ISSN 2250-3153

Estimation of Soil Gas Radon Concentration and the Effective Dose Rate by using SSNTDs

Abd-Elmoniem A. Elzain[1,2]

[1]Department of Physics, University of Kassala, Kassala, Sudan
[2]Department of Physics, College of Science & Arts in Oklat Al-Skoor, Qassim University, Oklat Al-Skoor, Saudi Arabia

Abstract- Measurements of radon concentration, and effective dose rate were made for a number of 168 measurements of soil samples in some towns of the Gezira State in the central part of the Sudan. In this survey we used the can technique, containing CR-39, to estimate the radon concentration from the soils of: El-Hosh, Um-Turibat and Medani cities. The results of radon concentrations from soil samples in the selected areas were found to be 5.50 ± 0.75 kBq.m^{-3}, 11.05 ± 4.95 kBq.m^{-3}, 15.10 ± 1.47 kBq.m^{-3}, while the effective dose was calculated to be from 24.51 ± 3.32 mSv.y^{-1}, 48.22 ± 10.25 mSv.y^{-1} and 67.28 ± 6.56 mSv.y^{-1}, for El-Hosh, Um-Turibat and Medani towns, respectively. The results were compared with national and worldwide results.

Keywords - Radon, CR-39 detectors, Can technique, Soil.

I. Introduction

Radon is a naturally occurring odorless, colorless, tasteless, inert gas which is imperceptible to our sense. It is produced continuously from the decay of naturally occurring radionuclide such as U-238, U-235, Th-232. The isotope ^{222}Rn, produced from the decay of U-238, is the main source (approximately 55%) of the internal radiation exposure to human life [1].

Gaseous radioactive radon (^{222}Rn), decay product of the radium isotope ^{226}Ra is present in all types of soil and rock. Radium atoms decays in soil particles, the resulting atoms of radon entering to air filled pores and then transported by diffusion and advection through this space in order to exhale into the atmosphere [2].

Radon concentrations in soil gas within a few meters of the surface of the ground are clearly important in determining radon rates of entry into pore spaces and subsequently into the atmosphere and it's depend on the radium concentration in the bedrock and on the permeability of the soil [3].

There are two main sources for the radon in home's indoor air – the soil and the water supply. Compared to radon entering the homes through water, radon entering homes through the soil is usually much higher. So the radon from soil gas is the main cause of radon problem.

The measurement of ^{222}Rn concentration in soil gas, in principle, can be used as a method of evaluating the potential for elevated indoor radon concentrations [4].

Radon-prone areas can be identified directly by using indoor measurements or indirectly using radon concentration in the soil, by previous established correlation with the indoor radon concentrations. For example, The United States of America developed its radon map based on a combination of indoor measurements, geological characteristics, aerial radioactivity, soil permeability and foundation type [5].

Based on the National Academy of Science 1998 BEIR VI Report, the US Environmental Protection Agency estimates that about 21,000 annual lung cancer deaths are radon related. EPA also concluded that the effects of radon and cigarette smoking are synergistic, so that smokers are at higher risk from radon, from which it can be concluded that radon is the second leading cause of lung cancer after smoking [6].

The factors which influence the diffusion of radon from the soil into the air are:

- The uranium and radium concentration in soil and rocks;
- The emanation capacity of the ground;
- The porosity of the rock and soil;
- Barometric pressure gradient between the interfaces;
- Soil moisture and water saturation grade of the medium;
- Other variables [7] .

The aim of the present investigation is to estimate the concentration of radon in the soil-gas and the effective dose rate of three towns in Sudan, see Figure 1.

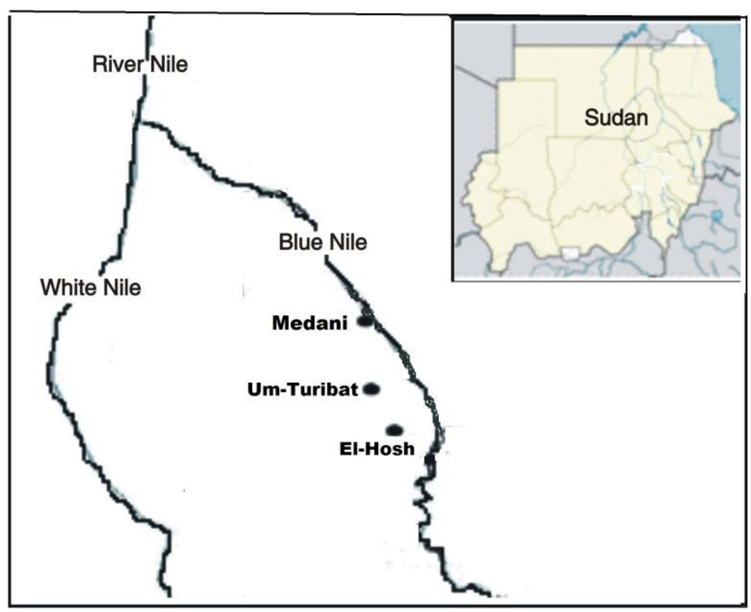

Figure 1. The map of the study area in, Sudan.

II. MATERIALS AND METHODS

The can technique [8–10] was employed for the measurement radon concentration and radon effective dose rates in soil samples from three towns in Sudan (Figure 1).
An amount of 4 kg from each sample was collected under the depth 30 cm within 1.5m of the foundations of the dwelling in selected locations, the samples were dried in a temperature controlled furnace (oven) at a temperature 100 ± 0.1°C for 24 h to ensure that moisture is completely removed, then the samples were crushed to a fine powder and sieved through a small mesh size to remove the larger grains size and render them more homogenous. About 250 g of each sample was placed in a plastic can of dimensions of 10 cm in height and 7.0 cm in diameter [11]. A passive method (can-technique) using SSNTDs for measurements of radon exhalation rate was used [11-14].
A piece of CR-39 detector of size 2 × 2 cm was fixed on the top of inner surface of the can, in such a way, that it is sensitive surface always facing the sample. The can is sealed air tight with adhesive tape and kept for exposure of about three months. During exposure period, the detector is exposed freely to the emergent radon from the sample in the can so that it could record alpha particles resulting from the decay of radon in the remaining volume of the can. After that, the dosimeters were separated from the sample cup, collected and chemically etched in a 30% solution of KOH, at $(70.0 \pm 0.10)^{o}C$ for a period of 9 hours. The resulting α tracks were counted under an optical microscope of magnification 400X.
The track density was determined and converted into activity concentration C_{Rn} ($Bq.m^{-3}$) by using Eq (1) [11, 15-18]:

$$C_{Rn} = \frac{\rho_{Rn}}{K_{Rn} t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where ρ is the track density (tracks per cm^2), t is the exposure time and K_{Rn} is the calibration constant which was determined previously to be: $K_{Rn} = 3.746\times10^{-3}$ tracks.$cm^{-2}h^{-1}$ per $Bq.m^{-3}$ [11].
The annual effective dose equivalent, E_{Eff}, was related to the average radon concentration C_{Rn} by Eq (2):

$$E_{Eff}\left(WLM.y^{-1}\right) = \frac{8760 \times n \times F \times C_{Rn}}{170 \times 3700} \quad \ldots\ldots(2)$$

Where: C_{Rn} is in $Bq.m^{-3}$; n is the fraction of time spent indoors; F is the equilibrium factor; 8760 is the number of hours per year; and 170 is the number of hours per working month. The values of n = 0.8 and F = 0.4 [3], were used to calculate E_{Eff}. For radon exposure, the effective dose equivalents were estimated by using a conversion factor of 6.3 $mSv.WLM^{-1}$ [17-19].

III. RESULTS AND DISCUSSION

This research presents the data of soil gas radon concentration and the effective dose rate from three towns in Sudan through its inner areas.

Table 1. show the radon concentration and effective dose for El-Hosh town in the Gezira State - Sudan. The values of soil gas radon concentration were ranged between 2.11 and 9.50 $kBq.m^{-3}$, with an average of 5.50 ± 0.75 $kBq.m^{-3}$. The soils of El-Hosh town were noticed to be more moist as compared with other soils in addition to that it some of soils are sandy soils. It was found that radon gas is likely to be emitted from drier soils more than from moist or water saturated soil [21, 22]. It might be useful to recall that, the radon concentration is lower for sandy soils near the saturation state [23].

The values of soil gas radon concentration for El-Hosh town are slightly lower than that found in Saudi Arabia of 6.71 $kBqm^{-3}$ [12], similar to that recorded in Iraq of 5.74 $kBqm^{-3}$**[23]** , slightly larger than the value founded in Egypt of 4.35 $kBqm^{-3}$ [24] and greater than that found for Kassala, Sudan of 2.63 $kBqm^{-3}$[25].

For the soil samples taken from Um-Turibat town, as we illustrated in Table 2. the concentration falls within the range of 7.31 and 12.75 $kBq.m^{-3}$, with an average of 11.05 ± 4.95 $kBq.m^{-3}$. This values of concentrations may be due to that the type of the town which is black clay soil with hard texture. The clay soil contain naturally the rare elements, and this will contribute in razing the probability of increasing radon concentration. Our value survey if compared it would be larger than that found in Rabak town Sudan of 8.20 $kBqm^{-3}$[18], lower than the average soil gas radon concentration of 40.1 $kBq.m^{-3}$ obtained in Slovenia [26].
Table 3. show the range of soil gas radon concentration in Medani town which is from 8.57 to 19.08 $kBq.m^{-3}$, with an average of 15.10 ±1.47 $kBq.m^{-3}$. This results may be attributed to the reason of that Medani town, is located along Blue Nile bank, hence its soil is known to being belonged to the river terrace soils. The soil is classified as alluvium soil that transported and deposited by the Blue Nile River as a result of its flowing from the Ethiopian highlands. The alluvium is thought to be derived mainly from igneous crystalline basement complex, but includes some admixture of sedimentary rocks such as marble and quartzite [27]. It was reported that, the soil gas radon concentration in Singa town of Sudan is 19.9 $kBqm^{-3}$, our result we found for Medani town is much lower than 75 $kBq.m^{-3}$ value reported for Austria [28], it is also greater than the recorded values of soil gas radon concentration found in France (Montipellier) with the value of 2.71 $kBq.m^{-3}$ [29].
Figure 2. show the average measured values of soil gas radon concentration with respect to each of the towns in our study.

Table 1. Statistical summary of soil gas radon concentration and the effective dose rate for El-Hosh town in Sudan

No	Area	No of samples	Min $kBq.m^{-3}$	Max $kBq.m_{-3}$	(C± S.D) $kBq.m^{-3}$	Effective Dose (mSv per year)
1.	E1	12	2.11	6.48	4.96 ± 0.60	22.10 ± 2.67
2.	E2	12	3.95	9.50	5.48 ± 0.56	24.42 ± 2.50
3.	E3	12	5.79	8.34	6.56 ± 0.84	29.24 ± 3.74
4.	E4	12	3.70	6.27	5.46 ± 0.76	24.33 ± 3.39

5.	E5	12	4.05	6.50	5.04 ± 0.97	22.46 ± 4.32
Overall		60	2.11	9.50	5.50 ± 0.75	24.51 ± 3.32

*E1, E2, E3, E4, E5 is the sections in El-Hosh town

Table 2. Statistical summary of soil gas radon concentration and the effective dose rate for Um-Turibat town in Sudan

No	Area	No of samples	Min $kBq.m^{-3}$	Max $kBq.m^{-3}$	(C± S.D) $kBq.m^{-3}$	Effective Dose (mSv per year)
1.	U1	12	9.15	12.49	10.82 ± 3.34	48.22 ± 10.25
2.	U2	12	7.31	10.46	8.88 ± 3.44	39.57 ± 9.89
3.	U3	12	12.57	12.75	12.66 ± 6.81	56.42 ± 17.56
4.	U4	12	11.17	12.52	11.84 ± 6.2	52.77 ± 18.05
Overall		48	7.31	12.75	11.05 ± 4.95	48.22 ± 10.25

*U1, U2, U3, U4 is the sections in El-Managil town

Table 3. Statistical summary of soil gas radon concentration and the effective dose rate for Medani town in Sudan

No	Area	No of samples	Min $kBq.m^{-3}$	Max kBq.m-3	(C± S.D) $kBq.m^{-3}$	EFFECTIVE DOSE (mSv per year)
1.	M1	12	12.54	16.00	13.69 ± 1.30	61.01 ± 5.79
2.	M2	12	14.10	19.08	17.24 ± 1.19	76.83 ± 5.30
3.	M3	12	13.69	18.10	15.57 ± 1.58	69.39 ± 7.04
4.	M4	12	13.69	17.06	15.32 ± 1.56	68.28 ± 6.95
5.	M5	12	8.57	16.44	13.66 ± 1.73	60.88 ± 7.71
Overall		60	8.57	19.08	15.10 ± 1.47	67.28 ± 6.56

*M1, M2, M3, M4, M5 is the sections in Medani town

Figure 2. Soil gas radon concentration with respect to the towns

The mean effective dose rate for soil samples in each town in this study were found to be 24.51 ± 3.32 mSv per year, 48.22± 10.25 mSv per year and 67.28 ± 6.56 mSv per year, for El-Hosh, Um-Turibat and Medani soils respectively. The maximum effective dose rate was found at Medani soils while the minimum effective dose rate was found to be for El-Hosh town.

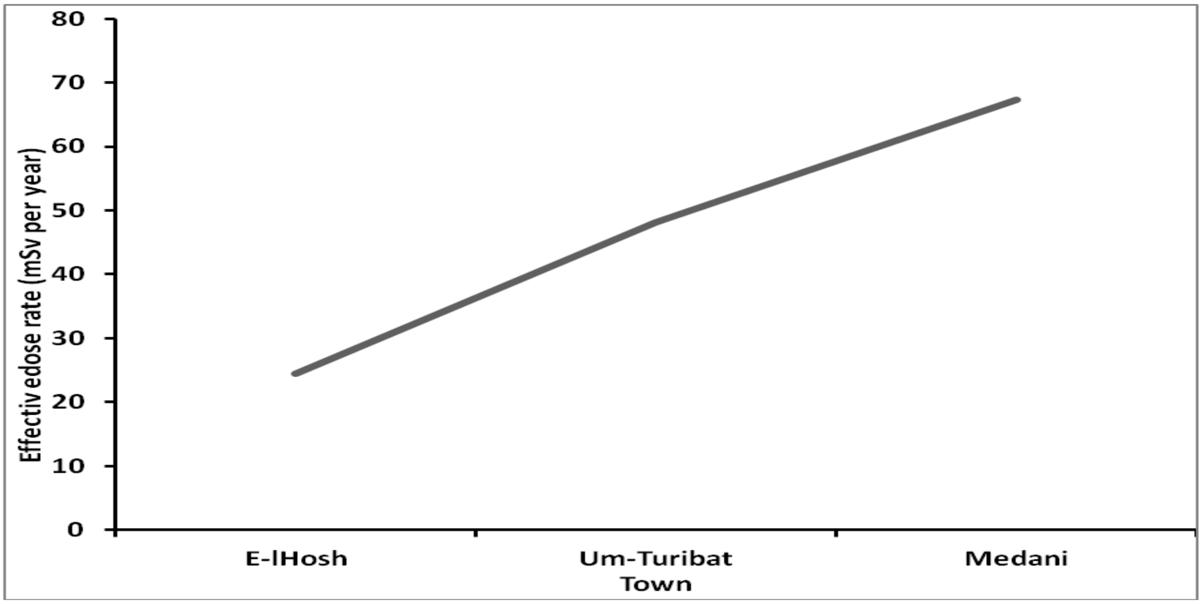

Figure 3. Effective dose rate values for soil samples in El-Hosh, Um-Turibat and Medani towns.

IV. CONCLUSION

In this study a total of 168 measurements of soil gas radon concentration measurements have been done in three towns in the central part of the Sudan namely: El-Hosh, Um-Tribat, Medani towns. The study was conducted using previously calibrated passive dosimeters containing CR-39. From the results of our study we conclude that the minimum soil radon concentrations were measured in moist, humid and arable saturated soils. The maximum values of concentration was found in a soil in Medani town, which is annually renewed by re-sedimentations of silt from the Blue Nile river. The computed values of soil gas radon concentrations for all towns were compares with data reported from different geographical regions. The effective dose rate for the soil samples were correlated to the soil gas concentration value measured for each town of this survey.

ACKNOWLEDGMENT

I gratefully acknowledge Kassala University and the working staff, for their kind patience and helps with the radon sampling, during the whole period of the research.

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AUTHOR

Corresponding Author:

Abd Elmoniem Ahmed Elzain

(Associate Professor in Applied Radiation Physics and researcher)

received the B.Sc. in Physics from Kassala University – Kassala - Sudan (1996) and High Diploma of Physics from Gezira University – Madani – Sudan (1997) and M.Sc. in Physics from Yarmouk University – Erbid – Jordan (2000) and PhD in Applied Radiation Physics from Kassala University – Kassala – Sudan (2006). He worked at Kassala University since 1996 up to 2010 then from 2010 up to now at Qassim University – Kingdom of Saudi Arabia. (E- mail: Abdelmoniem1@yahoo.com)