International Research Journal of Public and Environmental Health
Vol.9 (4), pp. 120-124 August 2022
ISSN: 2360-8803(e) ISSN: 2814-3817(p)
Available online at https://www.journalissues.org/IRJPEH/
DOI: https://doi.org/10.15739/irjpeh.22.015

Original Research Article

Measurements of radon and estimation of excess lifetime cancer risk in water-well samples along Iwaraja-Ifewara faults Southwestern, Nigeria

Received 23 May, 2022 Revised 29 June, 2022 Accepted 11 July, 2022 Published 8 August, 2022

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Health risks of Radon in water is a global concern. Radon is the major radioactive carcinogen in water causing lung cancer among non-smokers. The concentration of Radon in water depends on the geological nature of the zone. In this study, drinking water sourced from underground water wells in selected towns in southwestern, Nigeria, along the Iwaraja-Ifewara geological fault-line were sampled. Twenty (20) water samples were collected within 50 m to 150 m at the fault line. RAD-7 was used for Radon concentration measurement. Radiation doses due to ingestion and inhalation of Radon were determined and excess cancer risk were determined. The Radon concentration ranges 5.0 to 400.1 Bq/l with a mean value of 45.78±85.93 Bq/l. Radon concentration obtained is higher than US EPA recommended limit of 11.1 Bq/l in 70% of the samples. The mean value of total annual effective doses obtained was 59.4 µSv/y, which is below the US EPA recommended level of 100 µSv/y. The excess lifetime cancer risk (ECLR) due to inhalation from the water samples ranged from 75.6 to 6053.5 with a mean of 692.9, which is also below the recommended limit. Therefore, water samples from the study areas are safe for drinking.

Keywords: Radon, element, concentration, health risks, geological fault

INTRODUCTION

Radon is a naturally occurring radioactive gas having a half-life of approximately 3.82 days.. It is formed from the decays series of uranium (UNSCEAR, 2000). Radon decay quickly by emitting series of alpha and beta particles to produce radon daughters (Binesh et al., 2012. Radon gas emanating from the bedrock is transported by diffusion and advection into the well water. The movement of radon gas is limited by its half-life but can travel farther as a solute in water. Concentration of radon gas is mainly higher in areas underlain by granite that is rich in uranium and radium. Radon concentration is dependent on the uranium concentration of the soil and local bedrock (Choo and Choo, 2019).

During the faulting process, rocks are deformed, geological characteristics changed, porosity and permeability increased along the zones, which allow radon gas to migrate uphill easily (Seminsky and Demberel, 2013). Geological faults and active volcanoes contributed to

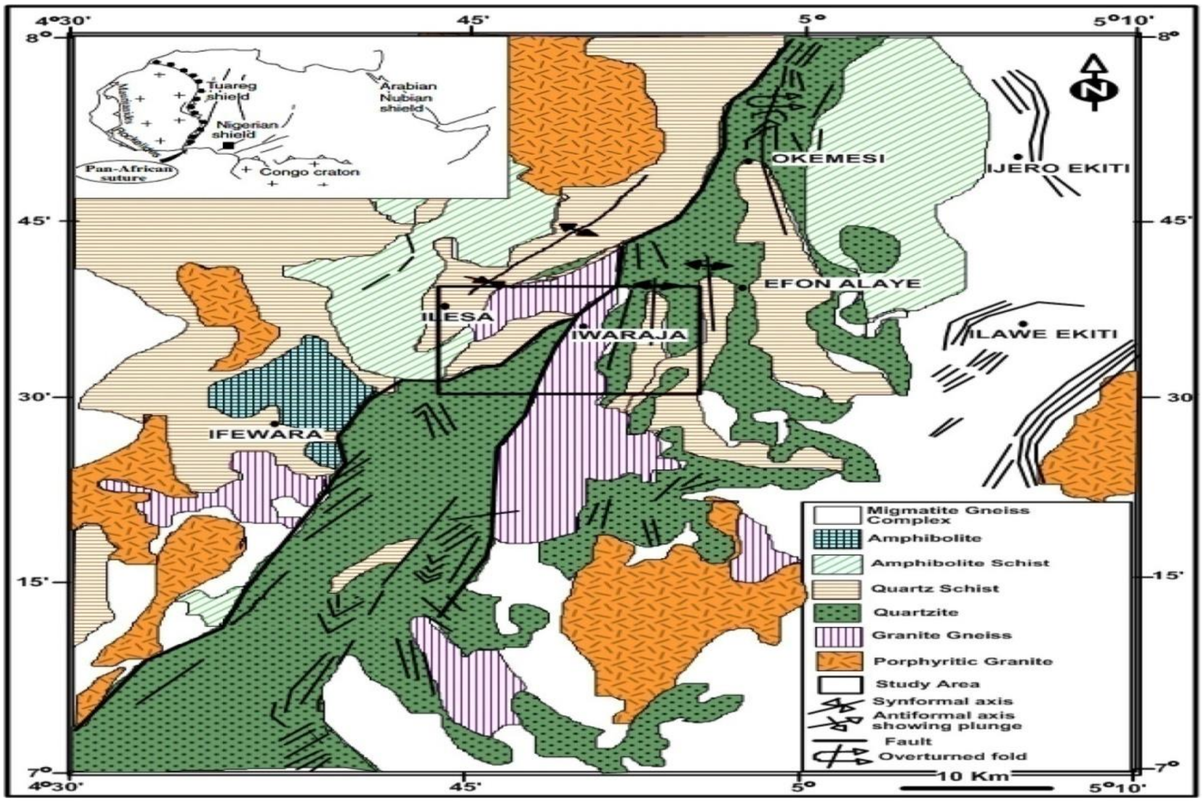

Figure 1: Geological map of the study area showing the fault line Adeoti and Okonkwo (2016).

the avalanche flow of radon gas into water and topsoil (Riggio and Santulin, 2012). Cracks and fractures also played an important role in radon migration.

Radon health risks are enormous and the major radioactive carcinogen in air or water causing lung cancer among non-smokers and gastro-enteric cancer (group of cancers that affect the accessory organs of digestive system). Due to this, different kinds of research had been carried out to evaluate cancer risk from waterborne radon in groundwater and drinking water around the world (Llerena et al., 2013; Oni et al., 2014; Ajiboye et al., 2018).

Detailed measurement of radon gas in some selected water samples in groundwater wells across along the Iwaraja - Ifewara geological fault-line is presented. The level of radon in groundwater wells across the fault zones and estimate cancer risks from the consumption of the samples were also determined.

MATERIALS AND METHODS

Geology of the Study Area

Iwaraja- Ifewara is a part of the Ilesha Schist belt of the Southwestern Nigerian basement complex. The lithography of the Ilesha schist belt is slightly distorted and traversed by two major fracture zones. The Ilesha schist belt is from Iloko to Ifewara with two major divisions (Akpan et al., 2014). The basement rocks show separate appearance of Late-Precambrian deformation (Adeoti and Okonkwo, 2016), (Figure 1).

Water Sample collection

Sample collection was undertaken in groundwater wells dug along the Iwaraja-Ifewara fault line in four towns (Ipole, Iloko, Iwaraja, and Ifewara). Five samples each were collected from each well at a distance of 50 m-150 m along the fault using 250ml glass vials. The containers were immediately covered with their screw caps and sealed with cellophane paper to avoid contamination with outside air. The samples were labelled, dated, timed and stored in a container filled with ice to avoid degassing of radon in the bottles and to maintain the field temperature until they were transported to the laboratory within 3 hours for radon analysis (Jidele et al., 2021).

Radon Measurements with RAD-7

The RAD-7 is a portable electronic radon-monitoring device that is well calibrated with a high degree of accuracy and sensitivity. The RAD-7 H_2O system used in this study was a closed-loop ventilation system where air is bubbled through the water and radon gas was continuously removed until equilibrium was achieved between water and air. The protocol used was a Wat250 procedure. This

Table 1. Radon concentration and annual effective doses in the samples

Sample ID	Radon Conc. (Bq/l)	E_{ing}(mSv/y)	E_{inh}(mSv/y)	E_{tot}(mSv/y)	ECLR
R1	66.1	4.8	166.5	85.7	1000.1
R2	81.9	5.9	206.4	106.2	1239.1
R3	93.4	6.8	235.4	121.1	1413.1
R4	82.6	6	208.2	107.1	1249.7
R5	400.1	29.2	1008.3	518.7	6053.5
R6	18	1.3	45.36	23.3	272.3
R7	5	0.4	12.6	6.5	75.6
R8	7.1	0.5	17.9	9.2	107.4
R9	5.2	0.4	13.1	6.7	78.7
R10	7.1	0.5	17.9	9.2	107.4
R11	13.9	1.1	35	18	210.3
R12	23.6	1.7	59.5	30.6	357.1
R13	15.3	1.1	38.6	19.8	231.5
R14	16.5	1.2	41.6	21.4	249.6
R15	19.3	1.4	48.6	25	292
R16	17.7	1.3	44.6	22.9	267.8
R17	10	0.7	25.2	13	151.3
R18	11.6	0.8	29.2	15	175.5
R19	13.9	1	35	18	210.3
R20	7.3	0.5	18.4	9.5	110.4
Mean	45.8	3.3	115.4	59.4	692.5

procedure involved automatic bubble blowing in the first 5 minutes (aeration stage). In the second stage, a pump was used to remove about 94% of radon gas in the water samples. Equilibrium was achieved in another five minutes while the system was refreshed and alpha particles counted after 5 minutes.

Radon level, Annual effective dose and Excess lifetime Cancer Risk

The ingestion dose E_{ing} was estimated from equation (1) Todorovic et al.(2012)

$$E_{ing} = C_{Rn} \times D_{ing} \times D_w \times T$$

Equ…………………… (1)

where C_{Rn} is the average activity of radon, D_w is the mean recommended consumption per day (2 l), D_{ing} is the dose conversion factor (10^{-8} Sv/Bq), and T is the number of days per year [1].

Also, inhalation dose (E_{inh}) was obtained from Equation (2), [1]

$$E_{inh} = C_{Rn} \times R \times D \times F \times T$$

Equ…………………… (2)

where C_{Rn} is the average activity of radon, R is the fraction of radon concentration in air to that in water (10^{-4}), D is (9 nSv h^{-1} $(Bq/m^3)^{-1}$), a converting factor, F is the equilibrium factor (0.4), and T is the time spent indoor in a year (0.8 x 8766 h/y) (ICRP, 2007).

Excess Lung Cancer Risk (ELC), which is the excess in deaths per million persons in one year due to lung cancer from exposure (inhalation) to radon and its short-lived daughters in the water samples was calculated using equation (3) below (UNSCEAR, 2010).

ELCR = 15.13CRn

Equ…………………… (3)

Where C_{Rn} is the radon concentration in Bq/l

RESULTS AND DISCUSSION

As presented in Table 1, the minimum Radon concentration was 5 Bql^{-1} while the maximum was 400.1 Bql^{-1} with mean of 45.78 Bql^{-1} and standard deviation of ± 85.93 Bql^{-1}. All the samples have Radon concentration below EPA recommended level (United States EPA, 2009) expect in R5, which is a site in Iwaraja. All the comparison of the results with the European Union (EU, 2001) recommended level revealed that all the samples analyzed have Radon concentration below the recommended limit except in R5 (Iwaraja at 400.1 Bq/l). As can be seen from Figure 2, mean Radon concentration in the four towns along Iwaraja-Ifewara fault line showed that the highest mean value was from Iwaraja (144.82 Bq/l). This high value may be due to the seismic activity at Iwaraja, which is predominantly higher than in the other towns down the fault line. Which mean that the concentration of Radon gas is dependent on the geological nature of the bedrock and generally increases with the uranium concentration in the local geology. In addition, geological fault influences Radon concentration in groundwater (Bhongsuwan et al., 2011). These factors explain the high Radon concentration obtained in this study.

The minimum ingestion dose was 0.365 while the maximum was 29.2 µSv/y with a mean of 3.34 µSv/y, which is lower than the UNSCEAR stipulated value of 100 µSv/y

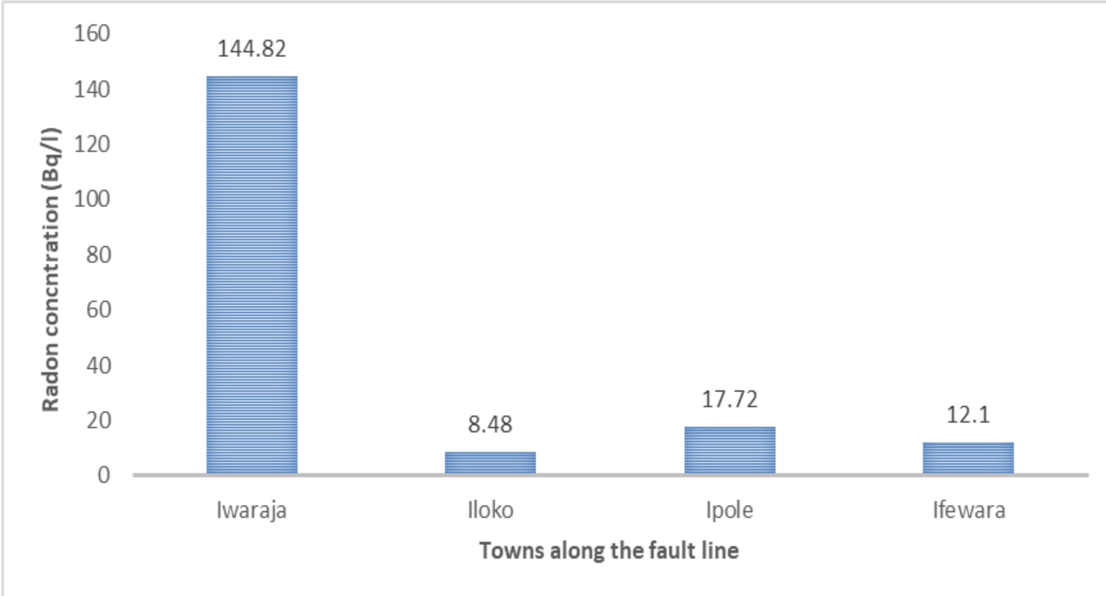

Figure 2: The mean Radon concentration along the fault line

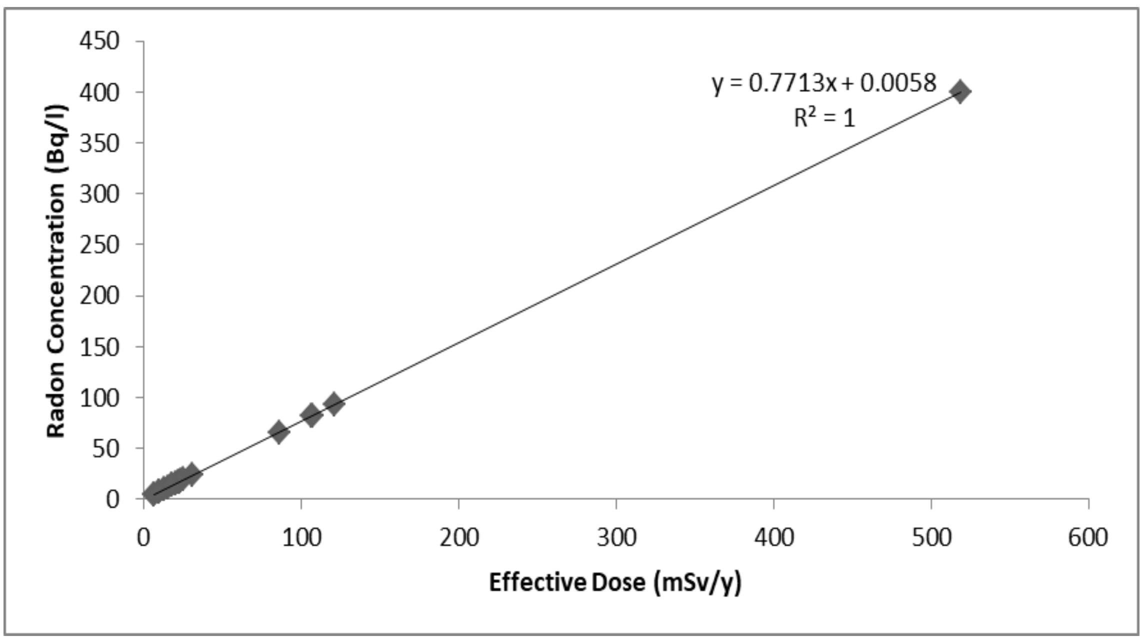

Figure 3: Relationship between Radon Concentration and effective dose

(UNSCEAR, 2000). In addition, the inhalation dose, which is the main cause of lung cancer, varied from 12.6 μSv/y to 1008.252 μSv/y. The total mean effective dose (ingestion and inhalation) was 59.35 μSv/y, which is below the year 2011 maximum value of recommended by the World Health Organization of 100 μSv/y (WHO, 2011). Figure 3 shows the relationship between the Radon concentration and the effective dose in this study. The excess lifetime cancer risk (ECLR) due to inhalation from the water samples ranged from 75.6 to 6053.5 with a mean of 692.9 as shown in column 6 in Table 1. These values were lower than the recommended level in all the sites except in R5 (Iwaraja).

Conclusion

The measurements of waterborne Radon concentration in groundwater wells, along Iwaraja-Ifewara faults line Southwestern Nigeria had been carried out. There exists a significant correlation between Radon concentration and effective dose in the groundwater. The abnormally high Radon concentrations in groundwater from Iwaraja indicated deep flow related to active faults. The cancer risk from the inhalation of Radon gas from the samples was estimated and found to be higher than the world average in Iwaraja. In general, Radon is a serious threat to human health in water. Therefore, it was recommended that deep wells should be dug far from the fault lines, and analytical measurements of Radon level be carried out before consumption of the water especially in Iwaraja.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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