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The Measurements of Natural Radioactivity, (Radon and Gamma concentrations), around the old fertilizer factory in Basrah/Iraq

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ABSTRACT

Radon concentration, exhalation rate, annual effective dose, radium activity, thorium, uranium potassium and radium equivalent have been measured in the present investigation for soil in the area around the old fertilizer factory in southern of Basrah Governorate. The measurements based on CR39 track detector for passive method, RAD7 for active method and NaI(Tl) for gamma concentration measurements. Average values for radon concentration in soil were 112.04±10.76 Bq/m^3 using passive technique and 104.56±6.05 Bq/m^3 using RAD7. From the result of the passive technique, area and mass exhalation rates and the annual effective dose were calculated. Gamma ray spectroscopy for the soil samples were performed and found that the average concentrations of ^{226}Ra, ^{232}Th and ^{40}K were 50.89 Bq/kg, 21.74 Bq/kg and 640.4 Bq/kg respectively. Gamma ray hazard indices were calculated and found they are within the world average.

Keywords

Radon; CR39; RAD7; NaI(Tl); gamma concentration; effective dose

Academic Discipline And Sub-Disciplines

Physics

TYPE (METHOD/APPROACH)

Radon and Gamma measurements using SSNTD and NaI(Tl)

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1. INTRODUCTION

It is widely known that, high radon concentration and its daughters are dangerous to human health. Radon is an odourless, colourless and tasteless gas and it is the second cause of lung cancer after smoking. The assessment of radon in soil and building materials helps to understand and minimized such effects. Soil is the prime source of radium ($t_{1/2}$=1600y), parents of radon gas. The natural abundance of radon gas consists mainly two isotopes; ^{222}Rn $t_{1/2}$=3.82 d and ^{220}Rn $t_{1/2}$=56s. The concentration of radon is soil varies in different quantities according to geological structure of the place, because radon is chemically unreactive, it freely to moves between particles and rocks. In some cases radon trapped in certain places and creates area of highly concentration of radon gas, called radon prone area [1]. The radon exposure is considered mostly as internal exposure, because it is dynamic gas. Gamma radiation from natural radionuclides and cosmic rays constitute as external exposure to humans. The radionuclides of concern in terrestrial environment are mainly potassium ^{40}K, radium ^{226,228} Ra, uranium ^{238}U and ^{232}Th[2-5]. Natural radio activities is widely spread in the earth's environment and depends primarily on the geological and geographical condition, and appear at different level in the soil of each region of the world [UNSCEAR 2000].

In the present work, sealed can technique is used for radon measurements, together with NaI(Tl) for gamma ray measurement.

2. MATERIALS AND METHODS

2.1. RADON GAS MEASUREMENTS

A. PASSIVE RECHNIQUE

Fifty two soil samples were collected from different location in the selected study area shown in Figure 1. Sealed can, 30 cm x 7.5 cm, technique was used for passive measurements[6]. The cans, with CR39 detectors stuck on the bottom of the tope cover, have been stored for 3

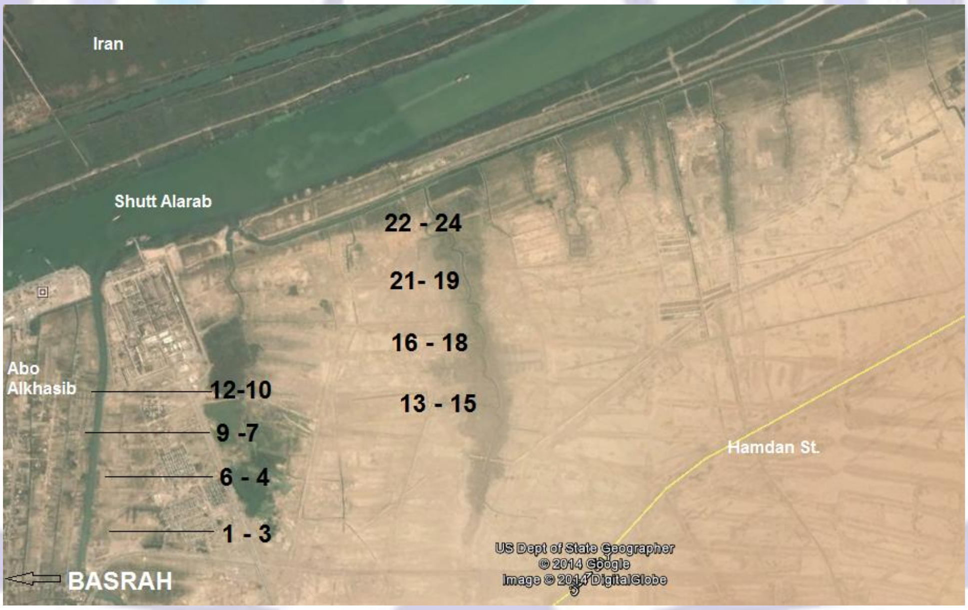

Figure 1 area of study around the fertilizer factory

months for irradiation process. The tracks were observed after etching and counted by using microscope with a magnification of 400x. The etching conditions were: 6.25N sodium hydroxide at 70^{0}C for 8 hours. The track density and radon gas activity was obtained through calibration factor of K=0.2857±0.01431 Tr cm^{-2} d^{-1} per Bq m^{-3} according to the relation [6]

Radongasconcentrationis givenby [7];

$$A_{Rn} = \frac{\rho}{tK} \quad (1)$$

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}. At the equilibrium state, final activity of radon exhalation from each sample inside the can is given by [8-9]

$$E_{ex} = \frac{ATV\lambda/S}{T+\lambda^{-1}(e^{-\lambda T}-1)} \quad (2)$$

where E_x is exhalation rate in unit Bq m^{-2}.h^{-1}, A is radon concentration measured by CR39 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.

The radon exhalation rate in terms of mass is calculated from the relation;

$$E_M = \frac{ATV\lambda / M}{T+\lambda^{-1}(e^{-\lambda T}-1)} \quad (3)$$

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

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

$$E_p\left(\frac{mSv}{y}\right) = 2.21 \times 10^{-3}\, n\, F\, A_{Rn} \quad (4)$$

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[10]

B. THE ACTIVE TECHNIQUE

A radon gas analyser RAD7 instrument (DURRIDGE Company USA) was used to measure radon emanation from soil samples. The soil sample was loaded into 1.32 $l$used as an emanation cylindrical container. The high of the container 30 cm, to insure radon detection only, was connected online with RAD7 instrument. To reduce the influence of humidity on the radon detection and measurements, the system purged for 10-15 minutes to reduce the humidity to less than 10% [11]. The alpha RAD7 detector was operated in grab mode for 2days protocol, with cycle 1h and recycle 48.

2.2. GAMMA RAY SPECTROSCOPY

The gamma ray spectroscopy used in this work consist of highly shield and well calibrated 3”x3” NaI(Tl) detector enclosed in 5 cm thickness lead shielding for background reduction. The system consist of computer based multichannel analyser for date acquisition and software to controls these data acquisitions, supplied by manufacturer. The spectrometer was calibrated with ^{57}Co, ^{60}Co and ^{137}Cs slandered sources. The background was counted for, by counting with empty Merelani beaker for 9000 s.

After measuring the count rate (area under the peak) for each peak and subtract the background, the activity concentration for each environmental isotope calculated from[12]

$$A = \frac{Net\ count}{\varepsilon \times I_\gamma \times M \times t} \quad (5)$$

where ε is absolute gamma peak efficiency of the detector at this particular gamma-ray energy, I_γ decay intensity for the specific energy peak (including the decay branching ratio information), M the mass of the sample in kg and t is the counting time of the measurement in second.

Radium equivalent activity (*Ra_{eq}*) is used to assess the hazards associated with materials that contain ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}, which is, determined by assuming that 370 Bq kg^{-1} of ^{226}Ra or 260 Bq kg^{-1} of ^{232}Th or 4810 Bq kg^{-1} of ^{40}K produce the same γ dose rate. The *Ra_{eq}*of a sample in (Bq kg^{-1}) can be achieved using the following relation [13];

$$Ra_{eq} = (A_{Ra}) + (A_{Th} \times 1.43) + (A_K \times 0.077) \quad (6)$$

The published maximal permissible *Ra_{eq}*is 370 Bq kg^{-1} [14].

The external and internal hazard indices are an evaluation of the hazard of the natural gamma radiation. The prime objective of this index is to limit the radiation dose to the admissible permissible dose equivalent limit around 1mSvy^{-1}. In order to evaluate this index, one can use the fallowing relations[13]

$$H_{ex} = (A_{Ra}/370) + (A_{Th}/259) + (A_k/4810) \quad (7)$$

$$H_{in} = (A_{Ra}/185) + (A_{Th}/259) + (A_k/4810) \quad (8)$$

This model takes into consideration that the external hazard which is caused by gamma-rays corresponds to a maximum radium-equivalent activity of 370 Bq/kg for the soil.

In order to estimate the annual effective dose rate in air, the conversion coefficient from absorbed dose in air to effective dose received by an adult must be considered. This value is published in UNSCEAR 2000 and UNSCEAR 1993, to be 0.7 SvGy^{-1} for environmental exposure to gamma rays of moderate energy. The outdoor occupancy factor is about 0.2 . The annual effective dose equivalent is given by the following equation [13];

$$AEDE_{oo}(mSv/y) = D(nGy/h \times 8760(h/y) \times 0.2 \times 0.7(Sv/Gy) \times 10^{-6} \quad (9)$$

$$\text{where} D\left(\frac{nGy}{h}\right) = 0.0417A_K + 0.462A_{Ra} + 0.606A_{Th} \quad (10)$$

The world average annual effective dose equivalent (AEDE) from outdoor or indoor terrestrial gamma radiation only is 0.560 mSv/year [UNSCEAR].

3. RESULTS AND DISCUSSION

3.1. RADON RESULTS

The activity concentration of radon emanated from soil and river sediment are presented in Table 1, for both passive and active methods. The range of radon concentration obtained by passive and active techniques varies from 29.35±4.39

Bq/m^3 to 242.15±20.38 Bq/m^3 and 22.0 ±1.2 Bq/m^3 to 231.0±14.3 Bq/m^3 respectively. The arithmetic average values for both techniques are 112 Bq/m^3 for passive and 105 Bq/m^3 for active. A correlation between the two techniques is presented in Figure 2, where the correlation is very strong, correlation factor R=100%. Radon concentration from animal manure is 63.6±7.1 Bq/m^3 and 29.4±4.4Bq/m^3, which is relatively low concentration. The radon concentration in Shellfish sample found to be 62.4±7.0 Bq/m^3, which is also relatively low. In general, all the radon concentrations were low in compare with surrounding areas. Table 2 contains radon area exhalation rate, mass exhalation rate and the annual effective dose related to radon gas inhalation by individuals. The results show that, the range of area exhalation rate varies from 0.0590 Bq/m^2. h to 0.4864 Bq/m^2.h , the range of mass exhalation rate varies from 0.0012 Bq/kg . h to 0.0098 Bq/kg , the outdoor annual effective dose in units mSv/y varies from 0.0450 to 0.0055 and the indoor effective dose varies from 0.0218 to 0.1799.

Table 1. Radon concentration measured by passive and active method. Latters: A is soil from surface, C is soil taken fifty centimetres from surface, D is animal manure and E is Shellfish free.

Sample ID	Radon by passive method in Bq/m^3	Radon by active method in Bq/m^3
1A	89.3±9.1	81.0±5.0
1C	95.4±9.6	86.0±8.0
2A	115.0±11.0	99.0±4.7
2C	123.5±11.7	113.0±10.0
3A	85.6±8.8	78.0±7.0
3C	73.4±7.9	65.0±7.0
4A	102.7±10.1	94.0±3.5
AC	100.3±9.9	91.0±6.0
5A	61.1±6.9	58.0±5.8
5C	95.4±9.6	84.0±4.6
6A	79.5±8.3	62.0±8.0
6C	83.2±8.6	85.0±9.0
7A	170.0±15.1	158.0±8.0
7C	106.4±10.4	93.0±6.0
8A	89.3±9.1	81.0±3.5
8C	104.0±10.2	97.0±4.4
9A	107.6±10.5	98.0±4.4
9C	242.2±20.4	231.0±13.3
10A	132.1±12.3	121.0±11.7
10C	33.0±4.7	22.0±4.7
11A	134.5±12.5	128.0±10.3
11C	115.0±11.0	108.0±7.2
12A	229.9±19.5	221.0±14.3
12C	108.8±10.6	101.0±5.1
13A	72.2±7.8	64.0±3.2
13C	145.5±13.3	135.0±11.1
14A	104.0±10.2	96.0±4.4
14C	86.8±8.9	75.0±3.4
15A	188.3±16.4	178.0±12.1
15C	138.2±12.8	130.0±9.6
16A	145.5±13.3	136.0±8.4

16C	107.6±10.5	94.0±3.3
17A	216.5±18.5	208.0±13.1
17C	101.5±10.0	94.0±3.1
18A	59.9±6.8	52.0±2.8
18C	79.5±8.3	71.0±3.5
18D	30.6±4.5	27.0±6.0
19A	88.1±9.0	81.0±2.9
19C	59.9±6.8	51.0±1.8
20A	119.9±11.4	112.0±2.4
20C	126.0±11.8	120.0±3.4
21A	200.6±17.3	194.0±3.2
21C	110.1±10.7	102.0±2.7
22A	69.7±7.6	59.0±1.3
22C	101.5±10.0	113.0±2.8
23A	97.8±9.7	101.0±4.8
23C	137.0±12.7	135.0±5.0
23D	63.6±7.1	71.0±4.3
24A	119.9±11.4	135.0±6.7
24C	239.7±20.2	231.0±10.1
24D	29.4±4.4	32.0±3.1
24E	62.4±7.0	41.0±1.2
Max.	242.15=±20.38	231±14.3
Min.	29.35±4.39	22±1.2
Aver.	112.04±10.76	104.56±6.05

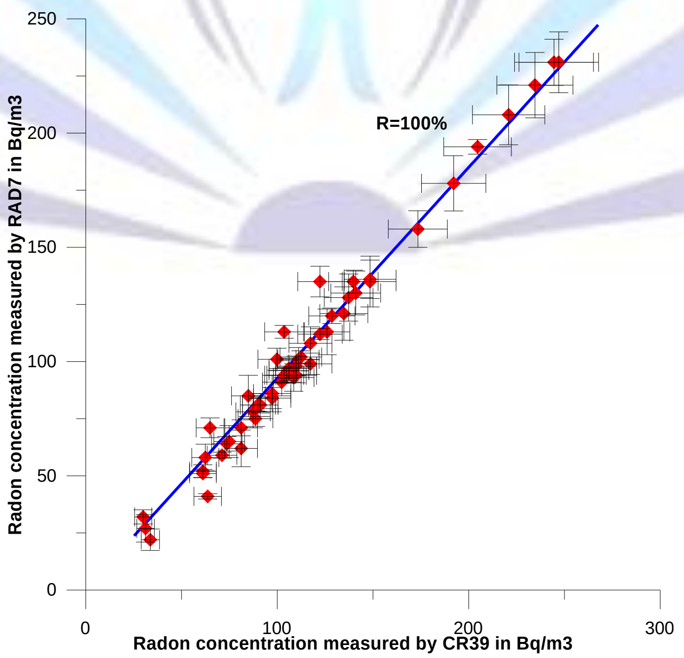

Fig. 2: The correlation between active and passive methods

Table 2. Radon area exhalation rate, radon mass exhalation rate and the effective dose related to radon exposed for out doo and indoor.

Sample ID	EX_A in $Bq/m^2 . h$	EX_M Bq/kq .h	E_p out mSv/y	E_p in mSv/y
1A	0.1793	0.0036	0.0166	0.0663
1C	0.1916	0.0038	0.0177	0.0709
2A	0.2309	0.0046	0.0213	0.0854
2C	0.2481	0.0050	0.0229	0.0917
3A	0.1720	0.0035	0.0159	0.0636
3C	0.1474	0.0030	0.0136	0.0545
4A	0.2064	0.0041	0.0191	0.0763
AC	0.2014	0.0040	0.0186	0.0745
5A	0.1228	0.0025	0.0114	0.0454
5C	0.1916	0.0038	0.0177	0.0709
6A	0.1597	0.0032	0.0148	0.0590
6C	0.1671	0.0034	0.0154	0.0618
7A	0.3415	0.0069	0.0316	0.1263
7C	0.2137	0.0043	0.0198	0.0790
8A	0.1793	0.0036	0.0166	0.0663
8C	0.2088	0.0042	0.0193	0.0772
9A	0.2162	0.0043	0.0200	0.0799
9C	0.4864	0.0098	0.0450	0.1799
10A	0.2653	0.0053	0.0245	0.0981
10C	0.0663	0.0013	0.0061	0.0245
11A	0.2702	0.0054	0.0250	0.0999
11C	0.2309	0.0046	0.0213	0.0854
12A	0.4618	0.0093	0.0427	0.1708
12C	0.2186	0.0044	0.0202	0.0808
13A	0.1449	0.0029	0.0134	0.0536
13C	0.2923	0.0059	0.0270	0.1081
14A	0.2088	0.0042	0.0193	0.0772
14C	0.1744	0.0035	0.0161	0.0645
15A	0.3783	0.0076	0.0350	0.1399
15C	0.2776	0.0056	0.0257	0.1026
16A	0.2923	0.0059	0.0270	0.1081
16C	0.2162	0.0043	0.0200	0.0799
17A	0.4348	0.0087	0.0402	0.1608
17C	0.2039	0.0041	0.0188	0.0754
18A	0.1204	0.0024	0.0111	0.0445
18C	0.1597	0.0032	0.0148	0.0590
18D	0.0614	0.0012	0.0057	0.0227

19A	0.1769	0.0036	0.0164	0.0654
19C	0.1204	0.0024	0.0111	0.0445
20A	0.2408	0.0048	0.0223	0.0890
20C	0.2530	0.0051	0.0234	0.0936
21A	0.4029	0.0081	0.0372	0.1490
21C	0.2211	0.0044	0.0204	0.0818
22A	0.1400	0.0028	0.0129	0.0518
22C	0.2039	0.0041	0.0188	0.0754
23A	0.1965	0.0039	0.0182	0.0727
23C	0.2751	0.0055	0.0254	0.1017
23D	0.1277	0.0026	0.0118	0.0472
24A	0.2408	0.0048	0.0223	0.0890
24C	0.4815	0.0097	0.0445	0.1780
24D	0.0590	0.0012	0.0055	0.0218
24E	0.1253	0.0025	0.0116	0.0463
Max.	0.4864	0.0098	0.0450	0.1799
Min.	0.0590	0.0012	0.0055	0.0218
Aver.	0.2251	0.0045	0.0208	0.0832

Radon is well known to be a good contributor toward the natural absorption radiation dose, and the total effective dose of natural radioactivity is 2.5 – 3 mSv/y and 56% from this dose is related to radon, which approximately equal to 1.4 mSv/y. The maximum value of the effective dose from the studied samples was found to be 0.1799 mSv/y, which is far smaller than the warning level. The recommendation of the ICRP 2011[15] is that, the action level of indoor radon should be set within a range of 3 – 10 mSv/y.

3.2. GAMMA SPECTROSCOPY RESULTS

Radionuclide activity concentration in soil samples were measured and listed in Table 3. The results contain specific activity concentration as well as the uncertainty of ^{226}Ra and ^{232}Th and ^{40}K. The range of ^{226}Ra in all the studied samples varies from 21.550±1.400 Bq/kg to 82.89±5.69 Bq/kg with mean value of 50.888±3.436 Bq/kg, which is closed to the allowed safe limit 50 Bq/kg [16].

Table 3.The values of radium, thorium and potassium contents in soil sample taken from the area of study.

Sample ID	Ra-226Bq/kg	Th-232Bq/kg	K-40Bq/kg
1A	30.6±2.0	26.2±1.8	623.4±2.7
1C	21.8±1.5	17.5±1.2	606.7±2.7
2A	33.7±2.2	12.9±0.9	438.8±1.9
2C	29.3±2.1	17.2±1.2	739.3±3.2
3A	25.6±1.6	11.8±0.8	545.8±2.4
3C	22.1±1.5	15.0±1.0	703.9±3.1
4A	30.4±1.5	19.5±1.4	770.2±3.4
AC	37.9±2.4	10.4±0.7	406.7±1.8
5A	32.4±2.1	19.1±1.4	792.4±3.5
5C	40.2±2.7	22.0±1.7	767.8±3.4
6A	36.9±2.4	17.0±1.2	745.8±3.3
6C	60.6±4.1	24.1±1.7	750.4±3.3
7A	44.7±3.0	15.8±1.1	682.0±3.0
7C	60.5±4.1	18.2±1.3	729.1±3.2

8A	56.0±3.7	23.6±1.7	731.3±3.2
8C	45.1±2.9	25.7±1.7	761.4±3.3
9A	65.1±4.5	39.5±2.8	629.0±2.8
9C	39.5±2.6	22.9±1.6	693.8±3.0
10A	45.1±3.0	14.7±0.9	470.7±2.1
10C	37.7±2.6	20.1±1.4	854.1±3.7
11A	39.1±2.7	19.5±1.3	690.7±3.0
11C	35.3±2.4	23.0±1.6	781.7±3.4
12A	68.1±4.5	16.2±1.0	632.7±2.8
12C	69.7±4.7	14.5±0.9	680.4±3.0
13A	57.3±3.9	10.5±0.7	469.4±2.1
13C	67.4±4.3	28.4±2.0	593.3±2.6
14A	49.2±3.2	19.1±1.3	648.4±2.8
14C	53.7±3.6	23.4±1.65	727.8±3.2
15A	60.8±4.1	27.4±1.4	677.4±3.0
15C	57.3±3.8	20.8±1.4	696.4±3.1
16A	55.7±3.9	24.5±1.7	754.9±3.3
16C	50.8±3.6	21.5±1.4	685.8±3.0
17A	63.0±4.3	21.8±1.5	682.8±3.0
17C	67.6±4.5	22.4±1.6	717.7±3.2
18A	75.0±5.2	31.4±2.3	644.0±2.8
18C	82.9±5.7	39.5±3.0	686.4±3.0
18D	21.6±1.4	12.2±0.8	334.6±1.5
19A	66.0±4.6	24.7±1.8	634.6±2.8
19C	63.7±4.4	18.7±1.5	627.7±2.8
20A	79.8±5.3	29.5±2.0	670.5±2.9
20C	82.6±5.5	32.9±2.3	668.6±2.9
21A	69.4±4.9	32.7±2.5	1111.2±4.9
21C	67.1±4.6	30.7±2.5	808.4±3.5
22A	44.3±3.1	19.7±1.6	417.4±1.8
22C	50.4±3.5	23.2±1.8	433.7±1.9
23A	52.4±3.7	28.7±2.1	483.2±2.0
23C	55.8±3.9	30.0±2.3	476.5±2.0
23D	48.3±3.5	20.2±1.5	466.3±2.0
24A	68.2±4.7	22.5±1.6	566.8±2.5
24C	55.1±3.8	20.3±1.5	572.4±2.5
24D	25.6±1.8	7.4±0.6	340.6±1.5
24E	45.8±3.3	16.9±1.2	323.8±1.4
Max.	82.89±5.69	39.52±2.95	1111.22±4.87
Min.	21.55±1.40	7.41±0.55	323.75±1.42
Aver.	50.89±3.44	21.74±1.55	640.43±2.80

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The specific concentration of ^{232}Th has a range between 7.410±0.550 Bq/kg to 39.520±2.950 Bq/kg with the mean value of 21.741 Bq/kg, which is less than 50 Bq/kg (UNSEAR prediction) for safe area. The specific concentration of ^{40}K ranges from 323.750±1.420 Bq/kg to 1111.220±4.870 Bq/kg with arithmetic mean value equal to 640.434±2.804 Bq/kg, which is more than the world average value of 500 Bq/kg[16]

Table 4 presented the calculated gamma indies using equations (6-10), the radium equivalent activity Ra_{eq} has a range from 62.37 Bq/kg to 201.63 Bq/kg and average of 130.96 Bq/kg, which is less than the UNSCEAR, adopted limit 370 Bq/kg. The values of external and internal hazard are less unity in all samples, as recommended. The average values for outdoor and indoor effective dose are 0.077 mSv/y, 0.370 mSv/y and this also less than 0.56 mSv/y recommended by UNSCEAR. Figure 3, shows the correlation between ^{226}Ra concentrations measured by gamma ray spectroscopy and ^{222}Rn measured by passive method. The correlation looks positive and strong, correlation factor R=0.92%.

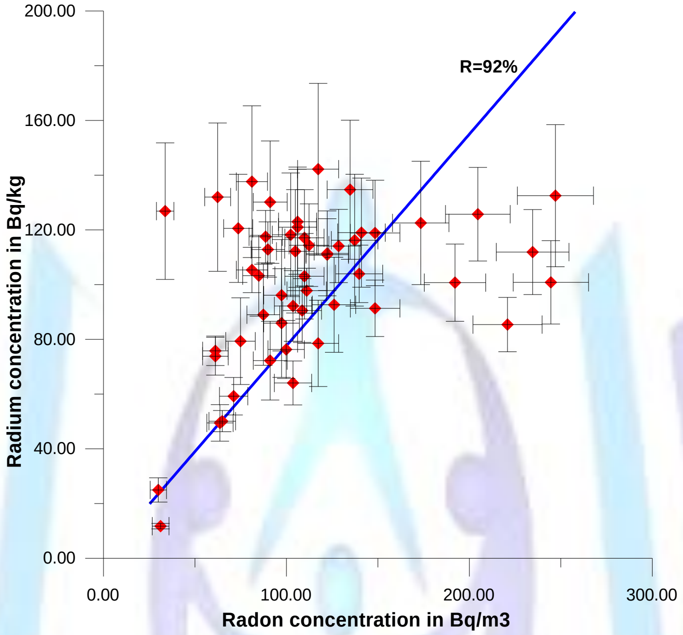

Fig.3 Correlation between radon and radium measured by different methods.

Table 4: The equivalent radium (R_{eq}), external and internal hazard and the annual effective dose for indoor and outdoor in soil samples.

Sample ID	Ra_{eq} Bq/kg	H_{ex}	H_{in}	D_{out}	$AEDE_{out}$ mSv/y	$AEDE_{in}$ mSv/y
1A	116.0	0.313	0.396	56.6	0.069	0.333
1C	93.6	0.253	0.312	46.4	0.057	0.273
2A	85.8	0.232	0.323	41.3	0.051	0.243
2C	110.8	0.299	0.378	54.9	0.067	0.323
3A	84.6	0.228	0.298	41.7	0.051	0.245
3C	97.8	0.264	0.324	48.9	0.060	0.288
4A	117.5	0.317	0.399	58.2	0.071	0.343
AC	84.1	0.227	0.330	40.2	0.049	0.236
5A	120.7	0.326	0.413	59.8	0.073	0.352
5C	130.7	0.353	0.461	63.9	0.078	0.376
6A	118.7	0.321	0.420	58.4	0.072	0.344
6C	152.9	0.413	0.577	73.4	0.090	0.432
7A	119.8	0.324	0.444	58.2	0.071	0.343
7C	142.7	0.385	0.549	68.5	0.084	0.403
8A	146.0	0.394	0.546	70.2	0.086	0.414

8C	140.5	0.379	0.501	68.2	0.084	0.402
9A	170.0	0.459	0.635	80.4	0.099	0.473
9C	125.6	0.339	0.446	61.1	0.075	0.360
10A	102.3	0.276	0.398	48.7	0.060	0.287
10C	132.2	0.357	0.459	65.3	0.080	0.384
11A	120.1	0.325	0.430	58.6	0.072	0.345
11C	128.4	0.347	0.442	63.2	0.077	0.372
12A	139.9	0.378	0.562	66.4	0.081	0.391
12C	142.7	0.386	0.574	67.9	0.083	0.400
13A	108.5	0.293	0.448	51.1	0.063	0.301
13C	153.7	0.415	0.597	72.5	0.089	0.427
14A	126.4	0.341	0.474	60.9	0.075	0.358
14C	143.2	0.387	0.532	69.0	0.085	0.406
15A	152.1	0.411	0.575	72.5	0.089	0.427
15C	140.7	0.380	0.535	67.5	0.083	0.397
16A	148.9	0.402	0.552	71.7	0.088	0.422
16C	134.3	0.363	0.500	64.7	0.079	0.381
17A	146.7	0.396	0.566	70.0	0.086	0.412
17C	154.9	0.418	0.601	73.8	0.091	0.435
18A	169.5	0.458	0.661	79.9	0.098	0.470
18C	192.3	0.519	0.743	90.4	0.111	0.532
18D	64.7	0.175	0.233	31.3	0.038	0.184
19A	150.2	0.406	0.584	71.2	0.087	0.419
19C	138.8	0.375	0.547	66.0	0.081	0.388
20A	173.5	0.469	0.684	81.7	0.100	0.481
20C	181.2	0.490	0.713	85.2	0.104	0.501
21A	201.6	0.545	0.732	97.9	0.120	0.576
21C	173.1	0.468	0.649	82.9	0.102	0.488
22A	104.7	0.283	0.402	49.5	0.061	0.291
22C	116.9	0.316	0.452	55.1	0.068	0.324
23A	130.6	0.353	0.494	61.6	0.076	0.363
23C	135.4	0.366	0.517	63.7	0.078	0.375
23D	113.0	0.305	0.436	53.6	0.066	0.315
24A	144.1	0.389	0.574	67.9	0.083	0.399
24C	128.1	0.346	0.495	61.0	0.075	0.359
24D	62.4	0.168	0.238	30.1	0.037	0.177
24E	94.8	0.256	0.380	44.3	0.054	0.261
Max.	201.6	0.545	0.743	97.91	0.120	0.576
Min.	62.37	0.168	0.233	30.11	0.037	0.177
Aver.	130.9	0.354	0.491	62.87	0.077	0.370

To investigate the correlation between the radioactive isotopes exists in the soil sample, we introduced drawing shown in Figures 4. In the figure on the left a graph between ^{226}Ra and ^{232}Th concentrations which shows a positive with intermediate correlation R=64. However, the correlation between these isotopes is not necessarily, because their concentrations depend on the geological structure of the area which is random. The second figure, on the right, presents a graph between ^{226}Ra and ^{40}K , which is show a week correlation R= 22%.

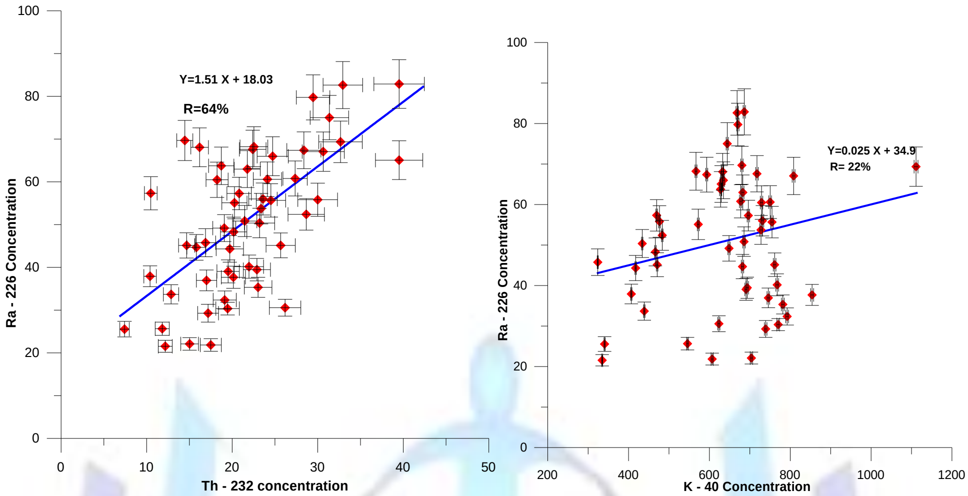

Fig. 4: The correlation between ^{226}Ra with ^{232}Th and ^{40}K.

4. CONCLUSION

- The measurements indicate normal level of radon exhalation from soil samples in the studied area. The average value of radon concentration, area and mass exhalation rates are found to be significantly lower than the current results of the world wide measurements of radon concentration and exhalation rate. This range is considered within the safe limits of international radiation committees.
- The investigation results clearly show that the area is safe as far as the health hazard of radon is concerned.
- The positive and strong correlations between active and passive measurements of radon concentrations in soil samples gives us indications that, it is possible to depend on the electronics instrument RAD7 in the investigation of radon concentration in soil (faster and precise).
- A strong correlation between radium and radon concentrations was found
- Week correlation between radium and thorium and potassium was found
- The results of radon and gamma concentrations reveal that the area is safe for human activities as far as the effect of radon and radium concerned.

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