Journal of Radiation and Nuclear Applications
An International Journal

http://dx.doi.org/10.18576/jrna/020102

Measurement of Radium Concentration and Radon Exhalation Rates of Soil Samples Collected From Selected Area of Basrah Governorate, Iraq Using Plastic Track Detectors

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Received: 10 Jul. 2016, Revised: 6 Nov. 2016, Accepted: 7 Dec. 2016.
Published online: 1 Jan. 2017.

Abstract: Radon emanated from soil at southern part of Basrah Governorate, Iraq, have been investigated. The measurements were carried out in location in the sites, using CR-39 Solid State Nuclear Track Detectors SSNTDs. The location of sample points were selected according to mesh map covered the surveyed area, 2x2 km for each mesh area. The results of effective radium concentrations in these sites were found to vary from 1.149 Bq kg^{-1} to 2.543 Bq kg^{-1} . The outdoor radon levels concentrations in these sites were found to vary from 236.4 Bq m^{-3} to 523.2 Bq m^{-3}, with average values of 367.8 Bq m^{-3}. The average radon annual effective dose was 0.066 mSv y^{-1} for outdoor and 0.263 mSv y^{-1} for indoor. The results indicate that the soil are quite safe for occupancies and to be used as building materials.

Keywords: soil, radon gas, CR-39, exhalation rate, annual effective dose.

1 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]. The ^{222}Rn isotope is originated by decay of ^{226}Ra ,which is naturally occurring radioactive element in the earth's crust [2], has a period of half-life 3.82 days emitting alpha particle whose energy is about 5.49 MeV. It is present in measurable quantities in all soil type. Thus the emission of ionizing radiation by rock and soil depends on its content of uranium in the case of ^{222}Rn emission [3].

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 [4]. Long term exposures to radon via inhalation in closed rooms or caves or open air saturated with Radon gas is the cause for about 10% of all deaths from lung cancer [5-6]. 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. There are two important natural occurring isotopes of radon; ^{222}Rn, a direct product of ^{226}Ra in the ^{238}U series and ^{220}Rn a direct product of ^{224}Ra in the ^{232}Th series. Because radon has relatively long half-life enabling it to migrate quit significant distance before decaying and can be found in everywhere.

Plastic detector CR-39 or LR-115 type II and Gamma Spectroscopy were used to estimate radon concentration in soil [7-8]. The motivation of work is to study the distribution of the soils gas radon concentrations define the background values and measure radiological health risk of radon exhalation rates using the sealed can technique [9-11].

2 Materials and Methods

The soil samples were taken from different depth of locations at selected area in Basrah Governorate, shown in figure 1. Samples were dried in the oven at 110 ^{o}C for 24h, milled in grinder, and sieved.

Each 100 gm dried sample of soil was placed in the bottom of closed hard plastic cylinder container of 12 cm height and diameter 7.5 cm and covered by 5mm sponge, as shown in Figure-2 [12]. The 1.5x1.5cm^2 of CR-39 films were sealed by double face adhesive tape on the bottom of the containers cover , to allow irradiation process with radon only to take place. After 90 days of irradiation the

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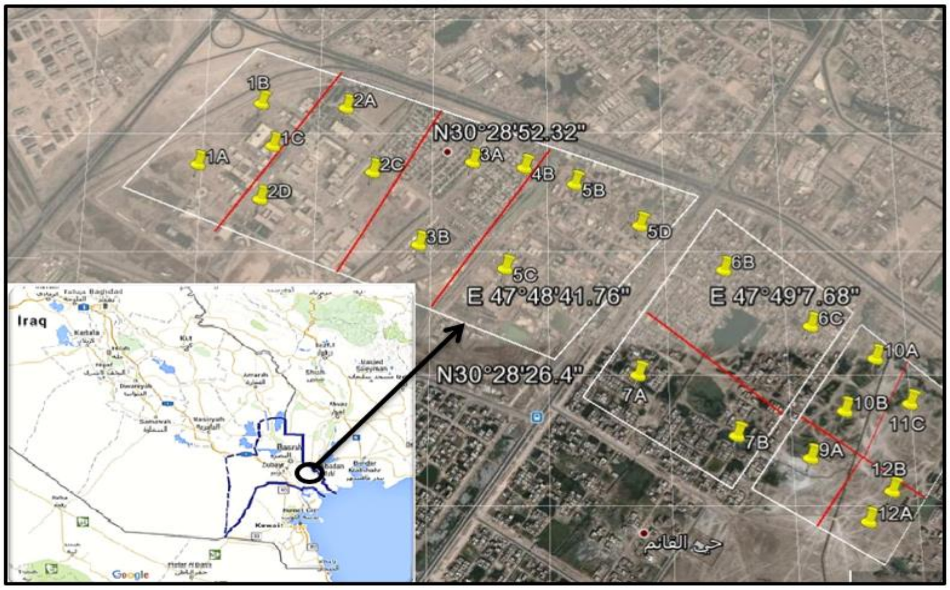

Figure 1. The studied area in Basrah governorate, southern part of Iraq.

detectors was removed carefully from the cylinder and etched with NaOH solution with condition 6.25N at 70 ºC for 8 hour. The detectors then washed many times by distill water and dried with tissue papers. The numbers of tracks due to alpha particles interaction are counted by the means of optical microscope 40X.

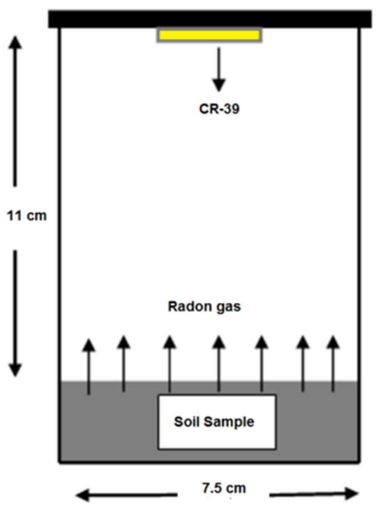

Figure 2. The hard plastic cylinder used as radon irradiator.

3 Theoretical Consideration

The track density is related to the radon activity concentration A_{Rn}(in Bq/m^3) by the following formula [13,14]:

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

where $\boldsymbol{\rho}$ 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. The calibration factor used in present work was K=0.323±0.045 Tr/cm^2.day / Bq.m^{-3}[11]

At the equilibrium state, final activity of radon exhalation from each sample inside the can in terms of area is given by the following formula [15,16]

$$E_{ex} = \frac{AV\lambda}{S.T_{eff.}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where $\mathbf{E_{ex}}$ is exhalation rate in unit Bq m^{-2}.d^{-1}, **A** is integrated exposure measured by the detector in unit Bq m^{-3} d, $\boldsymbol{\lambda}$ is radon decay constant, **V** the volume of the can and **S** is the cross-sectional area of the can in m^2, where $\mathbf{T_{eff}}$ is effective exposure time given by:

$$T_{eff.} = [T - \lambda_{Rn}^{-1}(1 - e^{-\lambda_{Rn}T})] \ldots\ldots(3)$$

Where T is exposure time in a day.

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

$$E_M = \frac{AV\lambda}{M.T_{eff.}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where $\mathbf{E_M}$ 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 the relation below [17]:

$$A_{Ra} = \frac{\rho h S}{KMT_{eff}} \quad \ldots\ldots\ldots\ldots \quad (5)$$

Where $\boldsymbol{\rho}$ is track density recorder, **h** distance between the detector and sample, **S** surface area of sample,

The annual effective dose equivalent, **E**, related to the average radon concentrations, $\mathbf{A_{Rn}}$, calculated by the following expression [18]:

$$E\ (WLM.y^{-1}) = \frac{8760 \times n \times F \times A_{Rn}}{170 \times 3700} \ \ldots\ldots\ (6)$$

Where $\mathbf{A_{Rn}}$ is in Bq/m^3; **n** is the fraction of time spend **n**=0.2 for outdoor and **n**=0.8 for indoor, **F** is the equilibrium factor which equal to 0.42 as suggested by UNSCEAR[1], the number **8760** is refer to the time of hours per year and **170** is the number of hours per working month. For radon gas exposure in the present work, the effective dose equivalents were estimated by using a conversion factor of **6.3** mSv/WLM [19].

4 Results and Discussion

Table 1 depicts the values of track density and radon concentration for soil samples taken from selected area in Basrah Governorate.

Table 1. The samples code, track density and radon concentrations in samples taken from selected region in Basrah Governorate.

Sample Code	ρ in Tr cm^{-2} d^{-1}	Rn concentration in Bq m^{-3}
1a	92.4	386.4
1b	83.8	350.4
1c	104.4	436.7
2a	54.4	227.5
2b	68.3	285.6
2c	78.5	328.3
2d	84.0	351.6
3a	75.0	313.8
3b	106.2	444.3
4b	84.7	354.5
5b	102.1	427.1
5c	68.5	286.5
5d	120.3	503.5
6b	83.5	349.3
6c	54.6	228.4
7a	84.0	351.6
7b	73.6	308.0
9a	67.4	281.8
10b	75.4	315.6
11c	117.6	491.9
12a	63.2	264.4
12b	113.9	476.5
Min. value	92.4	227.4
Max. value	120.3	503.5
Mean value	84.35	352.90

Radon specific concentration in the collected samples varies from 227.5 Bq/m^3 to 503.5 Bq/m^3 with mean average value 352.90 Bq/m^3. It is notices that, radon concentration in the studied area are within the recommended limits of ICRP and closed or less than the nearby countries [19-21].

Radon exhalation rate ($E_{ex.}$ in table 2) depends upon a number of parameters such as the radioactive disintegration of ^{226}Ra to produce radon gas, the direction of recoil of radon in the grain, the interstitial soil moisture condition the vicinity of the ejected radon atom and its diffusion in the pore space.

The radon flux rates measured in terms of area and mass of soil samples are found to vary from 201.1 mBq/m^2. h^{-1} to 445.1 mBq/m^2. h^{-1}with mean value of 311.91 mBq/m^2. h^{-1} and 2.13 mBq/kg . h^{-1} to 4.72 mBq/kg . h^{-1} with an average value of 3.31 mBq/kg . h^{-1} respectively.

Table 2. Radon area and mass exhalation rate in soil samples.

Sample Code	Radon Exhalation Rate per unit area mBq m^{-2} h^{-1}	Radon mass Exhalation rate in mBq.kg^{-1}. h^{-1}
1a	341.6	3.62
1b	309.7	3.28
1c	386.0	4.09
2a	201.1	2.13
2b	252.4	2.68
2c	290.2	3.08
2d	310.7	3.29
3a	277.4	2.94
3b	392.7	4.16
4b	313.3	3.32
5b	377.5	4.00
5c	253.2	2.69
5d	445.1	4.72
6b	308.7	3.27
6c	201.9	2.14
7a	310.7	3.29
7b	272.2	2.89
9a	249.1	2.64
10b	278.9	2.96
11c	434.8	4.61
12a	233.7	2.48
12b	421.2	4.47
Min. value	201.1	2.13
Max. value	445.1	4.72
Mean value	311.91	3.31

Many indexes dealing with radon inhalation originated from soil and building materials, one of them called the alpha internal index, which developed by Stoulos at al. [22] and defined as following:

$$I_\alpha = \frac{A_{Ra}}{200\ Bq\ kg^{-1}} \quad \ldots\ldots\ldots\ldots\ (7)$$

The value of $I_\propto$ should be always less than unity to insure that the indoor enhancement of radon concentrations in soil do not exceed the ICRP limit (200 Bq m^{-3}). The results of the present work confirm this criterion.

Effective radium content calculated from the measured radon gas concentrations should be correlated because it is not equal to radium content in the soil sample under normal condition (pressure, ventilation, temperature, humidity, and experimental errors).

It is notice from table 3 that the effective radium content of soil sample varies from 1.178 Bq/kg to 2.607 Bq/kg with mean value of 1.827 Bq/kg. The results of exhalation rates and effective radium content in soil sample are in agreement with the results of Subber et al. [11], whom used the same method for measurement of those parameters in soil samples.

Table 3. Effective radium, outdoor and indoor effective dose in soil samples.

Sample Code	Effective Ra in Bq/kg	Outdoor effective dos in mSv y^{-1}	indoor effective dos in mSv y^{-1}
1a	2.001	0.072	0.287
1b	1.814	0.065	0.260
1c	2.261	0.081	0.324
2a	1.178	0.042	0.169
2b	1.479	0.053	0.212
2c	1.700	0.061	0.244
2d	1.820	0.065	0.261
3a	1.625	0.058	0.233
3b	2.300	0.082	0.330
4b	1.835	0.066	0.263
5b	2.212	0.079	0.317
5c	1.483	0.053	0.213
5d	2.607	0.094	0.374
6b	1.808	0.065	0.259
6c	1.183	0.042	0.170
7a	1.820	0.065	0.261
7b	1.595	0.057	0.229
9a	1.459	0.052	0.209
10b	1.634	0.059	0.234
11c	2.547	0.091	0.365
12a	1.369	0.049	0.196
12b	2.467	0.088	0.354
Min. value	1.178	0.042	0.169
Max. value	2.607	0.094	0.374
Mean value	1.827	0.065	0.262

The effective radon dose is listed in tables 3 ,where the outdoor and indoor doses received by the inhabitants from soil are in the range of 0.042 mSvy^{-1} to 0.094 mSv y^{-1} with arithmetic average equal to 0.065 mSv y^{-1} and 0.169 mSv y^{-1} to 0.374 mSv y^{-1} with average value equal to 0.262 mSv y^{-1} respectively. Thus, results reveal that the area is safe as far the health hazard effects are concerned and less than the recommended limit for members of the public of 1 mSv $year^{-1}$ [23]

5 Conclusions

Area and mass exhalation rate of radon have been measured using CR-39 track detector by the sealed can technique. The present measurements indicate that the level of radon exhaled from soil samples collected from the studied are significantly lower than the world wide safe limit given by UNSCEAR 2000. The effective radium distribution in the soil samples varies from point to point in the same district. Its value is found to be much below the hazard limit.

Finally, our results clearly show that the area under investigation is safe as far as the health hazards of radon are concerned.

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