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Assessment of Radiation Level Within and Around Stonebridge Quarry Site, Km 22 Lagos Ibadan Express Way, Southwest Nigeria

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Abstract: Within and around major cities of Southwestern Nigeria, there are scores of quarry industries whose activities constitute menace into the immediate environments. This study assessed the level of natural radiations resident in different rock aggregate sizes, surface and subsurface soils within and around a typical quarry sites (Stone bridge quarry) located close to Ibadan, Southwestern Nigeria. Radiations were determined to a maximum depth of 2.0 m and up to 500 m away from the quarry phases. The radiation level was found to be higher in the freshly quarried coarse aggregate (138 count per minute (cpm)) than previously quarried coarse rock aggregate (132 cpm) and also higher in muscovitic coarse aggregate (120 cpm) than in biotitic coarse aggregate (108 cpm). However, the radiation levels in dust (<½ inch), 1.27 cm (½ inch), 1.91 cm (¾ inch) aggregates are 90, 126 and 120 cpm, respectively. Similarly the radiation levels generally ranged between 42 and 120 cpm in the surface soils and between 48 and 138 cpm in the subsurface soils. However, the maximum value of dose rate and annual effective dose of 47.7±1 ng h^{-1} and 58.54±1 μSv $year^{-1}$ was recorded for aggregate sizes, while the maximum dose rate of 43.4±1 and 49.9±3 ngy h^{-1} were recorded for surface and subsurface soils, respectively. The maximum annual effective dose of 53.30±1 and 61.4±2 μSv $year^{-1}$ for surface and subsurface soils, respectively. Continuous exposure on the parts of the quarry workers and the farmers in the study area may constitute health hazards in the near future. Regular monitoring of radiation level and determination of different types of radio-nuclides in the area is recommended in order to put in place appropriate policy on health of the citizenry.

Key words: Bedrocks, soil, quarry, radiation, aggregate, size, Southwest Nigeria

INTRODUCTION

Southwestern Nigeria has vast resources of dimension stones such as granites, granodorite, gneisses, amphibolites and many more which possesses colours and structures that impart a particular aesthetic appearance when cut and polished. The rocks are also rich in silica and are of high quality and give rise to high strength concrete (Akpokodje, 1992). They compared well with BS (1975) acceptance limits for absorption (<3%), bulk density (>2.60 g cm^{-3}) aggregate impact value (<30%) (Harvey *et al*., 1974; Collins, 1988; Hudec, 1980) which make these rocks quarrable for construction purposes. Most of the granites and its varieties are widespread in Abeokuta, Odeda, Akiode, Ajebandele, Gbokutaru areas of Ogun state; Okeigbo, Idanre, Ondo, Akure areas of Ondo state; Igbo Ora in Oyo state and Ado-Ekiti, Ikere all in Ekiti state where they appear massive and extensive (Jones and Hockey, 1964). This naturally occurring and abundant resource has great values that can be harnessed for the development of these states. Granite when used as cutstones or dimension stones are considered by many as the premium material for beauty and durability in institutional and monumental constructions. Granite as cutstones can be used in flagging, roofing slates and mills stock slates. They can be used as curbing and paving blocks and in laboratory furniture and sinks. They have been used to line tube mills for grinding one or other materials. However, the only notable usage of these dimension stones till date is its exploitation by the people in the quarry business as aggregates in small scale and monumental constructions especially in the nearby city of Lagos the economic nerve centre of Nigeria. The resultant effects of quarry activities is the extensive devastation of the environments in terms of deforestation, destruction of

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nearby farmlands with stone relics, gaseous pollution from the use of explosives, release of toxic metals into the surrounding environments. The natural radiations from these granitic bodies and other geological formations are other sources of environmental hazard (Fernandez *et al.*, 1992; UNSCEAR, 2000; Doveton and Merriam, 2004). In this study, measurements of radiations from various rock aggregates, surface and subsurface soils within and around a typical quarry sites, Stone Bridge quarry were carried out. The effects of aggregate sizes, soil distribution (i.e., surface and subsurface) and proximity of the quarry site on the radiation concentrations were assessed and the possible health implication also inferred.

MATERIALS AND METHODS

Study area: The study area, Stone Bridge quarry is found at 22 km LagosIbadan expressway, Oyo state, Southwestern Nigeria. It is situated on longitude (9°22' and 9°26') and latitude (7°98' and 8°08'E) and is accessible by network of asphalt and untarred graded roads. It has an undulating topography with iselberg of rocks that are quarried by Stonebridge, Ratcon, WASSI and many other quarries.

The area is tropical in nature with two climatic seasons viz: wet season which begins in March/April and ends in October with a break in August and the dry season which begins in November and end in March (Oguntoyinbo *et al.*, 1983). The soils of the area is generally lateritic with some clay intercalation, while the geology of the area is essentially crystalline Basement Complex with dominant rock suites being granite gneisses (Rahaman, 1988). This rock which belongs to the Late Phase Biotitemuscovite has been observed to be essentially biotitic in composition and occur separately or in juxtaposition with some muscovitic bends (Jones and Hockey, 1964) in the study area.

Sample collection: On the site measurements of radiations from different rock aggregate sizes (Quarry rock dust, 12.7, 19 and 44.4 mm of black and white colour, 9.6 mm coarse aggregate etc.) were carried out at the two phases of the Stonebridge quarry. The *in situ* measurements of the radiations from the surface of the soil was done directly in an undisturbed manner, while the measurement of the radiation from the subsurface soils was carried out directly inside the manually dug pits each of which is 0.85 m wide and either 1.5 or 2.0 m deep. Measurements of the radiations were achieved using rpi rad-monitor model, a portable digital radiation meter; inspector 6250 (S.E International, Inc., USA). The radiation meter which is optimized to detect low levels α, β, γ and X-ray radiations, measures radiation parameters in units of activity which was converted to dose rate and exposure rate. The meter consists of a halogen-quenched Geiger Muller tube detector with mica window of density 1.5-2.0 mg cm^{-1} and 3500 cpm/mR/h reference to Cs-137. The meter has an accuracy of ±15%. The measurements were carried out by positioning the radiation meter at the targeted sample (rock aggregates, surface and subsurface soil samples) located at varying distance from the quarry phase (s) established by Geographical Positioning System (GPS). For each measurement, the background radiation level was recorded. At each point, a sample of 10 measurements were taken and the mean value considered. The background reading was then deducted from the mean value to obtain the actual mean radiation levels emitted by each sample type. Measurements of the activity and exposure rate were carried out in units of count per minute (cpm) and milli Roentgew per hour (mR/h), respectively. The activity was further converted to dose equivalent rate by a conversion factor of 32240 cpm = 100 mSv h^{-1} as specified by the equipment manufacturers. This was achieved assuming an average of 8 working hours by the farmers and the quarry workers a day for 6 days of a week (excluding Sundays). The result was then compared with the dose reference of 0.02 mSV week^{-1} for protection against ionizing radiation (ICRP, 1992).

Quality assurance procedures: The precaution taken in order to ensure quality assurance include viz: standardization of the measuring equipment before usage, multiplicity of measurement for each sample type (n = 6 for radiation measurements for each sample type). The knob was turned to return the meter to zero after each measurement.

Data analysis/conversion: The generated data were converted to ngy h^{-1} using the relation 1.0 rad = 1.0×10^{-2} gy the results are presented as means and standard deviations, while the bar chart illustrations were carried out to determine the significant relationships between the radiations from different sample types.

RESULTS

The results obtained in this study are display of the average radiation levels emitted by each sample type with their standard errors even at varying distances away from the quarry. The errors were estimated using the standard error method. The results shown are for the measured parameters of activity (cpm), exposure rate (mR/h) and equivalent dose rate (mSv week^{-1}). The results of the radiation measurement obtained from the quarry sites and their corresponding various aggregate sizes are shown in Table 1, while measured radiations in both the surface and subsurface soil samples are shown in Table 2 and 3. These also show other valuable parameters such as the coordinates where each sample was collected and their corresponding altitudes. In order to have better evaluation of the different level of radiations emitted from different sample types, a plot of exposure rate against different locations and sample types weres shown in Fig. 1 and 2.

The study area is on a relatively high elevation with altitudinal values in the range of between 128 and 166 m above sea level. The highest rock exposed at the quarry phase is about 4 m high above ground surface. The surface radiations at the quarry phase was 120 cpm with an exposure rate of $4.34\pm0.01\times10^{-2}$ mR h^{-1} value and a dose eqviualent of $1.80\pm0.03\times10^{-3}$ mSv week^{-1}. Among the aggregates, the highest measured radiation was 138 cpm with an exposure rate of $6.20\pm0.01\times10^{-2}$ mR h^{-1} and a dose eqviualent of $2.16\pm0.03\times10^{-3}$ mSv week^{-1} obtained from the freshly quarried rock boulders (i.e., coarse aggregates) followed by 132 cpm with exposure rate of $4.77\pm0.02\times10^{-2}$ mR h^{-1} and dose equivalent of $1.99\pm0.01\times10^{-3}$ mSv week^{-1} obtained from the previously quarried rock boulders (i.e., coarse aggregates). Among the sizeable aggregates, ½ inch aggregates has the highest radiation value of 126 cpm with exposure rate of $4.56\pm0.03\times10^{-2}$ mR h^{-1} and dose equivalent of $1.89\pm0.02\times10^{-3}$ mSv week^{-1}, while <½ inch aggregates (i.e., quarry dust) has radiation value of 90 cpm with an exposure rate of $3.25\pm0.02\times10^{-1}$ mR h^{-1} and dose equivalent of $1.35\pm0.05\times10^{-3}$ mSv week^{-1}. Investigations have shown that levels of radiations vary considerably based on rock types and also in the types of

Table 1: Radiation Measurements of Rock Aggregates from the Quarry Environment

Rock aggregates	Count per minute (cpm)	Dose equivalent ($\times10^{-3}$ mSv week^{-1})	Dose rate Dg (ng yhh^{-1})	Annual effective doserate (µS year^{-1})
½ inch	126	1.89±0.03	45.6±2	56.00±3
Aggregate mixture	108	1.62±0.04	39.1±1	48.03±2
3/4 inch	120	1.80±0.03	43.4±1	53.32±1
Dust	90	1.35±0.05	32.5±2	39.93±2
7/8 (black)108	108	1.62±0.02	39.1±1	48.03±2
7/8 (white	120	1.80±0.01	43.4±2	53.32±1
½ inch with mud	108	1.62±0.02	39.1±1	48.03±2
QP1	132	1.99±0.00	47.7±1	58.54±1
QP2	138	2.10±0.05	49.0±3	61.35±1
Aggregate mixture 2	108	1.62±0.02	39.1±3	48.03±2
Quarry site	120	1.80±0.03	43.4±2	53.32±3

Table 2: Radiation Measurement of Surface soil of Quarry Environment

Pit no.	GPS readings	Altitude	Dose equivalent ($\times10^{-3}$ mSv week^{-1})	Dose rate Dg (ngy h^{-1})	Annual effective doserate (µS year^{-1})
1	N07.20874E003.81196	151	28.600±0.10	41.0±2	50.62±2
2	N07.20876E003.81200	151	0.180±0.05	43.0±4	53.30±1
3	N07.20919E003.81241	151	0.162±0.02	39.0±1	48.01±0
4	N07.20815E003.81215	145	0.135±0.03	32.0±5	39.90±3
5	N07.20867E003.81228	151	0.135±0.05	32.0±2	39.80±1
6	N07.20773E003.81322	128	9.04±0.010	21.0±3	26.63±1
7	N07.20712E003.81400	128	6.33±0.020	15.0±1	18.55±2
8	N07.20800E003.81495	145	9.04±0.030	21.0±1	18.55±1
9	N07.20837E003.81530	143	9.95±0.050	23.0±1	29.21±2
10	N07.20782E003.81522	166	7.23±0.030	17.0±1	20.89±1
11	N07.20644E003.82144	157	8.10±0.020	19.0±3	29.90±1

Table 3: Radiation in Subsurface Soil of Quarry Environment

Pit no.	GPS readings	Altitude	Dose equivalent ($\times10^{-3}$ mSv week^{-1})	Dose rate Dg (ngy h^{-1})	Annual effective dose rate (µS year^{-1})
1	N07.20874E003.81196	151	0.199±0.05	47.0±2	58.00±5
2	N07.20876E003.81200	151	0.208±0.01	49.0±3	61.35±2
3	N07.20919E003.81241	151	0.18±0.02	43.0±1	53.26±1
4	N07.20815E003.81215	145	0.18±0.04	43.0±3	53.20±2
5	N07.20867E003.81228	151	9.04±0.02	41.0±2	53.22±1
6	N07.20773E003.81322	128	9.04±0.01	21.0±3	36.21±1
7	N07.20712E003.81400	128	9.04±0.02	21.0±2	26.63±3
8	N07.20800E003.81495	145	0.08±0.01	26.0±1	31.91±2
9	N07.20837E003.81530	143	9.04±0.02	25.0±2	46.00±1
10	N07.20782E003.81522	166	9.95±0.02	21.0±1	26.56±2
11	N07.20644E003.82144	157	7.23±0.03	23.0±1	29.21±1

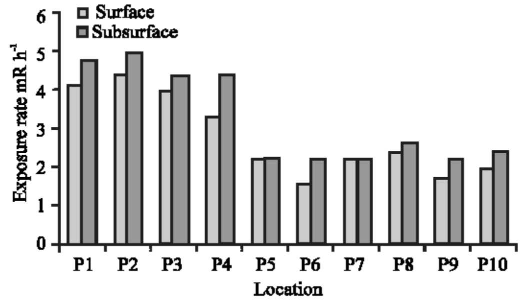

Fig. 1: Comparison of exposure rate of surface and subsurface soil from dug pits

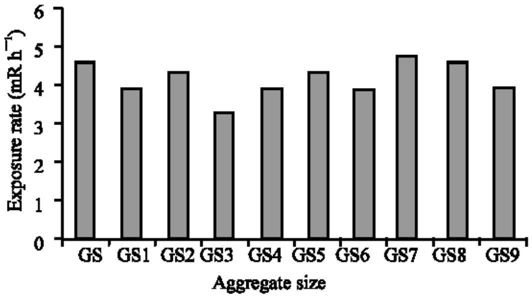

Fig. 2: Comparison of exposure rate for different rock aggregate sizes (GS)

radioisotopes. In particular high radiation levels from natural radionuclide have been associated with granitic and silicic igneous rocks like those in the study area (Brimhal and Adams, 1982). It is therefore possible that the measured radiation from the study areas are from the natural radionuclides like ^{238}U, ^{232}Th and ^{40}K which are the radioisotopes associated with igneous rocks.

Similarly, the radiation levels generally ranged between 42 cpm with an exposure rate of $1.51\pm0.01\times10^{-2}$ mR h^{-1} and dose equivalent of $6.33\pm0.01\times10^{-4}$ m Sv week^{-1} and 120 cpm with an exposure rate of $4.34\pm0.02\times10^{-2}$ mR h^{-1} and dose equivalent of $1.80\pm0.03\times10^{-3}$ mSv week^{-1} in the surface soils.

The values of radiations in the subsurface soil range from 48 cpm with an exposure rate of $1.70\pm0.02\times10^{-2}$ mR h^{-1} and dose equivalent of $7.23\pm0.03\times10^{-4}$ mSv week^{-1}. The higher values of radiations in the recently quarried coarse aggregate rocks at the quarry phase compared with the previously quarried coarse aggregate is suggestive of the fact that the radionuclide are resident in the parent rock materials. Also the relatively higher values of the radiations in the coarse rock materials compared with the subsurface and surface soils confirms that the natural sources of the radiations in the soils is from the underlying bedrocks.

DISCUSSION

Igneous rocks of plutonic or volcanic origin are known to be widespread in occurrence. This rock type may be older granite member of the Basement Complex rocks. In the study area, the rocks have been sub grouped by Rahaman (1988) which include Migmatite, gneissquartzite complex; slightly migmatized to nonmigmatized metasedimentary and metaigneous rocks; Chanockitic, gabbroic and dioritic rocks; older granite suite; metamorphosed and unmetamorphosed calcalkaline volcanic and hyperbasal rocks and unmetamorphosed diorite dykes, basic dykes and syenite dykes. These rock types are known to be associated with elevated levels of naturally occurring radionuclides (Kline and Mose, 1990; Scott, 1998; Piller and Adams, 1962; De Jong *et al.*, 1994; Richardson, 1964).

These radionuclides are unstable atomic nucleus ($Z>84$) that decays spontaneously to emit natural radiations. The three radiations viz gamma (γ), beta (β) and alpha (α) are indications of the presence of radioisotopes in the material. These (three) radiations have their own characteristics and possess different frequencies and wavelengths. These rocks have been observed to be more radioactive than the metamorphic rocks (Brimhal and Adams, 1982). The high value of radiations shown in Table 1 (120 cpm) obtained in the miscovitic coarse aggregates of banded gneiss (rocks with dark and white bands) compared with the values 108 cpm obtained in the biotitic coarse aggregates (i.e., rocks with dark bands) in this study may implies that rocks of multiple colours (dichromic) absorbs and reflects radiation than rock of predominantly single colour (i.e., monochromic). It is also likely that aggregate size distribution has effects on radiation levels since the finest quarry dust has the least radiation (90 cpm). This implies that fine grain aggregates allow the easy escape of radiations than coarse aggregates thereby giving shorter period of hazard compared with coarse aggregates.

The values of radiation are relatively higher in the subsurface soils that are closer to the parent bedrock materials vertically than the overlining surface soils. This is supported by the absorbed radiation dose (ngy h^{-1}) and annual effective dose (μS year^{-1}) calculated as shown in Table 2 and 3.

Therefore, there is a relationship between the radiations from bedrock and the subsurface soil materials next to it, while higher values of radiations in soils from some pits (i.e., P1-4) also indicates that the concentration level of radiations in soil may be controlled by particle size distribution. This finding confirms the fact that radionuclide distribution in soils is influenced by several factors and the physicochemical characteristics of the soils such as texture, porosity (Stricker *et al*., 1994; Mortredt, 1991; Morton and Evans, 1996). In this study, the radiation effects can only be felt only laterally within the few radius of meter away from the quarry phase, while vertically there is close relationship in the radiation values of the bedrocks and the proximate subsurface soils than the distant surface soils. The bar chart illustrations of the measured radiations indicate higher values of radiations in the subsurface soil compared with the surface soil. The obtained values of radiations dose rate and equivalents in this study (101.4-148.8 and 4.2-5.9 mSv year^{-1}) are generally higher when compared with the occupational dose rate (20 mSv year^{-1}) and public dose equivalent (1 mSv year^{-1}), respectively for the rocks and soils. This may signifies some health problem to the people around the quarry. The environmental impacts of radiations depend on the type and amount of a particular radiation. However, all forms of radiation constitute danger to biological tissues. The amount of damage of ionizing radiation to biological tissue is $\alpha>\gamma>\beta$. The health effects varies with level of exposure at an exposure of 70 rem it can results in vomiting and hair loss at the exposure of 100 rem it leads to hemorrhage while exposure rate of between 400-2000 rem will constitute death. This is so because the normal exposure to ionizing radiation is <1 rem year^{-1}. Besides, human exposure to radiations may increase if they live in houses or buildings constructed with aggregate materials having radiation doses above normal background value in the area.

CONCLUSION

The high radiation in the aggregate rocks sizes from the studied Stonebridge quarry is an indication that the quarried parent rock materials contains radioisotopes. The high radiations in the subsurface soils confirm the presence of radionuclides/radioisotopes in the underlying parent rock materials. There is therefore the possibility of radiation emitting radionuclides in most of the houses built from the various rock aggregates which are widely used in the numerous constructions in and around the study area. Similarly, their is possibility of exposure of the quarry workers and the farmers to different degree of radiations in the area. It is necessary to ascertain the radiation levels in and around our quarries and the different rock aggregate sizes before supply to the people that use these aggregates in construction works. This will definitely reduce the exposure of every stakeholder in quarry activities and aggregates to radionuclide radiations.

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