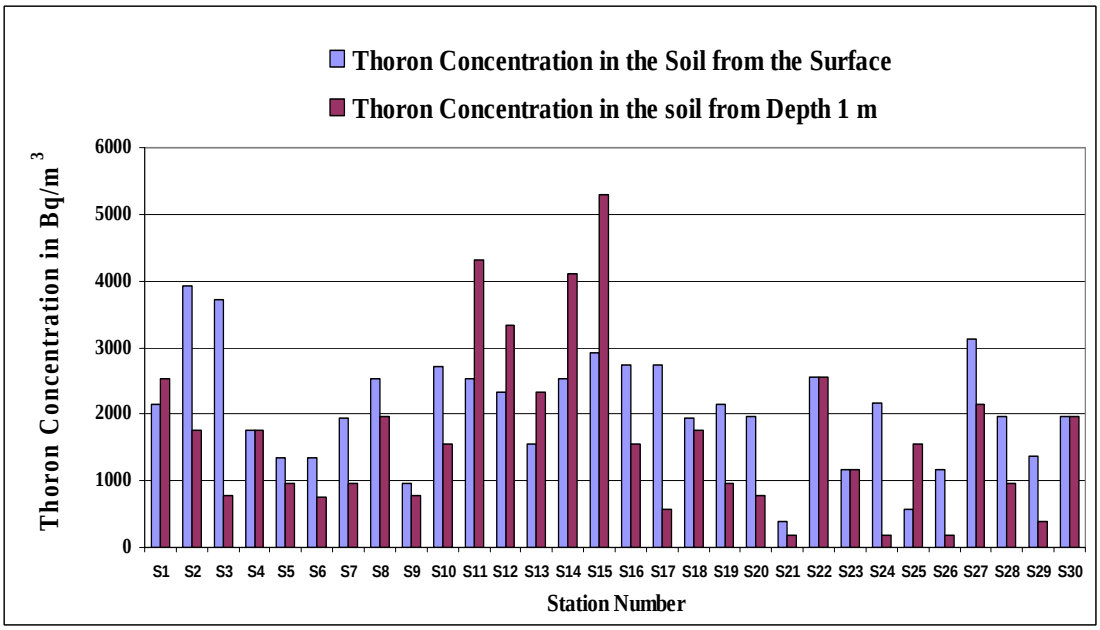
Station Number	$\rho_G^{LR} \times 10^{-5}$ *(tr .cm $^{-2}$.s $^{-1}$)*	$\rho_G^{CR} \times 10^{-5}$ *(tr .cm $^{-2}$.s $^{-1}$)*	A_c^{220} / A_c^{222}	A_c^{222} *(Bq.m^{-3})*	A_c^{220} *(Bq.m^{-3})*
1	49.51086	80.5765	0.18500	11583.414	2142.951
2	50.48166	81.5473	0.41200	9503.360	3915.355
3	53.39407	86.40131	0.35008	10617.333	3716.964
4	55.33567	90.28451	0.12643	13811.361	1746.169
5	47.56926	77.6641	0.11237	12066.454	1355.945
6	61.16048	99.99252	0.08413	16039.308	1349.386
7	52.42327	85.43051	0.15315	12697.388	1944.560
8	43.68605	70.86849	0.27147	9355.467	2539.734
9	39.80285	65.04368	0.09356	10321.548	965.721
10	67.95608	110.6713	0.16834	16187.201	2725.008
11	57.27727	93.19692	0.19006	13328.321	2533.175
12	60.18968	98.05092	0.16166	14442.294	2334.784
13	58.24807	95.13852	0.10370	14925.335	1547.778
14	57.27727	93.19692	0.19006	13328.321	2533.175
15	51.45246	83.4889	0.26395	11100.374	2929.958
16	40.77365	66.01448	0.33224	8241.493	2738.125
17	40.77365	66.01448	0.33224	8241.493	2738.125
18	52.42327	85.43051	0.15315	12697.388	1944.560
19	49.51086	80.5765	0.18500	11583.414	2142.951
20	38.83205	63.10208	0.22364	8724.534	1951.119
21	21.35763	34.94884	0.06710	5717.761	383.665
22	30.09484	48.54006	0.47306	5382.613	2546.293
23	23.29923	37.86125	0.22364	5234.720	1170.671
24	22.32843	35.91964	0.59270	3637.706	2156.069
25	32.03644	52.42327	0.06710	8576.641	575.498
26	23.29923	37.86125	0.22364	5234.720	1170.671
27	62.13128	100.9633	0.22364	13959.254	3121.790
28	38.83205	63.10208	0.22364	8724.534	1951.119
29	20.38683	33.00724	0.33224	4120.747	1369.063
30	38.83205	63.10208	0.22364	8724.534	1951.119



Figure(3): The Radon concentration of the soil samples from the surface and depth 1m in Hayy-Alabas in Basrah governorate.

Table (4): The radon and thoron concentration in the soil samples from the depth 1m in Hayy-Alabas in Basrah governorate.

Station Number	$\rho_G^{LR} \times 10^{-5}$ *(tr .cm $^{-2}$.s $^{-1}$)*	$\rho_G^{CR} \times 10^{-5}$ *(tr .cm $^{-2}$.s $^{-1}$)*	A_c^{220} / A_c^{222}	A_c^{222} *(Bq.m^{-3})*	A_c^{220} *(Bq.m^{-3})*
1	43.68605	70.86849	0.27147	9355.467	2539.734
2	41.74445	67.95608	0.17815	9838.507	1752.728
3	42.71525	69.89769	0.06710	11435.521	767.330
4	55.33567	90.28451	0.12643	13811.361	1746.169
5	39.80285	65.04368	0.09356	10321.548	965.721
6	56.30647	92.22612	0.04937	15408.375	760.771
7	39.80285	65.04368	0.09356	10321.548	965.721
8	38.83205	63.10208	0.22364	8724.534	1951.119
9	42.71525	69.89769	0.06710	11435.521	767.330
10	58.24807	95.13852	0.10370	14925.335	1547.778
11	58.24807	94.16772	0.38278	11248.266	4305.579
12	59.21887	96.10932	0.25847	12845.280	3320.181
13	60.18968	98.05092	0.16166	14442.294	2334.784
14	61.16048	99.02172	0.33224	12362.240	4107.188
15	57.27727	92.22612	0.54822	9651.252	5290.976
16	31.06564	50.48166	0.22364	6979.627	1560.895
17	32.03644	52.42327	0.06710	8576.641	575.498
18	41.74445	67.95608	0.17815	9838.507	1752.728
19	39.80285	65.04368	0.09356	10321.548	965.721
20	29.12404	47.56926	0.10370	7462.667	773.889
21	24.27003	39.80285	0.02712	6831.734	185.274
22	30.09484	48.54006	0.47306	5382.613	2546.293
23	23.29923	37.86125	0.22364	5234.720	1170.671
24	24.27003	39.80285	0.02712	6831.734	185.274
25	31.06564	50.48166	0.22364	6979.627	1560.895
26	24.27003	39.80285	0.02712	6831.734	185.274
27	63.10208	102.9049	0.13733	15556.268	2136.393
28	39.80285	65.04368	0.09356	10321.548	965.721
29	21.35763	34.94884	0.06710	5717.761	383.665
30	38.83205	63.10208	0.22364	8724.534	1951.119



Figure(4): The Thoron concentration of the soil samples from the surface and depth 1m in Hayy-Alabas in Basrah governorate.

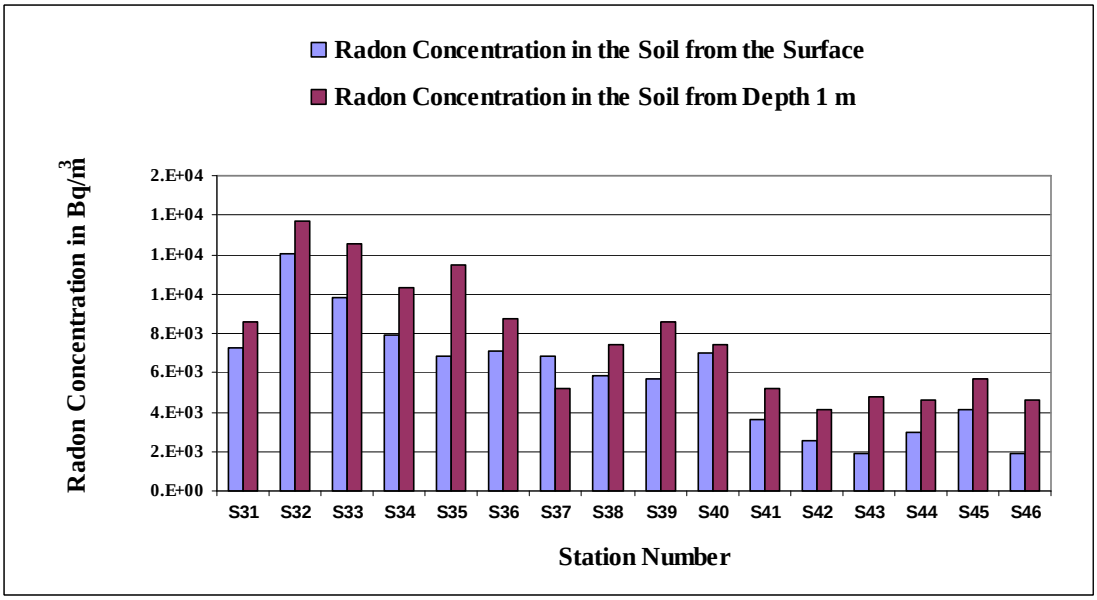
Table (5): The radon and thoron concentration in the soil samples from the surface in Hayy-Aljameeat in Basrah governorate

Station Number	$\rho_G^{LR} \times 10^{-5}$ *(tr .cm $^{-2}$.s $^{-1}$)*	$\rho_G^{CR} \times 10^{-5}$ *(tr .cm $^{-2}$.s $^{-1}$)*	A_c^{220} / A_c^{222}	A_c^{222} *(Bq.m^{-3})*	A_c^{220} *(Bq.m^{-3})*
31	44.65686	71.83929	0.59270	7275.413	4312.138
32	47.56926	77.6641	0.11237	12066.454	1355.945
33	41.74445	67.95608	0.17815	9838.507	1752.728
34	49.51086	79.6057	0.61985	7906.346	4900.753
35	24.27003	39.80285	0.02712	6831.734	185.274
36	37.86125	61.16048	0.41200	7127.520	2936.516
37	24.27003	39.80285	0.02712	6831.734	185.274
38	28.15324	45.62766	0.29993	5865.653	1759.286
39	21.35763	34.94884	0.06710	5717.761	383.665
40	31.06564	50.48166	0.22364	6979.627	1560.895
41	22.32843	35.91964	0.59270	3637.706	2156.069
42	19.41602	31.06564	0.93293	2523.733	2354.460
43	14.56202	23.29923	0.93293	1892.800	1765.845
44	17.47442	28.15324	0.52131	3006.773	1567.454
45	20.38683	33.00724	0.33224	4120.747	1369.063
46	14.56202	23.29923	0.93293	1892.800	1765.845

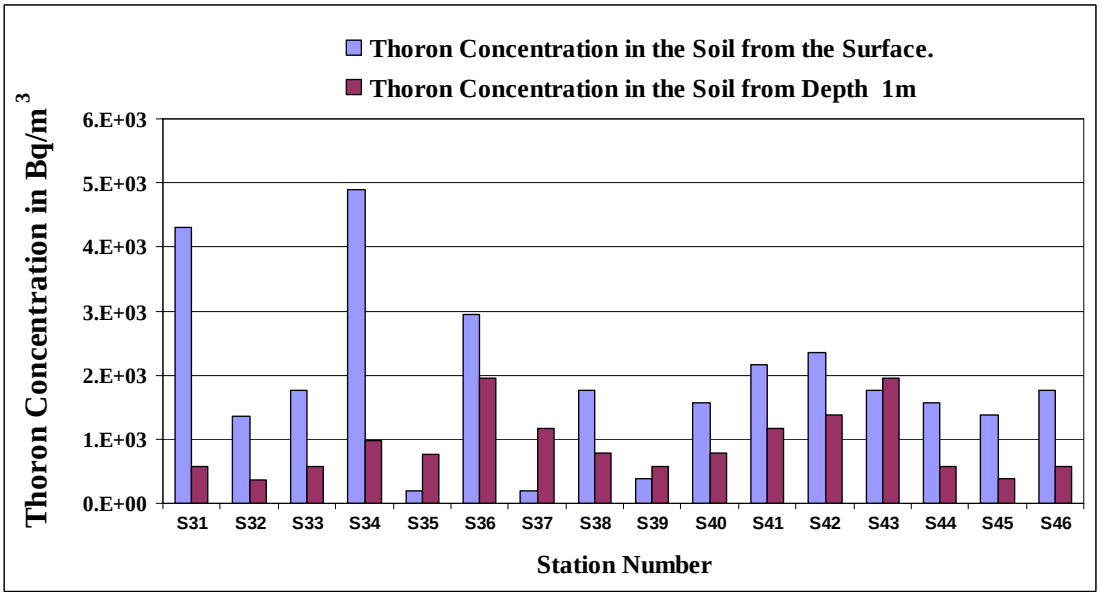
Table (6): The radon and thoron concentration in the soil samples from the depth 1m in Hayy- Aljameeat in Basrah governorate.

Station Number	$\rho_G^{LR} \times 10^{-5}$ *(tr .cm $^{-2}$.s $^{-1}$)*	$\rho_G^{CR} \times 10^{-5}$ *(tr .cm $^{-2}$.s $^{-1}$)*	A_c^{220} / A_c^{222}	A_c^{222} *(Bq.m^{-3})*	A_c^{220} *(Bq.m^{-3})*
31	32.03644	52.42327	0.06710	8576.641	575.498
32	48.54006	79.6057	0.02712	13663.468	370.548
33	45.62766	74.75169	0.04534	12549.495	568.939
34	39.80285	65.04368	0.09356	10321.548	965.721
35	42.71525	69.89769	0.06710	11435.521	767.330
36	38.83205	63.10208	0.22364	8724.534	1951.119
37	23.29923	37.86125	0.22364	5234.720	1170.671
38	29.12404	47.56926	0.10370	7462.667	773.889
39	32.03644	52.42327	0.06710	8576.641	575.498
40	29.12404	47.56926	0.10370	7462.667	773.889
41	23.29923	37.86125	0.22364	5234.720	1170.671
42	20.38683	33.00724	0.33224	4120.747	1369.063
43	25.24083	40.77365	0.41200	4751.680	1957.678
44	18.44522	30.09484	0.12643	4603.787	582.056
45	21.35763	34.94884	0.06710	5717.761	383.665
46	18.44522	30.09484	0.12643	4603.787	582.056

From table(5) and table(6) we noted the levels of radon concentrations for hayy-Aljameet stations are in the natural limits, but the soil from the depth 1m for stations number 32,33,34 and 35 have a high levels in compare with another stations. The data in table(5) and table(6) is shown in figure(5) and figure(6).



Figure(5): The Radon concentration of the soil samples from the surface and depth 1m in Hayy-Aljameeat in Basra governorate.



Figure(6): The thoron concentration of the soil samples from the surface and depth 1m in Hayy-Aljameeat in Basrah governorate.

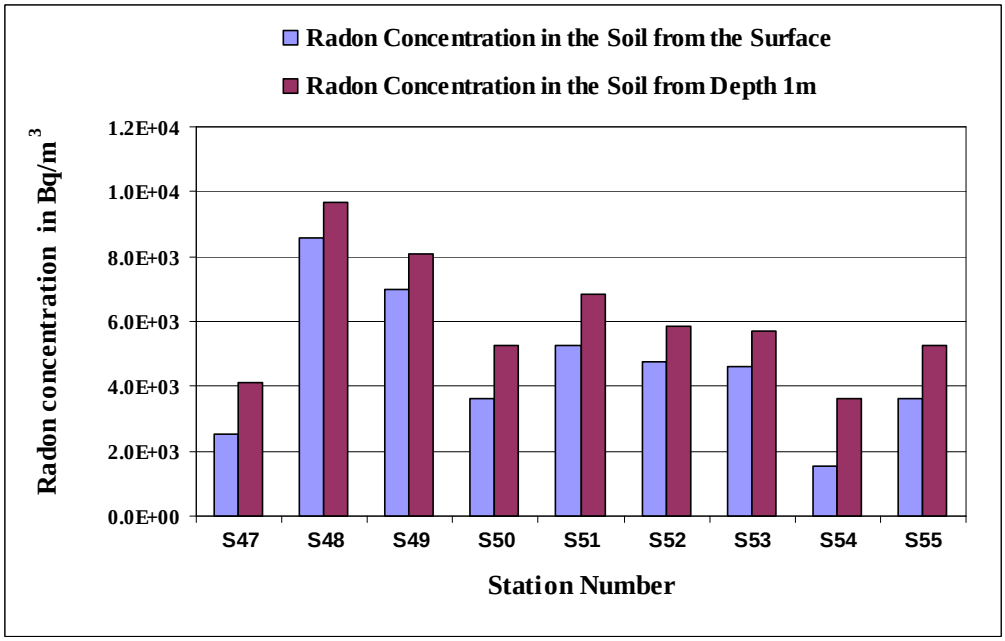
Table (7): The radon and thoron concentration in the soil samples from the surface in Al Muaficia in Basrah governorate .

Station Number	$\rho_G^{LR} \times 10^{-5}$ *(tr .cm $^{-2}$.s $^{-1}$)*	$\rho_G^{CR} \times 10^{-5}$ *(tr .cm $^{-2}$.s $^{-1}$)*	A_c^{220} / A_c^{222}	A_c^{222} *(Bq.m^{-3})*	A_c^{220} *(Bq.m^{-3})*
47	19.41602	31.06564	0.93293	2523.733	2354.460
48	32.03644	52.42327	0.06710	8576.641	575.498
49	31.06564	50.48166	0.22364	6979.627	1560.895
50	22.32843	35.91964	0.59270	3637.706	2156.069
51	23.29923	37.86125	0.22364	5234.720	1170.671
52	25.24083	40.77365	0.41200	4751.680	1957.678
53	18.44522	30.09484	0.12643	4603.787	582.056
54	23.29923	36.89045	2.52205	1557.652	3928.473
55	22.32843	35.91964	0.59270	3637.706	2156.069

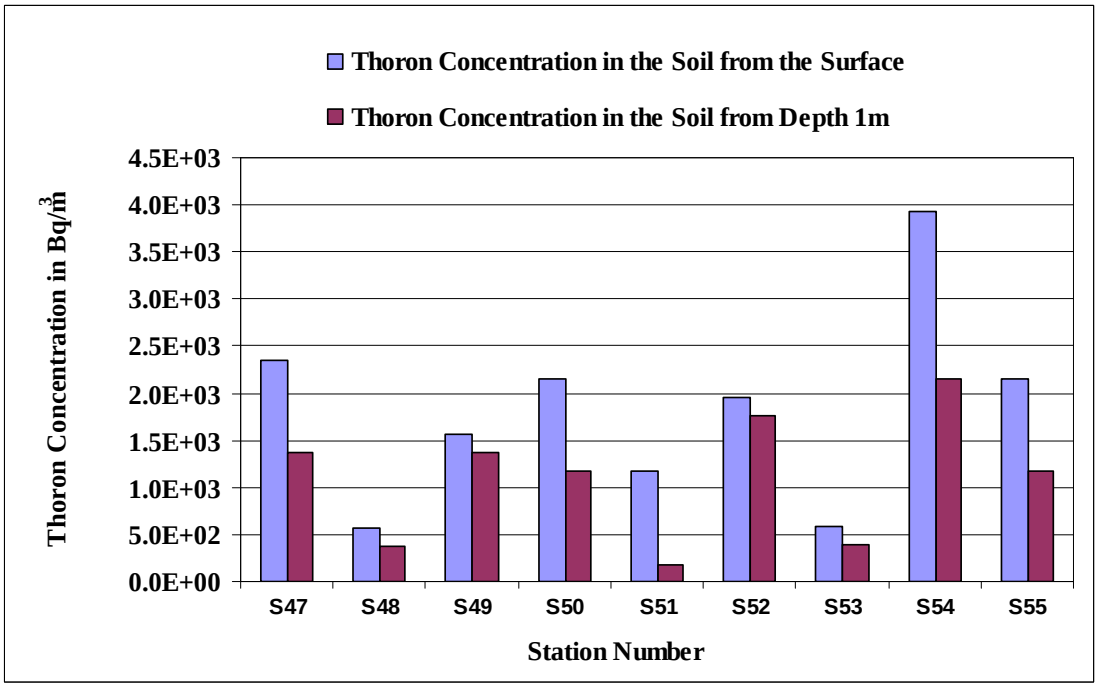
Table (8): The radon and thoron concentration in the soil samples from the depth 1m in Al Muaficia in Basrah governorate .

Station Number	$\rho_G^{LR} \times 10^{-5}$ *(tr .cm $^{-2}$.s $^{-1}$)*	$\rho_G^{CR} \times 10^{-5}$ *(tr .cm $^{-2}$.s $^{-1}$)*	A_c^{220} / A_c^{222}	A_c^{222} *(Bq.m^{-3})*	A_c^{220} *(Bq.m^{-3})*
47	20.38683	33.00724	0.33224	4120.747	1369.063
48	34.94884	57.27727	0.03891	9690.615	377.106
49	33.97804	55.33567	0.16834	8093.601	1362.504
50	23.29923	37.86125	0.22364	5234.720	1170.671
51	24.27003	39.80285	0.02712	6831.734	185.274
52	28.15324	45.62766	0.29993	5865.653	1759.286
53	21.35763	34.94884	0.06710	5717.761	383.665
54	22.32843	35.91964	0.59270	3637.706	2156.069
55	23.29923	37.86125	0.22364	5234.720	1170.671

From table(7) and table(8) we noticed the levels of radon concentrations for all stations of Almwaficia are in the natural limits. The data in table(7) and table(8) is shown in figure(7) and figure(8).



Figure(7): The Radon concentration of the soil samples from the surface and depth 1m in Almuaficia in Basrah governorate.



Figure(8): The thoron concentration of the soil samples from the surface and depth 1m in Almuaficia in Basrah governorate

From all above tables we noticed the ratio (A_c^{220} / A_c^{222}) <1 , this mean thoron concentration is smaller than radon concentration over all study area may be because of the short half life for thoron in comparison with radon and the long irradiation time(one month)[20]. The average value of the activity of thoron concentration A_c^{220} in the soil samples from the surface equal 2073.33 Bq.m^{-3}, 1893.75 Bq.m^{-3} and 1822.22 Bq.m^{-3} for Hayy-Alabas, Hayy-Aljameeat and Almuaficia respectively and the average value for the soil samples from the depth 1m equal 1666.66 Bq.m^{-3} , 906.25 Bq.m^{-3} and 1103.333 Bq.m^{-3} for Hayy-Alabas, Hayy-Aljameeat and Almuaficia respectively.

CONCLUSION

In this investigation, the activity of radon and thoron levels have been measured in the soil of the three districts in Basra governorate. In this study the maximum radon activity (16200 Bq.m^{-3})have been observed in Hayy-Alabas district, station number 10 for soil from the surface, while the minimum radon activity (1560 Bq.m^{-3}) has been observed in Almuaficia district, station number 54 for soil from the surface. The average value of the activity of thoron concentration A_c^{220} in the soil samples from the surface equal 2073.33 Bq.m^{-3}, 1893.75 Bq.m^{-3} and 1822.22 Bq.m^{-3} for Hayy-Alabas, Hayy-Aljameeat and Almuaficia respectively and the average value for the soil samples from the depth 1m equal 1666.66 Bq.m^{-3} , 906.25 Bq.m^{-3} and 1103.333 Bq.m^{-3} for Hayy-Alabas, Hayy-Aljameeat and Almuaficia respectively.

The high levels of radon concentrations which observed in the soil samples for any stations in this study are came may be from the high concentrations of uranium and thorium in this soil, the study of uranium concentrations of these soils are in progress. The high concentration of uranium and radium in the stations in Hayy-Alabas district are came from external pollutions because of the radon concentrations for the soil which got from the surface of almost stations of study is greater than for soil which got from the depth 1m.

The ratio (A_c^{220} / A_c^{222}) <1 , this mean thoron concentration is smaller than radon concentration over all study area may be because of the short half life for thoron in comparison with radon and the long irradiation time.

The data in this study is the first investigation and this study provided a basis for the radiation pollution and radon map in Iraq.

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