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ESTIMATION OF ANNUAL EFFECTIVE DOSE FROM SOIL-GAS RADON IN SELECTED REGIONS OF ILORIN, NIGERIA

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Abstract - In recent times, researchers have shown an increasing interest in the study of radioactive gas radon due to its radiological health hazard. Soil-gas radon (^{222}Rn) concentrations vary from place to place and human exposure level varies from one region to the other. The annual effective dose is commonly used for prospective assessment of yearly radiation dose received by the public for the purpose of optimization and planning in radiation protection within and around regions of high radioactivity concentration. In this study, soil-gas radon concentrations were measured in-situ at 100cm below the ground from ten (10) locations with granite rock basement within Ilorin using RAD7, a solid-state radon detector manufactured by Durridge Company (USA). Results of radon concentrations varied from 17.54 ± 500.59 Bq/m^3 to 1833.66±892.00 Bq/m^3 with an average value of 387.193±218.47 Bq/m^3. The estimated annual effective dose attributed to the inhalation of ^{222}Rn concentrations ranged from 0.00017 mSv/y at ASD location to 0.01735 mSv/y at TK location with average value of 0.00037 mSv/y in the study area. The obtained ^{222}Rn concentrations in all locations were found below the tolerable levels which range from (400 to 40,000) Bq/m^3. However, locations WS (543.67± 465.52) Bq/m^3 and TK (1833.66±892.00) Bq/m^3 showed values above 400 Bq/m^3 minimum range but below 40, 000 Bq/m^3 maximum range of the world range limit. Overall, values of annual effective dose in all locations of the study area are below the 1 mSv/y dose limit recommended for radon inhalation from all sources. From the result of this study, it is safe to conclude that dwellers within the study area have no radiological health concern due to soil-gas radon.

Keywords: Radon, annual effective dose, RAD7.

I. INTRODUCTION

The earth crust has been the major source of natural radiation, which continually emits some levels of radiation energy to the environment thereby making human exposure unavoidable (Oladapo *et al.,* 2019; Oni *et al.,* 2019 and Ajiboye *et al.,* 2016). Radon (^{222}Rn), a radioactive noble gas which is ordinarily imperceptible to humans has been reported to contribute about 55% human exposures to ionizing radiation (Fatimh et al., 2017; Shakir *et al.,* 2011 and George, 2009). ^{222}Rn has its origin from the natural disintegration of uranium (^{238}U) and thorium (^{232}Th) present in the earth crust (Ali *et al.,* 2010). Three natural isotopes of radon are known, but only ^{222}Rn having a half-life of 3.82 days has caught the attention of many researchers due to its health hazard, and also because other isotopes are short-lived and their existence cannot be swiftly determined in indoor or outdoor air (Oni and Adagunodo, 2019; Yousif Muhsin *et al.,* 2017 and Vikas *et al.,* 2014). ^{222}Rn has applications in geophysical studies as tracer for the detection of hidden faults in geological structures. It could as well be used to explore uranium mineralization of a region and thus predicting earthquake (Ali *et al.,* 2010; Al-Tamimi and Abumurad, 2001; Kritz *et al.,* 1990 and Tancer, 1980). However, ^{222}Rn pose a radiological health damage to humans which has necessitated its (^{222}Rn) study across the globe. The pores in soil serve as channels through which ^{222}Rn navigates underneath the ground and gets to the environment through cracks and openings in the ground at varying concentrations from one location to the other (Ajiboye *et al.,* 2016; Abd-Elmoniem, 2015; Jung *et al.,* 2015 and Vikasvis *et al.,* 2014). Being an alpha emitter, ^{222}Rn interacts with biological tissues when inhaled and if accumulated in tissue can cause damage, usually lung cancer (Hesham et al., 2019; Yousef *et al.,* 2016 and Abd-Elmoniem, 2014). Previous studies have revealed cancer induction due to long-term exposure to high radon concentration, and an annual lung cancer death of about 21, 000 have been associated to radon inhalation (Hesham et al., 2019; Yousef *et al.*, 2016; USEPA, 2012 and IARC, 2004). Measurement of soil-gas ^{222}Rn concentration is important to assess radiological risk (Bala *et al.*, 2017). This study investigated soil-gas radon concentrations and the corresponding annual effective dose in selected region of Ilorin, Kwara State, Nigeria.

II. MATERIALS AND METHOD

II.1 Study Area

Ilorin, being the capital city of Kwara State has population density of about 974,000 (National Bureau of Statistics, 2016) and lies within the coordinates 8.4799°N and 4.5418°E. Ilorin is rich in all kinds of mineral resources which are natural sources of radiation. The map of Kwara State showing Ilorin is presented in figure 1.

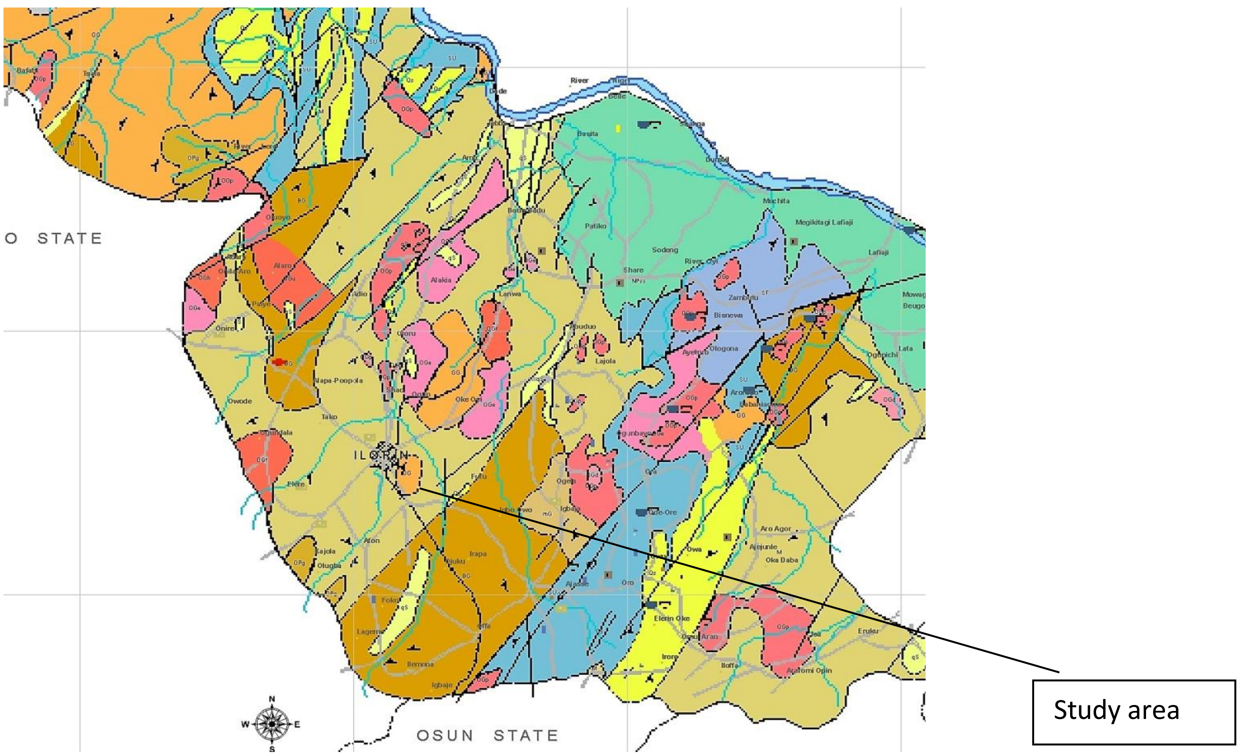

Figure 1: Map of Kwara State showing Ilorin

II.2 Radon Concentration Measurement

In-situ radon (^{222}Rn) concentration measurements were performed in ten (10) locations with granite rock basement using RAD7, a solid-state detector manufactured from Durridge Company (USA). Table 1 presents the names and location codes of the regions where measurements were taken. Literatures have established an increased radon concentration at high temperature (Ajiboye et al., 2016), therefore, measurements were done during harmattan from November, 2020 to February, 2021. Global Positioning System (Garmin) was used to take coordinates of the sampling points. RAD7 is a silicon-based alpha converter. It sniffs the energy of alpha particle and converts it into electrical signals while an inbuilt microprocessor saves it according to the particle energy.

After a square-grid design (100m×100m), the soil probe provided with RAD7 was dipped into the soil (100 cm below the ground) at the four corners and at the center of the grid with soft strokes of hammer according to the set-up of Ajiboye *et*

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al., (2018) shown in figure 2. Grab protocol mode of RAD7 was activated and was used to extract radon gas from the soil for duration of five minutes into the detector chamber. The machine delays for another five minutes before it starts a four 5-minute cycle counts, which after about 30 minutes stores and print out the result of the measurement which include a mean radon concentration.

Table 1: Name of sampling regions within the study area.

S/N	Name of Location	Location Code
1	Queen Park	QP
2	Sango	WS
3	Okelele	OK
4	Tanke	TK
5	Asa Dam	ASD
6	Wara	WR
7	Eiyenkorin	EYK
8	Malete	MLT
9	Ote	OT
10	Yakuba	YK

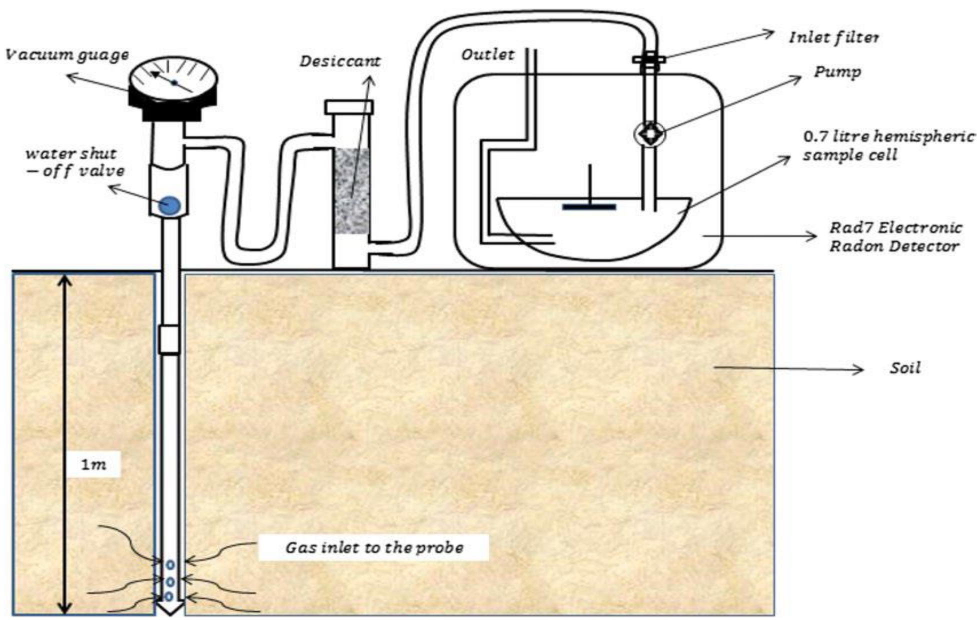

Figure 2: Experimental set-up for soil-gas radon measurement (Source: Ajiboye *et al.,* 2018)

2.3 Estimation of Annual Effective Dose

Radon concentrations at 100cm depth was used to estimate outdoor annual effective dose using equation (1) according to Yousif Muhsin *et al.*, (2017).

$$AED_{Rn}(mSv/y) = C_{Rn} \times F \times O \times (DCF) \times 8760 \quad (1)$$

Where AED_{Rn} and C_{Rn} represent annual effective dose due to radon and radon concentration in Bq/m^3 at 100cm depth respectively. F is the equilibrium factor (0.6) for outdoor radon and its daughter; O stands for outdoor occupancy (0.2) and 8760 is the number of hours per year. DCF represents the dose conversion factor (9 nSv/h per Bq/m^3).

III. RESULTS AND DISCUSSION

The mean value of radon concentration in Bq/m^3 obtained from each sampling location with corresponding values of annual effective dose (AED_{Rn}) in mSv/y are presented in table 2. The result of ^{222}Rn measurements revealed varying concentrations ranged from 17.54 ± 500.59 (0.00017 mSv/y) at ASD location to 1833.66±892.00 (0.01735 mSv/y) at TK location with an average value of 387.193±218.47 (0.00037 mSv/y) within the study area. High radon level is associated to several factors such as soil type, soil permeability or high content of uranium (Vikas *et al.*, 2014). TK location is observed to have higher value of radon concentration when compared to other locations of the study area. This could be associated to high uranium mineralization and radium content in the region. TK region is known to be densely populated which may contribute to an increased anthropogenic activity and consequently enhance radon emissions. On the other hand, ASD location is more a residential area than industrial area, which account for low radon concentration recorded in the area. This is due to little or no anthropogenic activity in the area. Figure 3 shows the variation in radon concentrations which is often due to uranium and radium contents present in the earth crust (Orosun et al., 2016) and Figure 4 shows the corresponding annual effective dose obtained in the study area. Among other sources of radon in homes such as water and building materials, the emission of soil-gas radon to the environment contributes to outdoor and indoor air radon concentrations which further increase human exposure risk. Even though, radon exposure may not necessarily have an early effect, it is important to emphasize its (^{222}Rn) long-term carcinogenic effect (Temaugee *et al.*, 2014). Overall, the average value of ^{222}Rn concentrations obtained in the study area is below the tolerable level which range from 400 Bq/m^3 to 40,000 Bq/m^3 and the estimated values of AED_{Rn} in all locations of the study areas are lower than the permissible limit of 1 mSv/y set by International Commission on Radiological Protection (ICRP). However, locations WS (543.67± 465.52) Bq/m^3 and TK (1833.66±892.00) Bq/m^3 show values above 400 Bq/m^3 minimum range but below 40, 000 Bq/m^3 maximum range. Also, 0.01735 mSv/y recorded at TK location is just 0.0735 less than 0.1 mSv/y limit recommended by the World Health Organization (Orosun *et al.*, 2016). This implies that further studies should be carried out at TK location in the future in order to keep human exposure as low as reasonably achievable and also to take remedial action in the area.

Table 2: Results of ^{222}Rn concentration and annual effective dose obtained in the study area.

S/N	**Location Code**	**Geographical Coordinates Lon / Lat**	**^{222}Rn Conc. (Bqm$^{-3)}$**	**AED (mSv/y)**
1.	QP	N8°47’76’’/ E4°53’55’’	245.22 ± 161.00	0.00232
2.	WS	N8°31’37’’/ E4°35’68’’ N8°43’65’’/ E4°24’15’’	543.67± 465.52	0.00514
3.	OK	N8°28’11’’ / E4°39’82’’ N8°26’97’’/ E4°32’45’’	376.89± 716.26	0.00356
4.	TK	N8°27.68’’/ E4°29’26’’	1833.66±892.00	0.01735
5.	ASD	N8°23’68’’/ E4°27’87’’ N8°70’81’’/ E4°47’40’’	17.54 ± 500.59	0.00017
6.	WR	N8°19’35’’/ E4°23’32’’ N8°33’45’’/ E4°37’44’’	64.84 ± 994.34	0.00061
7.	EYK		242.55± 907.73	0.00229
8.	MLT	Study area	151.89± 633.03	0.00144
9.	OT		171.34± 135.00	0.00162
10.	AYK		224.33± 860.00	0.00212
Max.			1833.66±892.00	0.01735
Min			17.54 ± 500.59	0.00017
Ave.			387.193±218.47	0.00037
WHO			-	0.1
ICRP			400 - 40,000	1

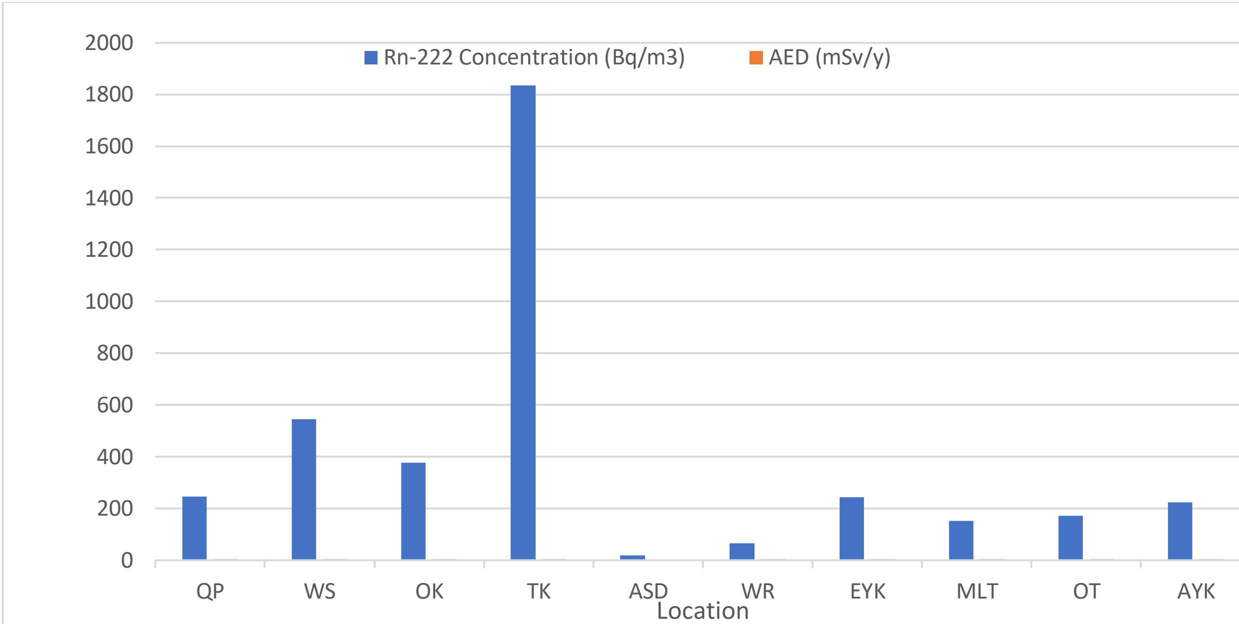

Figure 3: Radon distribution in the study area and their corresponding annual effective dose.

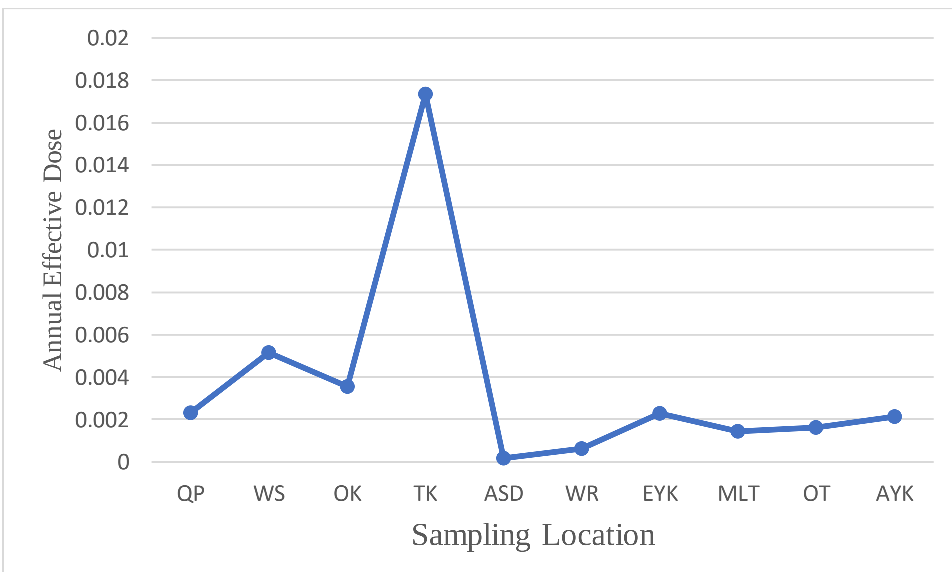

Figure 4: Annual effective dose obtained in the study area.

IV. CONCLUSION

Soil-gas radon concentrations measured within the study area revealed an average value that falls below the tolerable range of (400 – 40, 000) Bq/m^3. Values of annual effective dose obtained in all sampling locations are well below 1 mSv/y limit set by ICRP. From the result of this study, it is safe to conclude that dwellers within the study area have no radiological health concern due to soil-gas radon. Results of this study could be useful as a baseline data in setting national reference level for monitoring radiological risk of the general public.

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