Nigerian Journal of Physics (NJP)
ISSN: 1595-0611
Volume 32(2), June 2023

Estimation of Lung Cancer Risk Associated with Radon Exposure from Quarries in Ede, Southwestern Nigeria

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ABSTRACT
Radon and its progeny are invariably present in the environment. However, its concentration depends mainly upon the content of its parent radionuclide beneath the earth's surface and its diffusion through the surface. This research hereby measures the radon growth from pulverized rock samples collected from five (5) quarries located in Ede, Southwest Nigeria using RAD7 and estimates the cancer risk that may be associated with exposure to the quarry dust by the workers and nearby occupants. The result showed that the radon concentration ranged from 65.03 to 397.76 Bqm^{-3} while the annual effective exhalation dose ranged from 0.042 to 0.399 $mSvy^{-1}$ which is below the ICRP recommended limit of 1 $mSvy^{-1}$. The excess lifetime cancer risk (ELCR) ranged from 0.167×10^{-3} to 1.592×10^{-3} with esPRO quarry having the lowest and Tewo-Crown quarry having the highest compared to the recommended limit of 0.29×10^{-3}. Although low values were recorded for the assayed quarry sites, however, regular monitoring of the quarry site is important, as the continuous inhalation of the quarry dust may be hazardous to the health.

Keywords:
Rock,
Quarry,
Radon,
Exhalation rate,
Lung cancer risk

INTRODUCTION

Southwestern Nigeria is endowed with vast resources of rocks such as granite, granodiorite, gneisses, amphibolites, and many more, that are part of the Precambrian Basement Complex of Nigeria (Haruna, 2017; Akinloye *et al.,* 2019). These stones possess different colors and structural characteristics that when cut and polished, give very lovely and pleasing appearances. Quarrying is an industrial activity that deals with the process of extracting and breaking rocks into smaller aggregates. Owing to the increasing demand for these aggregates for small-scale and monumental construction purposes, the quarry business has grown enormously in Southwestern Nigeria (Gbadebo *et al.,* 2011; Akinloye *et al.,* 2019). Since rocks and their end products contain natural radioactive elements that are widespread in various geological locations. Radon-222 (^{222}Rn), a daughter of uranium-238 (^{238}U) may erupt during the quarry processes and attach itself to the aerosol particles in the atmosphere, which upon inhalation may cause damage to the lung tissue to cause lung cancer.

Hence, quarry activities release natural radiation into the environment, and of radiological concern to human health is the release of radioactive gaseous dust during the process (UNSCEAR, 2000). ^{222}Rn has been identified and classified to be a class I carcinogen by the International Agency for Research on Cancer, World Health Organization, and Environmental Protection Agency. In view of this, it is important to determine radon concentrations and calculate the risk of lung cancer from exposure to radon gas as a result of different quarry sites in Ede and its surroundings in Osun State, Southwestern Nigeria. This is in a bid to estimate how safe the workers and local residents are and also to provide more enlightenment on the risk associated with inhalation of radon gas.

MATERIALS AND METHODS

Study Area

The study areas are in Ede, a town in Osun State, Southwestern Nigeria. Ede is on a pegmatite vein characterized predominantly by Beryl, Tourmaline, Feldspar, Columbite, Mica, Quartz and Tantalite (Ajayi, 1981). The quarry sites considered within Ede are

Ayanfe quarry (AQ), Slavar quarry (SQ), Tewo-Crown quarry (TQ) and Wolid quarry (WQ), all of which are located in Awo town, Egbedore Local Government of Osun State, and esPRO quarry (EQ) situated around Gbongan area near Ikire in Osun State. Figure 1 shows the area from which the samples were collected.

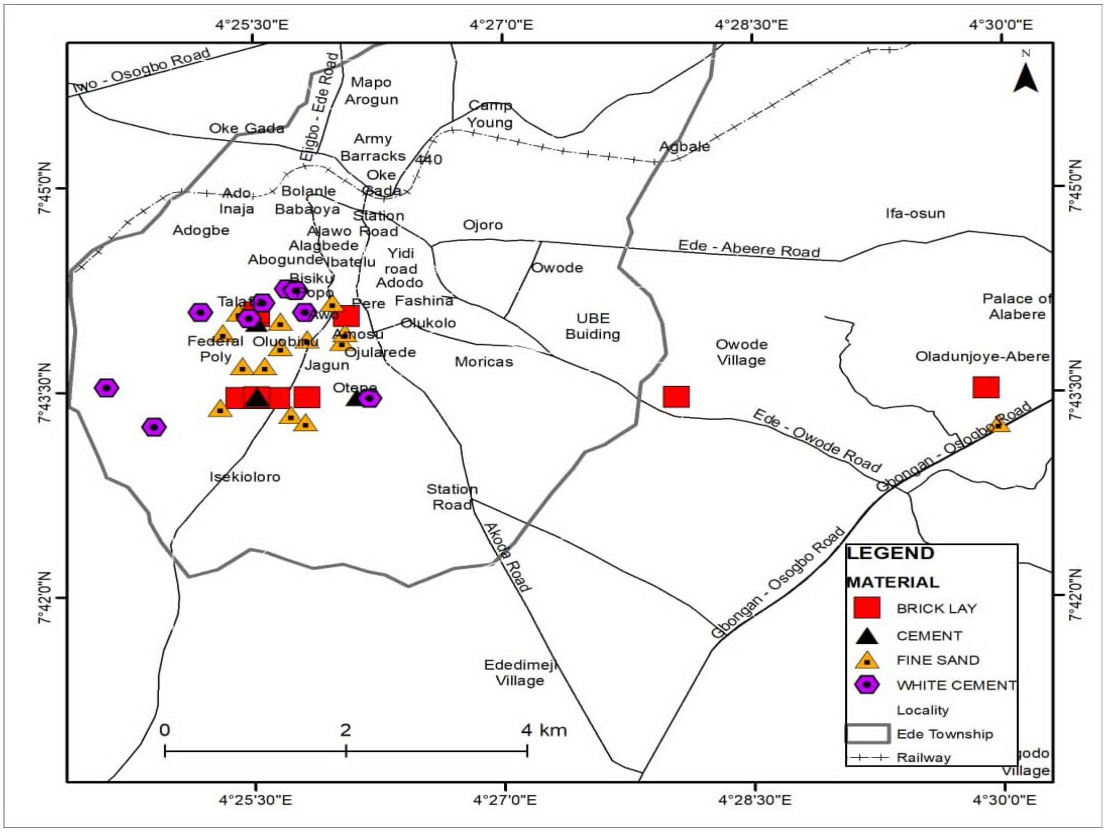

Figure 1. Map of Ede town, showing the sampling points.

Sample collection and preparation

Different granite rock chippings were collected from each of the sampling locations and crushed accordingly. The crushed samples pass through a 2 mm mesh and are oven-dried at 100˚C to ensure complete removal of water which otherwise would lead to self-absorption. Thereafter, the samples were pulverized to a size of 300 µm. Five hundred grams (500 g) of each pulverized sample was packed separately in an already decontaminated container having an internal volume (V_c) of 650 cm^3 under normal atmospheric conditions, sealed and made airtight for 30 days to prevent the escape of radon gas and ensure that radon and its progeny are confined within the container. The container is made of a one-way inlet and outlet probe connected to the top and base of the container, respectively (Lawal *et al.,* 2021).

Measurement of Radon Concentration

The prepared samples were analyzed using an active electronic solid-state detector RAD7 (DURRIDGE Company Inc., USA) operating on the alpha spectrometry technique. The detector was set following the procedure described by Lawal *et al.,* (2021 and the radon gas was monitored every two hours (2 h) pumping phase for forty hours (40 h). This allowed for the establishment of the samples' radon growth as a function of time (Stoulos *et al.,* 2003) expressed by Equation 1:

$$C_{Rn} = \frac{E(1-e^{-\lambda_f t})}{V_c \lambda_f} + C_0 e^{-\lambda_f t} \qquad (1)$$

where E represents the sample radon exhalation rate (Bqh^{-1}), V_c is the volume of the container (m^3), C_0 (53.96 Bqm^{-3}) is the radon background concentration in the container; λ_f is the effective removal rate (h^{-1}), which is the sum of the radon decay constant λ (7.56 $\times 10^{-3} h^{-1}$) and the container leakage rate λ_c. By monitoring the rate of pressure loss inside the container for a predetermined time period, the container leakage rate of 0.01509 h^{-1} was calculated. This was discovered by attaching a leak rate meter and watching the pressure changes over time and the effective removal rate was calculated to be 0.0227 h^{-1}. The exhalation rate of each of the samples was determined by fitting the experimental data collected from the continuous monitoring of radon growth.

Estimation of radiological indices

The time spent by individuals outdoors varies widely globally (UNSCEAR 2000). Hence, the annual exhalation of the dose absorbed was estimated using Equation 2.

D_{Rn} ($Bqkg^{-1}y^{-1}$) = E ($BqKg^{-1}h^{-1}$) x 24 x 365 (2)

where D_{Rn} is the annual exhalation absorbed dose, and E is the exhalation rate.

The annual effective dose was calculated using Equation 3:

$H_E\,(mSvy^{-1}) = D_{Rn} \times W_R \times W_T.$ (3)

where D_{Rn} remains as earlier defined, W_R is the radiation weighting factor (which is 20 for alpha particles), and W_T is the tissue weighting factor for the Lung 0.12 (ICRP, 1991; Ojo and Ajayi, 2015).

Excess lifetime cancer risk (ELCR) is the potential carcinogenic effect that are characterized by estimating the probability of cancer. The ELCR was calculated using Equation 4.

ELCR = H_E x DL x RF (4)

where H_E is the annual effective dose (mSv/y). DL is the average lifetime (assumed to be 70years), and RF is the risk factor measured in Sv^{-1} which was recommended to be $0.057Sv^{-1}$ for critical cancer risk conditions for public exposure (ICRP, 2009; Ojo and Ajayi, 2015).

RESULTS AND DISCUSSION

The results obtained for the radon growth as a function of time for the sample from each quarry site are presented in Table 1. It was observed that the radon activity grows till 24 h for AQ and EQ before instability set in, while those of WQ, SQ, and TQ grow throughout the measuring period (40 h). The results obtained for the radon exhalation rate, radon concentration annual absorbed dose, annual effective dose, and excess lifetime cancer risk are presented in Table 2. The findings revealed that the radon exhalation rate varies from one quarry site to another and was found to be below the annual limit of 370 $Bqkg^{-1}h^{-1}$. This variation can be attributed to the geological and geochemical composition of the earth surface on which each quarry was sited (UNSCEAR, 2000), as well as the quarry activities associated with each site (Gbadebo *et al.*, 2011; Akinloye *et al.*, 2019). Hence, the results of the exhalation rate revealed that proper precautionary measures are necessary for masking the ^{222}Rn emission inside a dwelling when rock samples from quarry sites with high exhalation rates are used for the construction of houses.

Table 1: Radon growth as a function of time for the quarry sites

T (h)	AQ	WQ	SQ	EQ	TQ
6	57.66	150.81	57.07	33.77	229.63
12	75.23	223.08	79.54	44.30	277.47
18	97.67	289.71	106.97	57.64	353.84
24	109.66	320.03	106.29	80.09	355.95
30	96.29	341.27	107.65	59.71	357.36
36	84.34	424.77	109.08	65.32	387.76
40	71.67	446.75	121.75	75.17	406.27

AQ - Ayanfe Quarry, WQ – Wolid Quarry, SQ – Slavar Quarry, EQ – esPRO Quarry, TQ – Tewo-Crown Quarry.

The radon concentration and annual effective dose for the quarry sites were also found to be lower than 600 Bqm^{-3} and 1 $mSvy^{-1}$ reference level respectively (ICRP, 2007). The rate of lung cancer risk was observed to be lower than the ICRP recommended limit of 0.29 $x10^{-3}$ (Taskin *et al*, 2009; Imeh and Emmanuel, 2016) at EQ, higher at WQ, SQ and TQ respectively, and approximately equivalent values were observed at AQ.

Table 2: Radon concentration, Exhalation rate, and estimated radiological indices

Quarry Site	E ($Bqkg^{-1}h^{-1}$)	C_{Rn} (Bqm^{-3})	D_{Rn} ($mSvy^{-1}$)	H_E ($mSvy^{-1}$)	ELCR ($x\ 10^{-3}$)
AQ	0.004	94.76	35.04	0.084	0.335
WQ	0.018	390.55	157.68	0.378	1.508
SQ	0.005	117.64	43.80	0.105	0.419
EQ	0.002	65.03	17.52	0.042	0.167
TQ	0.019	397.76	166.44	0.399	1.592

C_{Rn} – radon concentration, E – radon exhalation rate, D_{Rn} – annual exhalation absorbed dose, H_E – annual effective dose, ELCR – excess lifetime cancer risk, AQ - Ayanfe Quarry, WQ – Wolid Quarry, SQ – Slavar Quarry, EQ – esPRO Quarry, TQ – Tewo-Crown Quarry.

CONCLUSION

The result in the present work indicates that the pulverized rock samples from the quarry sites under investigation have different exhalation rates, radon concentrations, and radiological indices in the order TQ > WQ > SQ > EQ > AQ. Although low values were recorded for the assayed quarry sites, however, however, regular monitoring of the quarry site is important, as the continuous inhalation of the quarry dust may be hazardous to the health.

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