Civil and Environmental Research www.iiste.org
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.6, No.1, 2014

Measurement of Radon Gas Concentration in Soil and Water Samples in Salahaddin Governorate-Iraq Using Nuclear Track Detector (CR-39)

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Abstract

In the present work, we have measured the Radon gas concentration in environmental samples (soil and water) of selected regions in Salahaddin governorates by using alpha-emitters registrations which are emitted form Radon gas in (CR-39) nuclear track detector. The first part is concerned with the determination of Radon gas concentration in soil samples, results of measurements indicate that the highest value of Radon concentration in soil samples was found in (Takreat) region which was (100.75±11.25 Bq/m^3), while the lowest of Radon concentration was found in (Al-Faris) region which was (45.25±15.75 Bq/m^3) with an average value of (77.07±12.6 Bq/m^3), the present results show that the Radon gas concentrations in soil is below the allowed limit from (ICRP) agency which is (200 Bq/m^3). The second part is concerned with the determination of Radon gas concentration in water samples which are from stream channel in this areas, the results of measurements indicate that the highest value of Radon concentration in water samples was found in (Takreat) region which was (0.46±0.11 Bq/L), while the lowest one was found in (Al-Alim) region which was (0.24±0.10 Bq/L), with an average value of (0.333±0.5 Bq/L), the present results show that the Radon gas concentrations in water is below the allowed limit from (ICRP) agency which is (0.5994 Bq/L). In addition to the Radon gas concentrations, we have calculated the Radon exhalation rate in soil samples and the annual effective dose in water samples.

Keywords: environment (soil and water), Radon gas, solid state nuclear track detectors (CR-39).

1. Introduction

Radon (^{222}Rn) is a radioactive gas with a half- life of (3.82 d). It is produced by the decay of naturally occurring radionuclide (^{226}Ra), which is in turn is a decay product in the Uranium (^{238}U) series. Thoron gas (^{220}Rn), which is a Radon isotope, is a decay product in the Thorium (^{232}Th) series. The half- life of Thoron is (56 s) which is much shorter than that of Radon. Because of such a short half-life of Thoron, its emanation from building materials, as well as, its infiltration from the ground and further migration is restricted to a few centimeters only. When Radon is inhaled into the lungs it decays by means of alpha-emission which causes ionization damage when it strikes the lung tissue. Over time, this damage causes lung cancer (Guo *et al.* 1992).

Since Radon is a gas, it may escape into the air from the material in which it is formed, and since Uranium and Radium occur widely in soil, rocks and water, Radon gas is ubiquitous outdoors as well as indoors, the air that we inhale contains Radon. The Radon gas has been recognized as a radiation hazard causing excess lung cancer among underground miners (IAEA 2003).

In the present investigations, the passive technique using the Solid State Nuclear Track Detectors (SSNTDs) has been utilized for the comparative study of the indoor Radon level in the dwellings of Salahaddin governorate. Nuclear track detection technique based on Radon measurement with CR-39 detector was used during the currently conducted study because of its simplicity and long term integrated read out, high sensitivity to alpha-particle radiation ruggedness, availability and ease of handling.

The principle of this technique is based on the production of track in the detector due to alpha particles emitted from Radon and its progeny. After exposure, the tracks are made visible by chemical etching and counted manually under the optical microscope. The measurement track density is then converted into Radon concentration (ICRP 1993).

The aim of the present work is to determine the Radon gas concentration in soil surface and water samples in selected regions in Salahaddin governorates by using alpha-emitters registrations which are emitted form

Radon gas in (CR-39) nuclear track detector by using the sealed-cup technique.

2. Experimental Part

2.1 Calculation of Radon gas concentrations

The determination of alpha particles concentration emitted from Radon gas in soil surface and water samples were performed by using the nuclear track detector (CR-39) of thickness (250 µm) and area of about (1×1 cm^2).

The soil surface samples were collected from different sites in Salahaddin governorate and crushed to small pieces then to fine powder by using electrical mill, the fine soil powder will convert to the grain size of (300 µm). The weight of the sample was about (30 g). The samples of water were also collected from the same sites of the above Salahaddin governorate. (1/4 litter) volume of surface water were collected from some stream channels, the Radon gas concentration in soil and water samples was obtained by using the sealed-cup technique as shown in figure (1) and figure (2) respectively.

After the exposure time (30 day), the (CR-39) track detectors were etched in (6.25 N) (NaOH) solution at temperature of (60 ^oC) for (6 h) and the tracks density were recorded using an optical microscope with magnification (400x). The density of the tracks (ρ) in the samples was calculated according to the following relation (Amalds *et al.* 1989).

$$\text{Tracks density } (\rho) = \frac{\text{Average number of total pits (track)}}{\text{Area of field view}} \quad (1)$$

The Radon gas concentration in the soil and water samples were obtained by the comparison between track densities registered on the detectors of the sample and that of the standard soil and water samples which are shown in figure (3) and figure (4) respectively, using the relation (Durrani & Bull 1987, Karim 2005) :

$$C_x = \rho_x \, . \, (C_s / \rho_s) \quad (2)$$

Where:

C_x : alpha particles concentration in the unknown sample.

C_s : alpha particles concentration in the standard sample.

ρ_x : track density of the unknown sample (track/mm^2).

ρ_s : track density of the standard sample (track/mm^2).

2.2 Calculation of Radon exhalation rate in soil samples

The Radon exhalation rate of any sample is defined as the flux of Radon released from the surface of material. The surface exhalation rate (E_{exh}) in units $Bq.m^{-2}.h^{-1}$ can be calculated by (Mahur *et al.* 2010):

$$E_{exh} = \frac{CV\lambda}{A[T + \lambda^{-1}(e^{-\lambda T} - 1)]} \quad (3)$$

Where:

C: is the integrated Radon exposure ($Bq.m^{-3}$).

V: is the volume of air in cup (m^3) =150 cm^3= 0.00015 m^3

λ :is the decay constant for ^{222}Rn (h^{-1}) = 0.1812 day^{-1} =0.00755 h^{-1}

A: is the surface area of the sample (m^2) = 3^2×3.14=28.26 cm^2=0.002826 m^2

T: is the exposure time (h) = 30day =720 h

2.3 Calculation the annual effective dose in water samples

The annual effective dose of an individual consumer due to intake of Radon from drinking water is evaluated using the relationship (Alam *et al.* 1999):

$$AED_w = C_w \, C_{Rw} \, D_{cw} \quad (4)$$

Where: AED_w is the annual effective dose (Sv/y) due to ingestion of radionuclide from the consumption of water.

C_w is the concentration of Radon in the ingested drinking water (Bq/L).

C_{Rw} = 730 L/y

$D_{cw} = 5 \times 10^{-9}$ Sv/Bq

3. Results and Discussion

In the present work Radon concentrations were measured for soil and water samples in 10 different locations in Salahaddin governorate which includes regions (Al-Sarkat, Bijie, Al-Alim, Al-Touz, Takreat, Al-Door, Samarra, Balad, Al-Faris and AL-Mashahda), see figure (5). The first part were measured for soil samples, table (1) summarize the results obtained in the present work for Radon gas concentrations in soil samples, it can be noticed that the highest value of Radon concentration was found in Takreat region (S_5) which was (100.75±11.25 Bq/m^3), while the lowest value was found in Al-Faris region (S_9) which was (45.25±15.75 Bq/m^3) as shown in figure (6), with an average value of (77.07±12.6 Bq/m^3), the present results show that the Radon gas concentration in soil is below the allowed limit from (International Commission of Radiation Protection) (ICRP) agency which is (200 Bq/m^3) (Pzrbylowicz & Skowronski 1977). While the Radon exhalation rate (RER) ranged from (30.83-68.64 μBq/m^{2}h) with an average value of (52.51±9.2 μBq/m^{2}h).

The second part is concerned with the determination of Radon gas concentration in samples of water from stream channel in this areas, from table (2), it can be noticed that the highest Radon concentration in water samples was found in Takreat region (S_5) which was (0.46±0.11 Bq/L), while the lowest Radon concentration was found in Al-Alim region (S_3) which was (0.24±0.10 Bq/L) as shown in figure (7) with an average value of (0.333±0.5 Bq/L). The present results show that the Radon gas concentration in water is below the allowed limit from (International Commission of Radiation Protection) (ICRP) agency which is (0.5994 Bq/L) (Al-Ubaidi 2006), while the Radon exhalation rate (RER) ranged from (0.87-1.70 μSv/y) and the average value was (1.22±0.16 μSv/y).

It might be mentioned that, Thoron gas is an alpha emitter which is also present in soil and water environments, however, the average diffusion distance of Thoron gas is very small compared to that of Radon (Alam *et al.* 1999), 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 of (ICRP) agency. Also it should be remembered that the half–lives of Radon and Thoron are about (3.82 d) and (56 s) respectively (Saad 1998).

4. Conclusion

The results of the present work provide an additional database on soil and water Radon concentration level in Salahaddin governorate. The highest average Radon concentration in soil samples was found in Takreat region, while the lowest average Radon concentration was found in Al-Faris region, see figure (2), this is due to the samples are taken from different places and the materials contain radioactive elements in different proportions depending upon local geology. The highest average Radon concentration in water samples was found in Takreat region, while the lowest average Radon concentration was found in Al-Alim region. The concentrations which found in the present work was agree with the another research of this field, that's prove that this governorate was not subjected to bombing fortified with depleted uranium, therefore the results were within normal limits compatible with the geological nature of the soil in Iraq, contrary to other governorates which gives high concentrations of radon gas or uranium-238.

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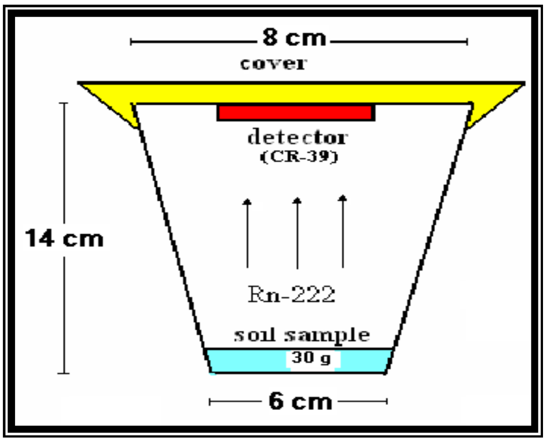

Figure 1. A schematic diagram of the sealed-cup technique in soil sample.

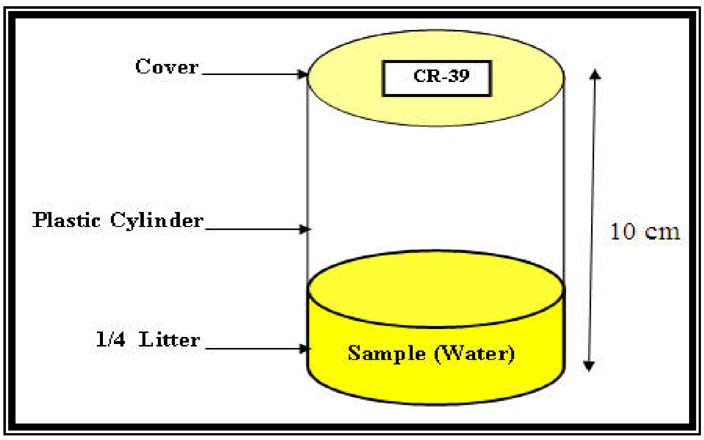

Figure 2. A schematic diagram of the sealed-cup technique in water sample.

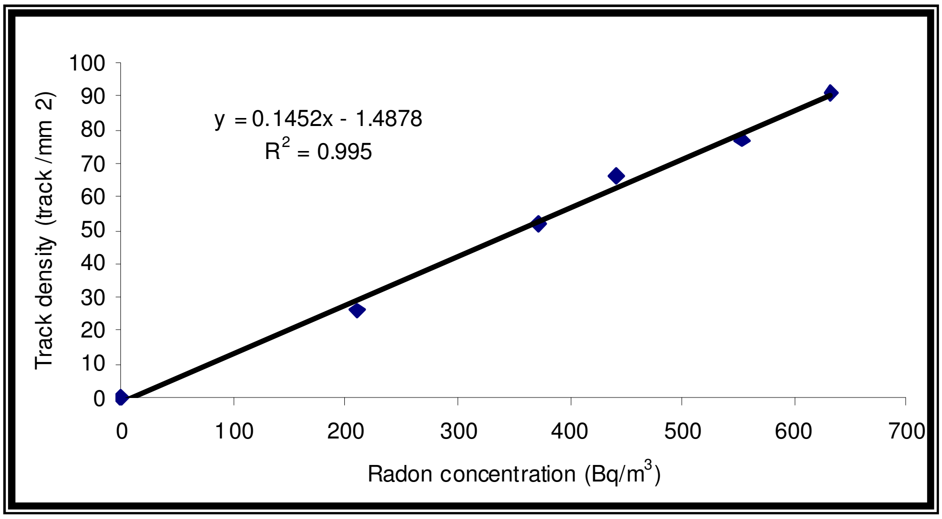

Figure 3. Relation of Radon gas concentration and track density in soil standard samples.

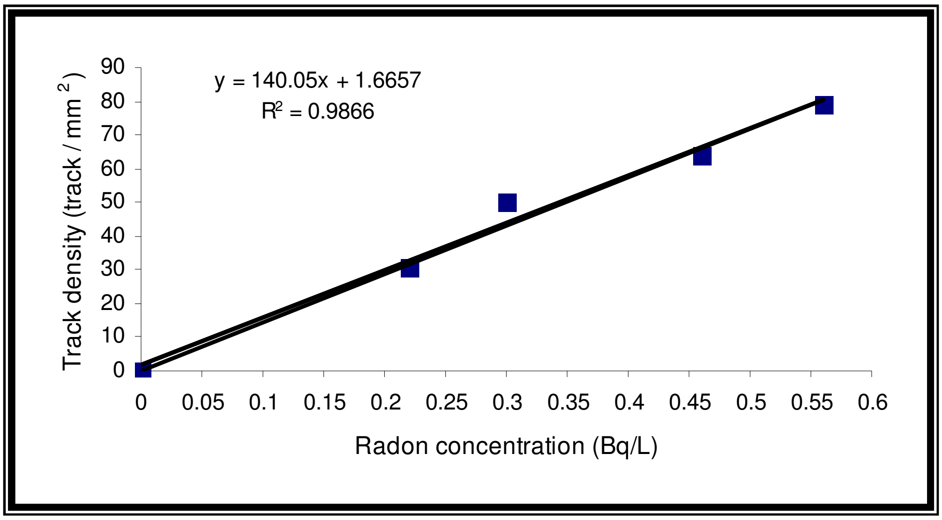

Figure 4. Relation of Radon gas concentration and track density in water standard samples.

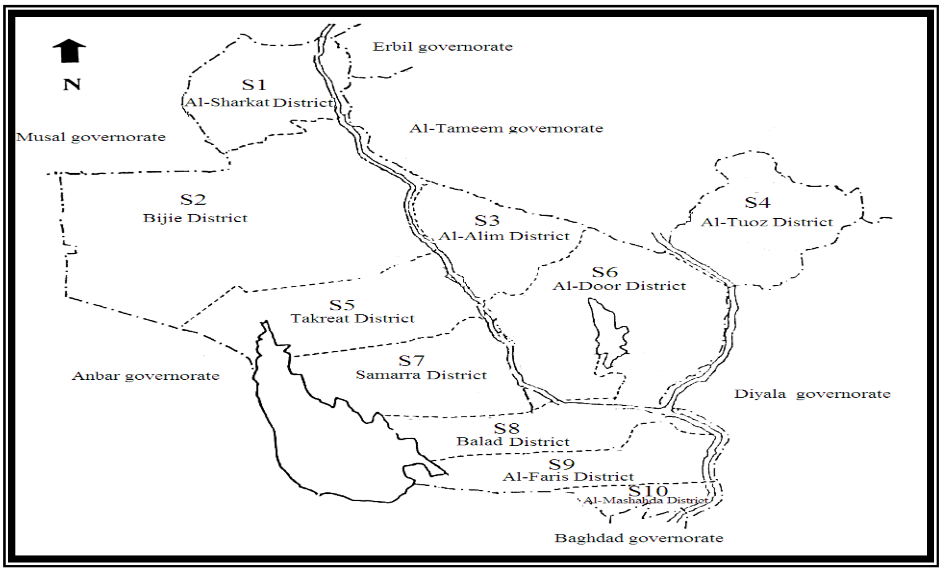

Figure 5. Sketch map shows locations of study samples in Salahaddin governorate.

Table 1. Shows the Radon gas concentration C_{Rn} (Bq/m^3), Radon exhalation rate (RER), for soil surface samples in Salahaddin governorate.

No.	Location Sample	C_{Rn} (Bq/m^3)				Mean of C_{Rn} (Bq/m^3)	(RER) (μBq/m^{2}h)
		1	2	3	4		
1	S_1	68	72	94	103	84.25±14.25	57.40
2	S_2	32	48	59	71	52.50±12.5	35.77
3	S_3	83	85	90	118	94.00±12	64.04
4	S_4	38	58	89	93	69.50±21.5	47.35
5	S_5	87	92	103	121	100.75±11.25	68.64
6	S_6	58	67	86	96	76.75±14.25	52.29
7	S_7	76	85	93	95	87.25±6.75	59.44
8	S_8	77	79	88	104	87.00±9	59.27
9	S_9	22	37	53	69	45.25±15.75	30.83
10	S_{10}	62	72	75	85	73.50±6.5	50.08
Average						**77.07±12.6**	**52.51±9.2**

Table 2. Radon gas concentration C_{Rn} (Bq.L^{-1}), annual effective dose (AED), for water samples in Salahaddin governorate.

No.	Location Sample	Mean of C_{Rn} (Bq.L^{-1})				Mean of C_{Rn} (Bq.L^{-1})	(AED) (μSv/y)
		1	2	3	4		
1	S_1	0.12	0.24	0.45	0.54	0.34±0.16	1.24
2	S_2	0.24	0.24	0.43	0.46	0.34±0.10	1.24
3	S_3	0.11	0.17	0.31	0.37	0.24±0.10	0.87
4	S_4	0.16	0.19	0.28	0.36	0.25±0.07	0.91
5	S_5	0.27	0.41	0.54	0.61	0.46±0.11	1.70
6	S_6	0.12	0.22	0.37	0.49	0.30±0.13	1.10
7	S_7	0.24	0.26	0.40	0.47	0.34±0.09	1.24
8	S_8	0.21	0.36	0.38	0.47	0.36±0.07	1.31
9	S_9	0.23	0.30	0.44	0.58	0.39±0.12	1.42
10	S_{10}	0.10	0.27	0.39	0.52	0.32±0.13	1.17
Average						**0.333±0.5**	**1.22±0.16**

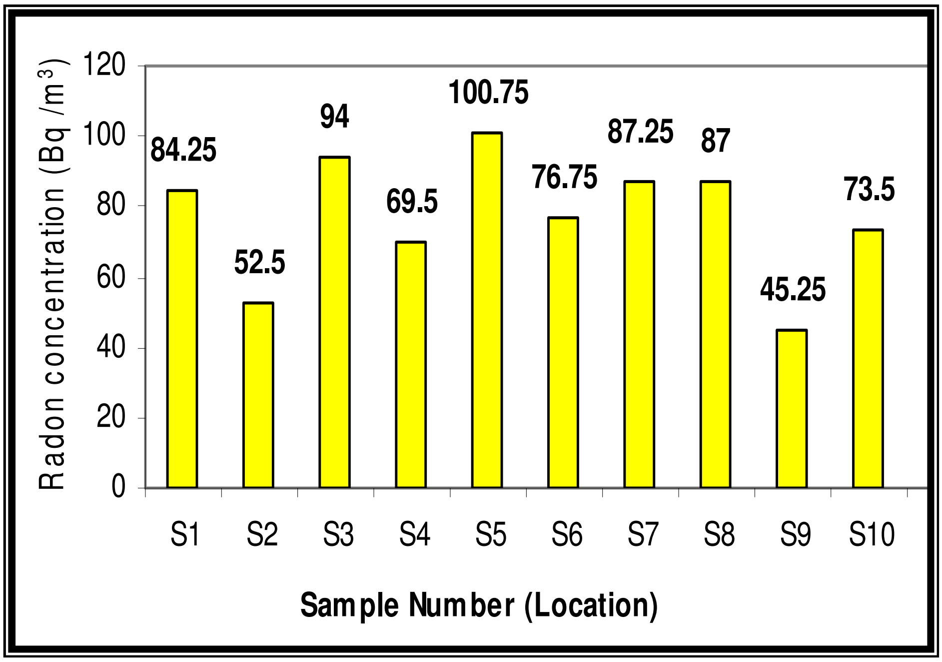

Figure 6. A histogram illustrating the change in Radon gas concentration (Bq/m^3) in soil samples in all regions studied.

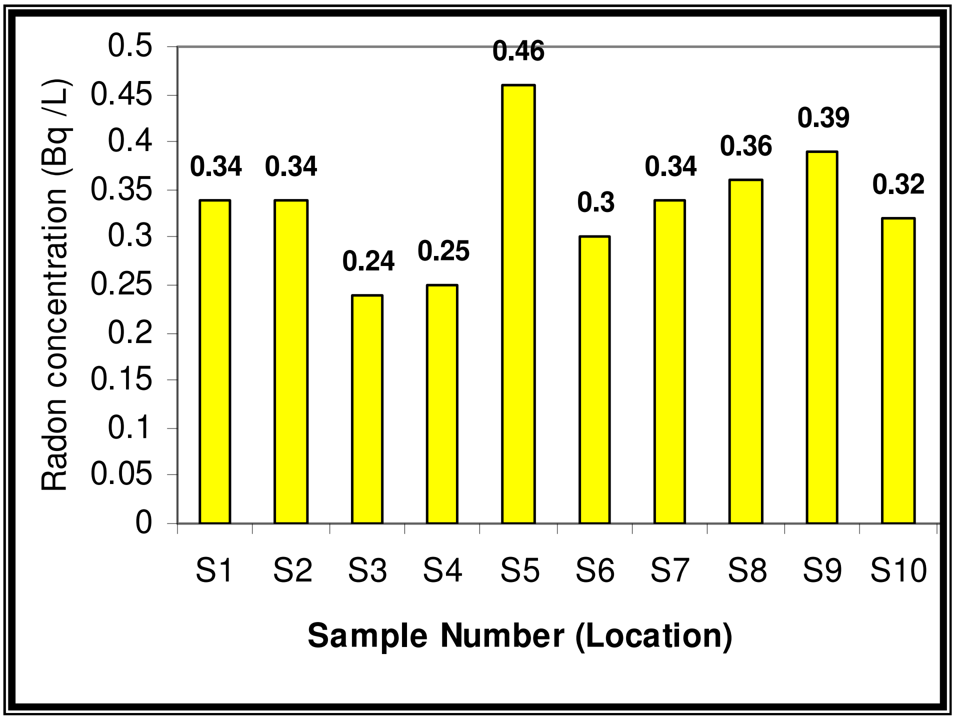

Figure 7. A histogram illustrating the change in Radon gas concentration (Bq/L) in water samples in all regions studied.