Comparative Study on Radiological Impact of Quarry Industries: a case study of Johnson Quarry, Ondo State and Irepodun Quarry, Osun State, Nigeria

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Abstract: The radiological impact of quarry activities on workers and local residents due to the presence of naturally occurring radionuclides have been investigated for two quarry industries. The study employed an in-situ measurement using a portable gamma-ray scintillometer. The mean value obtained for the various radiological indicators estimated for Johnson quarry are 1.03 x 10^{-3} μSv/hr, 1.81 μSv/y and 6.34 x 10^{-3} for exposure rate, annual effective dose equivalent and excess lifetime cancer risk respectively, while those of Irepodun quarry are 0.49 x 10^{-3} μSv/hr, 0.85 μSv/y and 2.98 x 10^{-3} respectively. The various radiological indicators estimated are lower than the permissible limits for occupational and public exposure.

Index Terms: Natural Radiation, Radiological Impact, Quarry Industries, Ond o State, Osun State, Nigeria

1 INTRODUCTION

Radiation had always been an integral part of human environment, and exposure to radiation is a continuing and inescapable phenomena on Earth. Both radionuclides and the radiation emitted are present naturally and can also be produced artificially (UNSCEAR, 2008). Natural radiation can be classified into primordial and cosmogenic radionuclides, with those of primordial origin being in existence long before the emergence of the Earth. Radiation emanating from rocks is produced by the radioactive elements and their isotopes that are part of the minerals and rocks that constitute the Earth's crust (Johnson, 1991). The rocks and its end products contain natural radioactive elements, and of most importance are the uranium (^{238}U) and thorium (^{232}Th) decay series and singly occurring non-series potassium (^{40}K). These rocks are generally widespread in various geological environments, most of which depend on their mineralogy and geochemistry (Chang *et al.*, 2008). Artificial radiation results from radioactive materials concentrated by human activities such as medical practices, nuclear reactors, mining and so on. However, both the natural and artificial radiations constitute damage to biological matter. Exposure to natural background radiation is the most significant part of the total exposure to radiation. Out of which radon is the largest natural source of radiation, accounting for half the total exposure from all sources. (UNSCEAR, 2008).

Southwestern part of Nigeria is endowed with vast resources of rocks that are part of the Precambrian Basement complex of Nigeria (Haruna, 2017). Trace quantities of radioactive elements have been reported in all types of rocks, however radioactivity concentrations vary based on classifications of rocks and radioelements. Higher levels of naturally occurring radionuclides are associated with igneous rocks compare with metamorphic and sedimentary rocks (Johnson, 1991).Quarry is an industrial activity that deals with the process of extracting and breaking of rocks into smaller aggregates. Owing to the increasing demand for aggregates in small scale and monumental construction purposes, quarry business has grown enormously in Nigeria. However, the resulting effects due to quarry activities are the extensive devastation of the environments in terms of deforestation, destruction of nearby farmlands with stone relics, releasing of gaseous pollution and toxic metals from the use of explosives and chemicals into the environment (Gbadebo *et al.*, 2011). In addition, quarry activities are fast method of releasing natural radiation into the environments, and the major radiological concern to human health is the gaseous dust released during the

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quarry process. This gaseous dust may contain radionuclides traverse into the atmosphere spreading far and wide, thus causing large areas to be contaminated in varying degrees with radionuclides and toxic metals. Radon, a daughter product of both ^{238}U and ^{232}Th erupt and attach themselves to the aerosol particles in the atmosphere. This gaseous radionuclide finds its way into human lungs through inhalation, thereby causing biological damage to the lung tissue. Example of such damage is the occurrence of cancer, a major stochastic effect produced by radiation. Hence, it is important to monitor and evaluate the radiation level in order to keep the radiation exposure as low as reasonably achievable (ALARA principle).

In many parts of the world, radiation exposure level is being monitored regularly, and with the increased public concern over radiation safety. Studies on natural background radiation have provided good scope for evaluating biological effects caused by exposure to radiation on a long-term basis, no matter how small the dose may be (Jan *et al.*, 2005). In Nigeria, radiation monitoring started in the 1960's after the French carried out nuclear weapons tests in the Sahara Desert. Ever since, there had been an increased monitoring and awareness about radiation levels in air, soil and water and the implications on biological matter (Nwosu *et al.*, 1974; Olomo *et al.*, 1994; Akinloye and Olomo, 1995; Olomo *et al.*, 2003; Ugwu *et al.*, 2008; Akinloye *et al.*, 2012; Isola and Ajadi, 2015; Akinloye *et al.*, 2018 and many more). This study is aimed at assessing and comparing the radiation exposure rate due to naturally occurring radionuclides resulting from quarry activities in Ondo and Osun States, Nigeria. This is necessary so as to assist in monitoring the radiological impact of the quarry businesses, protect the safety of its workers and local residents of the surrounding settlements.

2 MATERIALS AND METHODS

2.1 Study Area

The quarry industries assessed are Johnson and Irepodun quarries. Johnson quarry is situated at kilometre 6, Akure-Owo road, Akure, Ondo State. The quarry site covers an area of about 7.7874 Hectares. The nearest four settlements away from the quarry are Araromi, Ibatayo, Ilado and Oba-ile, all located in Akure South Local Government Area, Ondo State. Irepodun quarry is situated along Awo-Iwoye road, Awo, Osun State. The nearest four settlements away from Irepodun quarry are Agogo, Elekuro, Elerin and Olokusa; all located in Egbedore Local Government Area of Osun State. The two States, Ondo and Osun located beside each other are situated in the Southwestern part of Nigeria as shown in Figure 1.

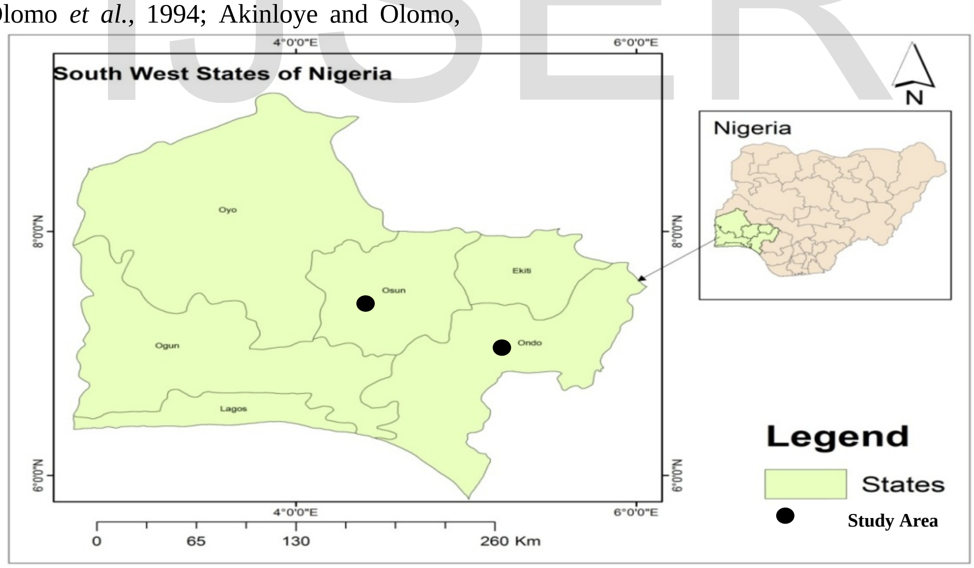

Figure 1: Map showing the location of the study area.

2.2 Instrumentation and Measurements

The assessment of exposure to radiation due to the quarry activities was done through an in-situ survey conducted at specific distances from the quarries. The survey meter employed is a portable gamma-ray scintillometer (GRS) model GR-101A, a Geometric product of Sunnyvale, California, USA. The instrument was designed to provide high accuracy and stable measurements of all naturally occurring gamma radiation of energies above 0.05 MeV. Prior to commencing the field measurements, the instrument was calibrated at the Federal Radiation Protection Services (FRPS) situated at University of Ibadan, Nigeria. This was necessary so as to ensure quality assurance and standardization of the instrument. The calibration equation obtained is as expressed in Equation 1:

$$Y = 19514X \quad (1)$$

Equation 1 gives the count rate Y (counts per second) in terms of the exposure rate X (μSv/hr) (Akinloye *et al.*, 2002). The exposure rate represents the background radiation level of the quarry site being investigated.

Thereafter, measurements of the radiation exposure rate was carried out by taking readings at intervals of 60 strides, approximately 44 m, from the main processing unit of the quarry down to the administrative blocks. The four neighbouring settlements at certain distances from each quarry industry were also assessed so as to determine the distribution of the natural background radiation as one moves away from the quarry site. This was done in order to determine the possible radiological effect of the quarry on the surrounding settlements. The procedure employed for taking the readings include the positioning of the GRS at 1m away from the ground surface at a sampling point both within and outside the quarry site. Readings were taken from the meter of the instrument after the pointer had stabilized. All the readings were taken using the meter full scale range of 0.1k and audio range of 75% specification. The measurements of the exposure rate was carried out in units of count per second (cps) which was later converted to exposure rate (μSv/hr) using Equation (1)

2.3 Estimation of Radiological Parameters

The contribution of the natural background radiation to the annual effective dose equivalent as a result of the quarry activities was estimated using Equation (2):

$$AEDE(\mu\text{Sv}y^{-1}) = X \times O_f \times T \quad (2)$$

Where X is the exposure rate in (μSv/hr), O_f is the outdoor occupancy factor (0.2), and T is the time of exposure for a year (8760 h) (UNSCEAR, 2000).
The excess lifetime cancer risk (ELCR), a radiological indicator that quantifiestheprobabilityofdevelopingcanceroveralifeti meatagivenexposurelevelfrom the ingestion or inhalation of radionuclides. This was determined using Equation (3):

$$ELCR = AEDE \times D_l \times R_f \quad (3)$$

Where D_l is the average duration of life (70 y), and R_f is the risk factor (0.05 Sv^{-1}) obtain from ICRP (2007).

3 RESULTS AND DISCUSSION

Table 1 presents the results obtained for the measured count rate (cps) and the estimated radiological indicators at a distance of 44 m within the vicinity of the quarry industry assessed. The results obtained for the count rate at Johnson quarry range from 17 cps to 38 cps, with the highest value of 38 cps recorded at the main processing unit of the quarry. The mean value of 20.17 cps was obtained for the whole premises of Johnson quarry. At Irepodun quarry, the results obtained for the count rate range from 7 cps to 19 cps, with the highest value of 19 cps recorded at the main processing unit of the quarry. The mean value of 9.5 cps was obtained for the whole premises of Irepodun quarry. It was observed that as one moves away from the processing unit of each of the quarry site, the intensity of the count rate reduces. The difference in values obtained for the two quarry sites may be attributed to the differences in the geology of the locations (UNSCEAR, 2008).

The results obtained for the various radiological indicators estimated show that at the main processing unit of the two quarry sites, the quarrying process contribute to the inhalation of environmental background radiation, as activities related to the extraction and processing of ores can lead to enhanced levels of naturally occurring radioactive material (NORM) in products, by-products and wastes (UNSCEAR, 2008). The results show that higher value of exposure rate was obtained at the main unit where the major rock blasting and crushing occur. This is an indication that spending too much working hours in the vicinity of the pit may results in the inhalation of the gaseous dust that is hazardous to human health, thereby contributing to occupational exposure and may result later in a chronic health effect. However, the AEDE value obtained at the processing units of Johnson quarry (3.41 μSv/y) and Irepodun quarry (1.70 μSv/y) is lower than the total inhalation exposure value (1.26 mSv/y) for public exposure to natural radiation from various sources (UNSCEAR, 2008). Figure 2 show the chart comparing the AEDE obtained at the two quarries, indicating that, as the distances increase, the AEDE value decreases.

The mean AEDE values obtained for the working premises of each of quarry site is lower than the permissible limit of 20 mSv/y for occupational exposure recommended by UNSCEAR (2008). The probability of any worker developing cancer over a lifetime of exposure to radiation from the quarry activities is therefore minimal, as the mean ELCR value obtained for each of the quarry is lower than $1 x 10^{-4}$ recommended by international bodies.

Table 1: Radiation Count rate and estimated radiological parameters within the premises of the quarry sites.

S/N	Distance (m)	Johnson Quarry				Irepodun Quarry			
		Y (cps)	**X** $x10^{-3}$ (µSv/hr)	**AEDE** (µSvy^{-1})	**ELCR** ($x10^{-6}$)	**Y** (cps)	**X** $x10^{-3}$ (µSv/hr)	**AEDE** (µSvy^{-1})	**ELCR** ($x10^{-6}$)
1	0	38	1.95	3.41	11.94	19	0.97	1.70	5.97
2	44	26	1.33	2.33	8.17	8	0.41	0.71	2.51
3	88	20	1.03	1.81	6.28	9	0.46	0.81	2.83
4	132	15	0.77	1.35	4.71	9	0.46	0.81	2.83
5	176	18	0.92	1.61	5.66	10	0.51	0.89	3.14
6	220	18	0.92	1.61	5.66	7	0.36	0.63	2.20
7	264	24	1.23	2.16	7.54	8	0.41	0.71	2.51
8	308	17	0.87	1.52	5.34	7	0.31	0.54	2.20
9	352	19	0.97	1.70	5.97	7	0.36	0.64	2.20
10	396	17	0.87	1.52	5.34	10	0.51	0.89	3.14
11	440	16	0.82	1.44	5.03	10	0.51	0.89	3.14
12	484	14	0.72	1.26	4.40	10	0.51	0.89	3.14
Range		**14– 38**	**0.72 - 1.95**	**1.26 -3.42**	**4.40 - 11.94**	**7 - 19**	**0.31 – 0.97**	**0.63 – 1.70**	**2.20 – 5.97**
Mean		**20.17**	**1.03**	**1.81**	**6.34**	**9.5**	**0.49**	**0.85**	**2.98**

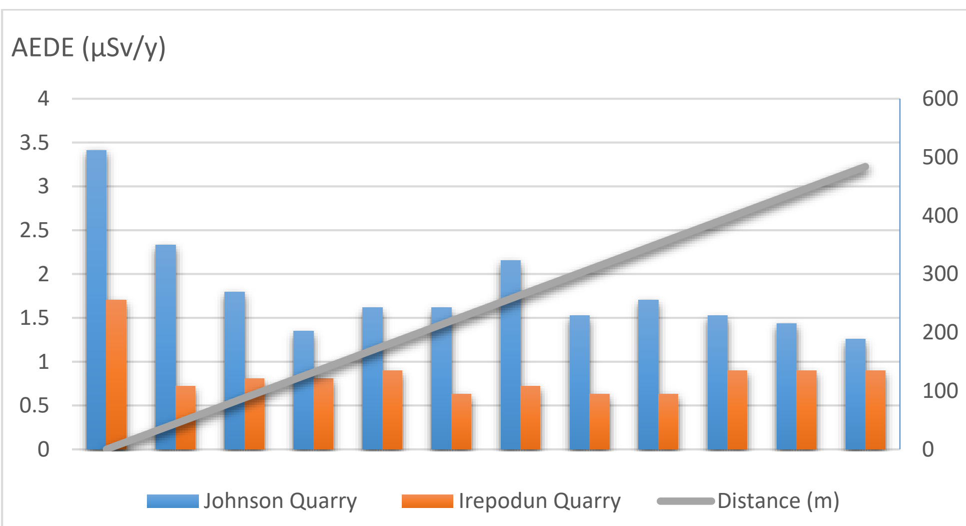

Figure 2: Comparison of the AEDE obtained for Johnson and Irepodun Quarry

This indicates that the working premises of the two quarry sites may not constitute any immediate radiological effect to the workers of the quarry industries. The values obtained for the various radiological parameters are in agreement with report on quarry activities found in literature (Gbadebo, 2010; Isola and Ajadi, 2015; Ugbede and Echeweozo, 2017).

Tables 2 and 3 presents the results obtained for the count rate and the estimated radiological indicators at various distances from the main processing unit to the surrounding settlements of each quarry site. The results obtained for the count rate at 200 m to 850 m from Johnson quarry range from 7.4 cps to 10 cps, with the highest value of 10 cps recorded 200 m from the quarry. Also for Irepodun quarry, the count rate obtained range from 11 cps to 16 cps, with the highest value of 16 cps recorded 1500 m away from the quarry. The difference in values obtained from the two quarry sites may be attributed to the differences in the geology of the locations. However, both the count rate and various radiological indicators estimated show that as one moves away from the quarry site into the nearby settlements, the values reduce. The mean AEDE value obtained for the environment of Johnson quarry (0.79 µSv/y) and Irepodun quarry (1.21 µSv/y) was lower than the permissible limit of 1 mSv/y for public exposure recommended by UNSCEAR (2008), and in agreement with other reported studies on quarry activities (Ademola, 2011; Nwankwo *et al.*, 2014; Ugbede and Echeweozo, 2017). The low values of the radiological indicators obtained for the study area indicate that the environment of the quarry industries may not constitute a radiological hazard to the residents of the neighbouring settlements.

Table2: Radiation Count rate and estimated radiological parameters at various distances from the main processing unit of Johnson quarry to nearby settlements.

S/N	Settlements	Distance (m)	Y (cps)	X $x10^{-3}$ (µSv/hr)	AEDE (µSvy^{-1})
1	Agogo	200	10	0.51	0.90
2	Elekuro	300	9.4	0.48	0.84
3	Olokusa	700	8.4	0.43	0.75
4	Elerin	850	7.4	0.38	0.66
Range			**7.4 - 10**	**0.38 – 0.51**	**0.66 – 0.90**
Mean			**8.8**	**0.45**	**0.79**

Table 3: Radiation Count rate and estimated radiological parameters at various distances from the main processing unit of Irepodun quarry to nearby settlements.

S/N	Settlements	Distance (m)	Y (cps)	X $x10^{-3}$ (µSv/hr)	AEDE (µSvy^{-1})
1	Oba-ile	1500	16	0.82	1.44
2	Igbatayo	2300	15	0.77	1.34
3	Araromi	2400	12	0.62	1.08
4	Ilado	3000	11	0.56	0.99
Range			**11 - 16**	**0.56 – 0.82**	**0.99 – 1.44**
Mean			**13.5**	**0.69**	**1.21**

4 CONCLUSION

Measurement and comparative study of the distribution of background radiation levels in Johnson and Irepodun quarries have been undertaken using a portable gamma-ray scintillometer. The results obtained show that maximum peak radiation level occurred at the processing unit of each of the quarries, where the rock blasting and crushing take place. The mean value obtained for the various radiological indicators estimated for Johnson quarry are 1.03 *x* 10^{-3} µSv/hr, 1.81 µSv/y and 6.34 *x* 10^{-3} for exposure rate, annual effective dose equivalent and excess lifetime cancer risk respectively, while those of Irepodun quarry are 0.49 *x* 10^{-3} µSv/hr, 0.85 µSv/y and 2.98 *x* 10^{-3} respectively. The results obtained are in agreement with other reported studies on quarry activities in Nigeria. The study shows that the radiation levels are still below the permissible level recommended by international bodies, thus may not pose immediate radiological health damage to the workers and the residents of the neighbouring settlements.

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