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Measurement of Radon Concentration Using SSNTD in Bartella Region

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Abstract

The alpha-radioactive inert gas Radon exhalation is associated with presence of Radium and its ultimate precursor uranium in the earth crust. Uranium decay deposits radon in soil, which is harmful on human and environment. The exposure of population to high concentration of alpha radioactivity mainly of Radon for a long period leads to lung cancer. The radon activity concentrations, radium contents, radon exhalation rates in twenty one soil samples collected from Bartella region, were measured using the sealed-can technique based on the CR-39 SSNTDs. In the present paper the estimated values for radon activity concentration in air space are in the range 323.2-2424 Bq/m^3 with mean value of 1212.7 Bq/m^3, the radon concentration in soil sample are 31.66-237.46 KBq/m^3 with mean value of 118.83 KBq/m^3, the radium contents were found vary between 1.36-10.24 Bq/Kg with mean value 5.11 Bq/Kg, the radon mass exhalation rate vary between 10.34-77.56 mBq/Kg/hr with mean 38.81 mBq/Kg/hr, the radon surface exhalation rate are between 234.2-1756.4 mBq/m^2/hr with mean value of 878.6 mBq/m^2/hr. All values of the samples under the test are below of permissible values 370 Bq/Kg of radium content and 57600 mBq/m^2/hr radon exhalation, recommended by Organization for Economic Cooperation and Development (OECD). Hence the area under investigation is safe as for as health hazards of radium and safe in radiological risks due to radon exposure from the soil.

Keywords: Radon measurement, Radium content, Bartella region, SSNTDs, CR-39.

الخلاصة

يرافق زفير غاز الرادون الخامل المشع الباعث لالفا وجود الراديوم وسلفه النهائي اليورانيوم في قشرة الارض . انحلال اليورانيوم يودع الرادون في التربة التي هي ضارة للانسان والبيئة . تعرض الناس لتركيز عالي من اشعاع الفا وبصورة اساسية الرادون لفترة طويلة يؤدي الى السرطان . تراكيز فعالية الرادون ، محتوى الرادون ومعدلات زفير الرادون لاحدى وعشرون عينة تراب جمعت من منطقة برطللة واجريت القياسات بتقنية الاناء وباستخدام كاشف CR-39 وكانت النتائج المحصلة لتراكيز الرادون هواء العينة داخل الاناء تقع ضمن الفترة 323.2-2424 Bq/m^3 وبمعدل 1212.7 Bq/m^3 وتراكيز الرادون في التربة يتراوح بين 31.66-237.46 KBq/m^3 وبمعدل 118.83 KBq/m^3 ومحتوى الراديوم وجد بالمدى 1.36-10.24 Bq/Kg وبمعدل 5.11 Bq/Kg ومعدل الزفير الكتلي للرادون كان ضمن الفترة 10.34-77.56 mBq/Kg/hr وبمعدل 38.81 mBq/Kg/hr كما ان معدل الزفير السطحي للرادون كان ضمن الفترة 234.2-1756.4 mBq/m^2/hr بمعدل 878.6 mBq/m^2/hr ، كل القيم للنماذج هي اقل من القيم المسموحة 370 Bq/Kg لمحتوى الراديوم و 57600 mBq/m^2/hr لزفير الرادون التي اوصت بها منظمة التعاون الاقتصادي والتطوير (OECD) . ان المنطقة قيد البحث هي امنة من الاخطار الصحية الناتجة من الراديوم وامنة من المخاطر الاشعاعية الناتجة من التعرض للرادون الصادرة من التربة.

Introduction

The exposure of population to high concentration of alpha radioactivity mainly of Radon for a long period leads to pathological effects like there respiratory functional changes and the occurrence of lung cancer[1]. The radioactivity is a spontaneous decay and transformation of unstable nuclei accompanied with the emission of nuclear particles or photons, therefore the analysis of this processes may be found in wide range of complexities because nuclear radiation can occur in various types, abundances and energies[2]. Radiation plays an important role in our everyday life as the world is naturally radioactive therefor each of us is exposed to naturally occurring quantities of radiation, in fact, radioactivity can be in the air we breathe, the soil on which we walk the dwellings in which we live and even within in our bodies[3].

Radon is found in air, rock, soil, water, and it is indicate the presence of radium and its ultimate precursor uranium in the ground. The vast variation in radon exposure depends on location considered and is mainly governed by the exhalation rate (i.e., the amount of activity released per unit area of the surface per unit time) from the ground[4],[5]. Measurement of radon exhalation rates from soil and rocks is useful in studying the health risks[6][7]. The soil–gas radon concentration and its exhalation rate depend on the local geology of the area associated mineralization geophysical and climatological parameters[8]. As a gas, radon has three main natural isotopes; namely, radon-222 (^{222}Rn), a decay product of ^{238}U, radon-220 (^{220}Rn, known as thoron), produced in the decay series of thorium-232 (^{232}Th), and radon-219 (^{219}Rn), a decay product from the chain originating with ^{235}U[9]. Both ^{238}U and ^{232}Th occur naturally in soil and rocks at variable concentrations of about 1PCi/g and also ^{226}Ra, the parent of ^{222}Rn[10]. The ^{222}Rn isotope has a half-life of 3.82 days, while ^{220}Rn isotope has half-life about 55 seconds and ^{219}Rn isotope has a half-life of about 3.96 seconds[11]. Since radon ^{222}Rn has long half-life time related to other isotopes, its considered to be the most significant isotope in decay series of ^{238}U, this is show the radon problem in the environmental studies because tracing of ^{238}U are found in most natural rocks, soil, and water. It can be measured using SSNTD (Solid State Nuclear Track Detector) technique[12].

The plastic SSNTD detectors are most widely used because they are more sensitively than crystal and glass. This type like CR-39 Polymer can record all charged radiations, the shape and type of damage positions (tracks) on the film plastic detector depend on the mass, energy, the charge of the incident particle and on the type of solid state detector[13], and these tracks may be observed by optical microscope after enlargement by etching process .

Materials and Methods

1. Radon gas concentration in soil samples

The radon activities, were detected by passive technique of solid state nuclear track detectors using “Sealed Can technique”[14][17]. Twenty one soil samples were collected from various locations of Bartella region (the location of study area Bartella is in Iraq, 21 kilometers East of Mosul city, between Latitude: 36° 21' 13.3" (36.3537°) north and Longitude: 43° 22' 52.6" (43.3813°) east, elevation:307 meters, 1,007 feet), these samples milled, crushed, sieved by 2-mm mesh, 75 gm of each sample was placed inside a plastic cylindrical container facing a CR-39 track detector into a diffusion chamber Figure 1.

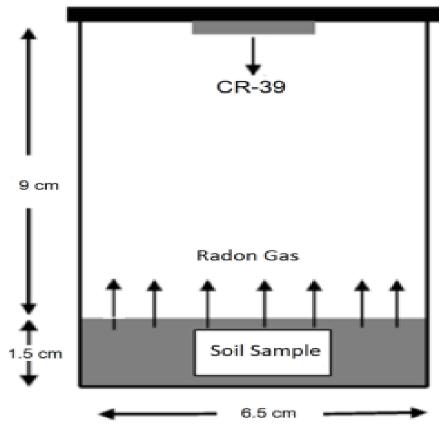

Figure 1: A schematic diagram of the sealed-cup technique in soil sample.

Which was then closed for a period of 90 days (from 5 March 2017 to 3 June 2017) after getting equilibrium between radium and radon. CR-39 detector of area (1×1 cm^2) were placed at the closed top end of a plastic cup (6.5 cm in diameter, 10.5 cm length) while the distance between the sample surface to the detector is 9 cm and the sample thickness is 1.5 cm .

After 90 days, the detectors are removed and etched by NaOH at normality 6.25 N and heat 70 °C in water bath to reveal the tracks. The detectors were washed and dried, tracks were counted using a microscope at a magnification of 400x.

The track densities were measured using the following equation[18]:

$$Track\ density\ \rho = \frac{Total\ number\ of\ tracks}{Area\ of\ the\ field\ of\ view} \qquad (1)$$

The track density ρ(in track/cm^2) is related to the radon activity concentration (in air space) C_{Rn}(Bq/m^3) and the exposure time T (in day) by the formula[19]:

$$\rho = KC_{Rn}T \quad (2)$$

Where K is the sensitivity or calibration factor of CR-39 its value (2.758×10^{-2} Traks.cm^{-2}.day^{-1} / Bq.m^{-3}) given by[20].
Radon concentration in the soil samples calculated using the relation[21][22]:

$$C_s = \lambda_{Rn}\, C_{Rn}\, H\, T/L \quad (3)$$

Where C_s Radon concentration in the soil samples (Bq/m^3), C_{Rn} Radon concentration in air space (Bq/m^3), λ_{Rn} decay constant for radon (0.1814 day^{-1}), H height of air space in the can (9cm), T exposure time (90 day), L thickness of the sample in the can (1.5cm).

2. Radium content in soil samples

Since the half-life of ^{226}Ra is 1600 years and that of ^{222}Rn is 3.82 days, it is reasonable to assume that an effective equilibrium (about 98%) for radium- radon members of the decay series is reached in about four weeks. Once the radioactive equilibrium is established, one may use the radon alpha analysis for the determination of steady state activity concentration of radium. The activity concentration of radon increase with time T, after the closing of the can, according to the relation[23]:

$$C_{Rn} = C_{Ra}(1 - e^{-\lambda_{Rn}T}) \quad (4)$$

Where C_{Ra} is the effective radium content of the sample, λ_{Rn} is the decay constant of ^{222}Rn.
Since a plastic track detector measures the time-integrated value of the above expression, i.e. the total number of alpha disintegrations in unit volume of the can with a sensitivity K during the exposure time T, hence the track density observed is given by the relation[24]:

$$\rho = KC_{Ra}T_e \quad (5)$$

Where T_e denotes, the effective exposure time given by[25]:

$$T_e = \left[T - \lambda_{Rn}^{-1}\left(1 - e^{-\lambda_{Rn}T}\right)\right] \quad (6)$$

The effective radium content of the soil sample can be calculated by formula[24]:

$$C_{Ra}(Bq.Kg^{-1}) = \left(\frac{\rho}{KT_e}\right)\left(\frac{HA}{M}\right) \quad (7)$$

Where M is the mass of the soil sample in Kg, A is the area of cross-section of the can in m^2, H is the distance between the detector and top surface of the soil sample in meter, T_e effective exposure time in day.

3. Radon exhalation in soil samples

The surface exhalation rate E_A in (Bq.m^{-2}.hr^{-1}) of the sample for release of radon can be calculated by using the expression[26]:

$$E_A = \frac{CV\lambda}{AT_e} \quad (8)$$

The mass exhalation rate E_M (in Bq.Kg^{-1}.hr^{-1}) of sample can be calculated by expression[26]:

$$E_M = \frac{CV\lambda}{MT_e} \quad (9)$$

Where in the above tow expressions λ is the decay constant for radon in (hr^{-1}), V is effective volume of the can in (m^3), C in (Bq/m^3.hr) is the integrated radon exposure, A is area cross-section of can in (m^2), M is the sample mass in (Kg), T_e is effective exposure time in (hr), the integrated radon exposure was computed using the relation[6]:

$$C = C_{Rn}T \quad (10)$$

Where C_{Rn} (Bq/m^3) radon activity concentration, T the total exposure time in (hr).

Results and Discussion

The results of mass and surface exhalation rates of radon, the radon activity concentration in air space, radon concentration content in soil, and radium content for twenty one soil samples are presented in Table 1.

Table 1: Results of radon and radium concentrations, radon exhalation rates in soil samples.

No.	Sample number	ρ Track/cm^2	C_{Rn} Bq/m^3	$C_S\times10^3$ Bq/m^3	C_{Ra} Bq/Kg	E_A Bq.m^{-2}. hr^{-1}	E_M Bq.Kg^{-1}. hr^{-1}
1	BART01	4520	1826	178.86	7.68	1323	58.43
2	BART02	6000	2424	237.46	10.24	1756	77.56
3	BART03	4133	1670	163.58	7.05	1210	53.44
4	BART04	4573	1847	181.00	7.81	1338	59.10
5	BART05	3906	1578	154.61	6.67	1143	50.49
6	BART06	2933	1185	116.09	5.00	858.6	37.92
7	BART07	2400	969.7	94.98	4.10	702.6	31.03
8	BART08	4266	1723	168.88	7.28	1249	55.16
9	BART09	5066	2047	200.52	8.65	1483	65.50
10	BART10	2266	915.8	89.71	3.87	663.5	29.30
11	BART11	1733	700.3	68.60	2.96	507.4	22.41
12	BART12	1040	420.2	41.16	1.77	304.4	13.44
13	BART13	3240	1309	128.23	5.53	948.5	41.89
14	BART14	1200	484.8	47.49	2.04	351.3	15.51
15	BART15	3600	1454	142.48	6.14	1053	46.54
16	BART16	1600	646.4	63.32	2.73	468.4	20.68
17	BART17	933	377.1	36.93	1.59	273.2	12.06
18	BART18	1280	517.1	50.65	2.18	374.7	16.54
19	BART19	2093	845.7	82.85	3.57	612.8	27.06
20	BART20	5466	2208	216.36	9.33	1600	70.67
21	BART21	800	323.2	31.66	1.36	234.2	10.34
	Min	800	323.2	31.66	1.36	234.2	10.34
	Max	6000	2424	237.46	10.24	1756	77.56
	Mean	3002	1212.7	118.83	5.11	878.6	38.81

The calculated values for radon activity concentration in air space are in the range 323.23-2424 Bq/m^3 with mean value of 1212.7 Bq/m^3, the radon concentration in soil sample are 31.66-237.46 KBq/m^3 with mean value of 118.83 KBq/m^3, the radium contents were found vary between 1.36-10.24 Bq/Kg with mean value 5.11 Bq/Kg, the radon mass exhalation rate vary between 10.34-77.56 mBq/Kg/hr with mean 38.81 mBq/Kg/hr, the radon surface exhalation rate are between 234.2-1756.4 mBq/m^2/hr with mean value of 878.6 mBq/m^2/hr. The min values found in the sample BART21 and max values in sample BART02, radium content comparable with 2.85-4.37 Bq/Kg of ref.[27]. In Table 2 comparison between the obtained results and the published data in different countries for soil samples.

Table 2: The comparison with the other published data in different countries.

No.	Country	C_{Rn} (Bq.m^{-3})	References
1	Iraq	1212.7	present work
2	Iraq	1386.23	2014 ref.[28]
3	Iraq	616.6	2014 ref.[29]
4	Iraq	478	2012 ref.[30]
5	India	2200	2014 ref.[31]
6	India	1308.8-2105.6	2013 ref.[6]
7	India	448	2010 ref.[32]
8	India	457	2013 ref.[33]
9	India	1117	2014 ref.[34]
10	Egypt	717	2015 ref.[35]
11	Egypt	136.99- 874.51	2016 ref.[36]
12	Egypt	36.98- 576.18	2012 ref.[37]
13	Algeria	285	2008 ref.[38]
14	Libya	516	2013 ref.[39]
15	Nepal	2321	2015 ref.[40]
16	Turkey	1795	2006 ref.[41]

Figure 2 represent the values of radium content with the samples, its vary from one sample to another due to radium content in sample location.

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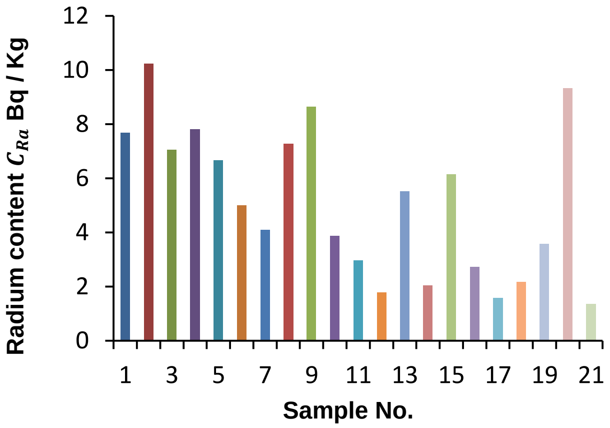

Figure 2 : Radium content (Bq / Kg) in samples.

Figure 3 shows a good positive correlation (1.00) has been obtained between the radium content and the radon exhalation rates for soil samples, it is evident that as the content of radium increased, the exhalation rates as well as increase.

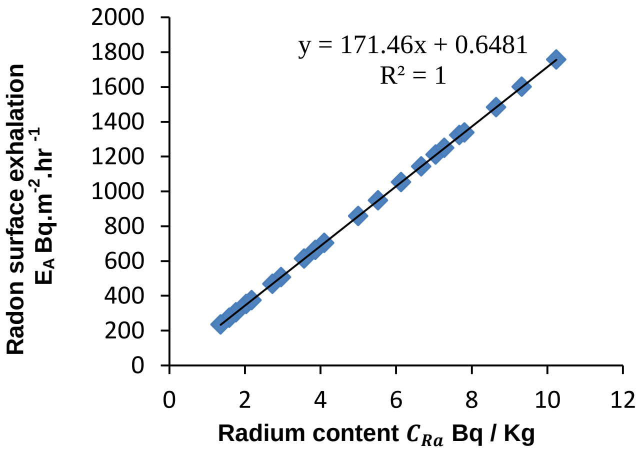

Figure 3: Variation between radium content and radon surface exhalation rate.

The variation in radon exposure depends on location considered and is mainly governed by the exhalation rate, the soil–gas radon concentration and its exhalation rate depend on the local geology of the area associated mineralization geophysical and climatological parameters. The Bartella region is an open area around houses, it has large amount of wind and air causes raised radon gas from soil to diffusion to air, so the results of the measurements show very low values of radon and radium concentrations, thoron gas (half-life 56 s) is an alpha emitter which is also present in soil and environments, the average diffusion distance of thoron gas is very small compared to that of radon, which means that the present results might also contained a small amount of thoron and therefore might be considered roughly as an upper limit results which are still within the allowed limit therefor the area under study is safe for life from natural radiation.

Conclusions

The results of this investigation showed considerable presence of radon and radium in soil samples in Bartella region. Radon concentrations in the soil air are known to vary with time due to changes in soil moisture, soil permeability, wind, air temperature and air pressure. A correlation coefficient of 1.00 between the radium content and radon exhalation rate has been obtained. The obtained values of radium contents and radon exhalation were found to be less than the maximum permissible values of 370 Bq/Kg and 57600 mBq/m^2/hr as the recommendation of OECD[42]. Hence the area under investigation is safe as for as health hazards of radium and safe in radiological risks due to radon exposure from the soil.

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