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Assessment of Radionuclide Pollutants in Bedrocks and Soils from Ewekoro Cement Factory, Southwest Nigeria

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Abstract: The results of the radionuclides analysis in the bedrock (i.e., limestone and shale) and soil samples (surface and subsurface) samples collected from locations around Ewekoro cement factory indicated an average total specific activity values of 7.78±2.74, 8.99±3.90 and 17.63±1.98 Bq kg^{-1} for ^{238}U, ^{232}Th and ^{40}K, respectively in the surface soils while average total specific activity values of 8.07±2.88, 8.25±3.18 and 16.52±1.98 Bq kg^{-1} for ^{238}U, ^{232}Th and ^{40}K, respectively were obtained for subsurface soils. Similarly, the average total specific activity values of 91.30±2.33, 5.75±2.57 and 35.86±7.06 Bq kg^{-1} for ^{238}U, ^{232}Th and ^{40}K, respectively were obtained for limestone bedrock type while values of 3.74±11.42, 5.95±2.26 and 348.20±61.82 Bq kg^{-1}, for ^{238}U, ^{232}Th and ^{40}K, respectively were obtained for the shale bedrock type. From the above, geogenic source of the radionuclides with some anthropogenic implications can be inferred.

Key words: Radionuclides, specific activity, bedrock, limestone, shale

INTRODUCTION

Natural radionuclides have been reported in various concentrations in different components of the environments (i.e., air, water, soils, rocks, plants and animals). It include those that were formed with the parent bedrocks during the earth formation e.g., Uranium (U), Thorium (Th) and Potassium (K) series (Gessel and Prichard, 1975; Hutchinson, 1994). Trace quantities of radionuclides have been reported in all rocks. However, it has been observed that the types and concentrations vary considerably depending on the rock types. The effects of the radiations emitted by the different radionuclides depends on the overlining soil materials (thickness and types), its chelating agents and physicochemical properties (Belivermis *et al*., 2009). It also depends on the rock types and it various usage. Limestone and shale deposits, which are bedrocks of concern in this study are not only widely distributed throughout the earth's crust but are used extensively in cement production for building or construction purposes. The presence of radionuclides (i.e., thorium and uranium series) have been reported in limestone (Kim, 1995) while elevated concentrations of thorium, uranium and potassium have been found in black shale in some regions. Investigations have shown that natural radioactivity and the associated exposure due to gamma radiation (i.e., from radionuclides) depend primarily on the geological (i.e., rock types)

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conditions (Matiullah *et al*., 2004). Similarly, radioactivity of soil environment is one of the main sources of exposure to humans hence it is important to know its distribution, gamma radiation from radionuclides such as ^{40}K and also from ^{238}U and ^{232}Th series (Abusini *et al*., 2007). However, the radionuclides contents of most bedrocks and their neighbouring soil as sources of pollutants in Nigeria are yet to be documented (Ajayi, 2000; Doveton and Merriam, 2004; Tzortis and Tsertos, 2004; Selvasekarapandian *et al*., 1999). These radionuclides in limestone and shale bedrocks and their overlining soil materials can become pollutant when present in greater levels than their natural concentrations. The elevated concentrations of the radionuclides either in the exposed bedrocks (i.e., limestone and shales) or cement raw materials and products may be harmful. Their presence in different food crops grown on the soil around the cement factory may constitute a health hazard. Elevated concentrations of radionuclides have been reported in food chains and rock salts (Garner, 1970; Gofman, 1990; Tahir and Alaamer, 2008). The greatest threat of radionuclides is the damage to the gene pool (Sankaranarayanan, 1990). The kind of symptoms experienced by many victims of radiation sickness may not be as significant as childhood leukemia, stillbirths, cancer or birth defects. However, beyond the physiological effects, mental and emotional consequences of trauma of exposure have been documented (Odunaike *et al*., 2008) while the spiritual consequences can be speculated (Schell, 1982; Lynch, 1995).

In this study, assessment of naturally occurring radionuclides (i.e., thorium, uranium and potassium) was carried out in the limestone and shale which are the principal components of raw materials in cement production at the Ewekoro Cement Factory. The soils around the factory were also assessed for their natural radionuclide concentration. The values obtained were compared with world occupational and public dose rate equivalent for the purpose of deducing possible radionuclide health hazards in the area.

MATERIALS AND METHODS

Study Area

The study area comprising of Ewekoro Cement Factory, Lapeleke and Papalanto is located along Abeokuta-Sango-Lagos route, Southwest Nigeria. It is located within longitude 3°.11'E and 3°12'E and latitude 6°53'N and 6°56'N. Both the quarry, Lapeleke and Papalanto are about 1.1, 2.4 and 3.5 km, respectively away from the cement factory. The physiography of the study area is that of extensive lowland that is gently undulating with a gently sloping dissected escarpment known as Southern uplands (Jones and Hockey, 1964). The area is drained mainly by Ewekoro River which according to Akanni (1992) is obsequent, endorcic and forms a dense network all over the area with anstromatic pattern, along its course. The area falls within humid tropical region (Millers, 1965) and the vegetation is essentially the forest type. The soil of the study area has been classified as ferralitic and belongs to oxisol order according to USDA classification scheme (Gbadegesin, 1992). In term of regional geology, the study area belongs to the Eastern part of Dahomey Basin, extending from the Volta Delta (Southeastern Ghana) to the Western flank of the Niger Delta in Nigeria (Ogbe, 1972). The stratigraphy of the basin has already been studied by various authors (Reyment, 1965; Billman, 1976). However, the general succession of the rock units is that of underlying rock which comprises of Abeokuta group, followed by Ewekoro, Akinbo, Oshosun and Ilaro Formations, respectively. On top of Ilaro formation is the coastal plain sands. The Ewekoro Formation which is the local geology in the study area comprises of the non-crystalline and highly non-fossiliferous limestone and thinly laminated, fissile and probably non-fossiliferous shale.

Sample Collection

This project was carried out between April and September, 2008. A total of ten bedrock samples which include limestone 6 and shale 4, collected at various depths from freshly cut sections of the Quarry phase and a total of thirty-two soil samples collected from both surface and subsurface from the four sampling locations (Ewekoro Cement plant, Quarry, Lapeleke and Papalanto all located in Ogun State, Southwestern part of Nigeria) were used for this study. The details of the soil (rock samples) studied with the aid of hand lens are presented under results. The rocks and soil samples were air dried, pulverized/crushed and made to pass through a 2 mm mesh sieve. The powdered rock samples were stored in plastic containers and taken to the laboratory for radionuclide determination. In the laboratory, the soil samples were transferred to one liter merinelli beakers and formly sealed for secular equilibrium prior to gamma spectroscopy. The soil remained sealed in the merinelli beakers for about 28 days which was a sufficient time required to attain a state of secular radioactive equilibrium after their progeny (Karahan and Bayulken, 2000) which were analyzed for radionuclide concentrations. This same treatment was repeated for the rock samples.

Quality Assurance Procedures

The method of gamma ray spectroscopy adopted in this analysis has been severally reported (Ajayi, 2000; Jibiri *et al*., 1999). However, the gamma counting equipments used consists of camberra vertical High-Purity coaxial Germanium crystal (HPGe) enclosed in the 100 mm thick lead shield. The detector was properly connected to a canberra Multi-Channel Analyzer (MCA). A well calibrated sand and water sources supplied by the International Atomic Energy Agency (IAEA), Vienna, Austria were used for energy and efficiency calibrations and corrected for the counting losses due to coincidence summing effects (Olomo *et al*., 1994). Accurate energy and efficiency of the gamma spectroscopy system were made to quantify radionuclides present in a sample, since, the accuracy of all quantitative results depend on the attainable accuracy of the system's calibration. The EMA MCA was calibrated to display gamma photo peaks between the energy range of 100 and 1500 KV, being the energy range covering all the gamma energies of radionuclides identified with reliable regularity.

RESULTS

The results of this study highlights the presence and concentration level of different natural radionuclides in the limestone and shale deposits and the overlain soils within and around Ewekoro cement factory. The mean values and the standard deviations for radionuclides for surface soils, subsurface soils and bedrock samples are shown in Table 1-3 while the comparisons of the values obtained in this study with that of other authors and world standards are presented in Table 4-7. The higher values of the radionuclides (^{238}U, ^{232}Th and ^{40}K) in the surface soils of the Ewekoro and Quarry when compared with the subsurface may be attributed to the abundance of cement dust in the parking plant around the Ewekoro and also the mining/quarrying activities in and around the Quarry site. In the case of Lapeleke and Papalanto that are 2.4 and 3.5 km away from the cement factory, the values of the radionuclides are higher in the subsurface soils than the surface. This is likely due to the bedrock effects since, the underlining parent rock materials have higher values of radionuclides than the soils. Although, there is variation in the order of magnitude in the concentration of the radionuclides from the sample types and locations however, the mean values of each of the radionuclides according to sample types indicates that there is higher values of ^{40}K in all the samples followed by ^{232}Th and least for ^{238}U especially in the soil types while ^{238}U is much more higher in bedrocks than ^{232}Th. It was also

Table 1: Physico-chemical characteristics and radionuclide concentrations in the surface (0-5 cm) soil

	Physico-chemical characteristics								
				Organic			Radionuclide concentrations (Bq kg^{-1})		
	Sand	Silt	Clay						
Location	(%)			Carbon	Matter	pH	^{238}U	^{232}Th	^{40}K
Ewekoro	79.1	10.1	10.8	2.8	4.8	8.2	8.76±2.31	7.22±3.06	12.40±1.38
Quarry	88.7	2.5	8.8	2.5	4.3	7.2	6.83±1.97	6.46±2.10	44.24±4.60
Papalanto	77.9	12.0	10.1	2.3	4.0	7.4	3.02±1.23	5.78±2.54	6.03±1.03
Lapeleke	77.1	14.3	8.6	3.7	6.4	7.3	12.52±5.43	16.48±7.09	7.85±0.91
Mean							7.78±2.74	8.99±3.70	17.63±1.98

No. of samples collected per location = 4 samples

Table 2: Physico-chemical characteristics and radionuclide concentrations in the sub surface (25-30 cm) soil

	Physico-chemical characteristics								
				Organic			Radionuclide concentrations (Bq kg^{-1})		
	Sand	Silt	Clay						
Location	(%)			Carbon	Matter	pH	^{238}U	^{232}Th	^{40}K
Ewekoro	80.4	8.6	11.0	1.1	1.9	8.5	8.11±3.05	3.59±1.24	13.05±1.46
Quarry	87.6	3.1	8.1	1.6	2.8	7.8	5.84±2.08	5.53±1.86	37.87±4.05
Papalanto	84.7	4.8	1.5	1.5	2.6	7.5	4.97±1.53	6.27±3.04	6.32±0.71
Lapeleke	76.5	12.4	11.1	1.4	2.4	7.7	13.36±4.87	17.59±6.57	8.85±0.97
Mean							8.07±2.88	8.25±3.18	16.52±1.98

No. of samples collected per location = 4 samples

Table 3: Mean radionuclide concentrations in the bed rock samples

		Radionuclide concentrations (Bq kg^{-1})		
Location	Sample name	^{238}U	^{232}Th	^{40}K
Quarry	Limestone 1	80.47±13.76	5.07±1.98	74.17±13.80
	Limestone 2	68.99±10.57	4.35±1.52	15.12±2.63
	Limestone 3	124.45±29.30	7.84±4.22	18.28±4.75
	Mean	91.30±21.83	5.75±2.57	35.86±7.06
	Shale1	3.63±11.87	5.89±1.71	350.29±65.36
	Shale 2	3.85±10.96	6.01±2.80	346.10±58.27
	Mean	3.74±11.42	5.95±2.26	348.20±61.82
	MEAN	91.89±16.38	5.79±2.36	114.47±21.64

No. of samples collected per location = 2 samples

Table 4: Comparison of the mean radionuclide concentrations in soil (Bq kg^{-1}) from studies conducted worldwide and results obtained with the world average

Region	^{238}U	^{232}Th	^{40}K	References
Amman, Jordan	56.4	28.8	501	Ahmad *et al.* (1997)
Taiwan	54.0	32.4	794	Chen *et al.* (1993)
Taiwan	30.0	44.0	431	Lin *et al.* (1987)
Istanbul, Turkey	21.0	37.0	342	Karahn and Bayulken (2000)
Agaba-Amman	44.4	36.3	208	Al-Jundi *et al.* (2003)
Highway				
Ewekoro	7.92	8.62	17.45	This study
World average	17-60	11-64	140-850	UNSCEAR (2000)

Table 5: Comparison of radionuclide concentrations obtained in Nordic rocks and results obtained in this study

		^{238}U	^{232}Th	^{40}K
Region	Type of rock	(Bq kg^{-1})		
Nordic	Limestone	2-30	0.5-10	130-150
	Shale	10-150	10-60	600-1900
Ewekoro	Limestone	68.9-124.5	4.4-7.8	15.1-74.2
	Shale	3.6-3.9	5.9-6.0	346.1-350.3

References for Nordic: (Akerblom *et al.*, 1988)

Table 6: Comparison of absorbed dose rates (nGy h^{-1}) and dose equivalent (mSv y^{-1}) in soil with world standards

Location	Depth (cm)	Absorbed dose (nGy h^{-1})	Dose equivalent (mSv y^{-1})
Packing Plant	0-5	9.089	0.08
	25-30	6.417	0.06
Quarry	0-5	9.090	0.08
	25-30	7.778	0.07
Papalanto	0-5	5.524	0.05
	25-30	6.573	0.06
Lapeleke	0-5	16.68	0.15
	25-30	17.81	0.16
World range (UNSEAR, 2000)		18-93	
ICRP (1990)			Occupational: 20 mSv y^{-1} Public: 1 mSv y^{-1}

Table 7: Correlation of radionuclide and physicochemical parameters analyzed for the surface (0-5 cm) soil

Parameters	Sand	Silt	Clay	Organic Carbon	Organic Mater	pH	^{238}U	^{232}Th	^{40}K
Sand	1.000								
Silt	-0.981*	1.000							
Clay	-0.359	0.173	1.000						
Organic carbon	-0.423	0.543	-0.464	1.000					
Organic matter	-0.435	0.556	-0.472	1.000**	1.000				
pH	-0.340	0.184	0.853	-0.050	-0.066	1.000			
^{238}U	-0.201	0.298	-0.415	0.944	0.935	0.092	1.000		
^{232}Th	-0.434	0.578	-0.578	0.975*	0.980*	-0.240	0.861	1.000	
^{40}K	0.995**	-0.964*	-0.416	-0.330	-0.342	-0.346	-0.101	-0.347	1.000

*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed)

Table 8: Correlation of radionuclide and physicochemical parameters analyzed for the subsurface (25-30 cm) soil

Parameters	Sand	Silt	Clay	Organic Carbon	Organic Mater	pH	^{238}U	^{232}Th	^{40}K
Sand	1.000								
Silt	-0.996**	1.000							
Clay	-0.589	0.634	1.000						
Organic carbon	0.593	-0.551	-0.524	1.000					
Organic matter	0.629	-0.588	-0.527	0.999**	1.000				
pH	-0.231	0.217	0.640	-0.851	-0.828	1.000			
^{238}U	-0.909	0.942	0.716	-0.315	-0.351	0.087	1.000		
^{232}Th	-0.697	0.736	0.322	0.160	0.115	-0.436	0.858	1.000	
^{40}K	0.660	-0.598	0.175	0.457	0.490	0.074	-0.346	-0.339	1.000

**Correlation is significant at the 0.01 level (2-tailed)

observed that ^{40}K is exceptionally higher in shale rocks than other radionuclides. It can also be observed from the Table 1 and 2 that higher concentration of ^{238}U and ^{232}Th are obtained from the soils of lapeleke which is dominantly of silty materials and also rich in organic matter while ^{40}K are found in higher concentrations in the soils of Quarry which has higher percentage of sand.

The relationship observed from the correlation matrix (Table 7) for ^{238}U, ^{232}Th, ^{40}K concentrations against the physico-chemical characteristics of the soil samples indicates highly negative correlation between silt and sand (-0.981) and ^{40}K and silt (-0.964) at 0.05 level of significance. There also exist a highly positive correlation between; ^{232}Th and organic carbon (0.975); ^{232}Th and organic matter (0.980) at 0.05 level of significance and also between organic matter and organic carbon (1.000) and ^{40}K and sand (0.995) at 0.01 level of significance for surface (0-5 cm) soil samples. From table 7, sand is negatively correlated to all the parameters except ^{40}K. In addition, the correlation matrix for the subsurface soil samples (Table 8) revealed a highly negative correlation between silt and sand (-0.996) and organic matter and organic carbon (0.999) at 0.01 level of significance.

DISCUSSION

The concentrations of the radionuclides were identified with reliable regularity in the rock and soil analysis by gamma-spectrometry. Except for ^{40}K, all the gamma-lines detected come from the ^{238}U and ^{232}Th decay series. The results show that the natural radionuclides are almost uniformly distributed in the surface and subsurface soil samples. Generally, the ^{238}U concentrations range from 3.02±1.23 to 13.36±4.87 Bq kg^{-1} with an average of 7.93 ±2.81 Bq kg^{-1} in the soil samples. The concentrations of the ^{232}Th range from 3.89±1.24 to 17.59±6.57 Bq kg^{-1} with a mean of 8.62±3.44 Bq kg^{-1} and the activity concentrations for ^{40}K range from 6.32±0.71 to 44.24±4.60 Bq kg^{-1} with an average of 17.45±1.89 Bq kg^{-1} in all the soil samples from the study locations. The results obtained indicates that the mean activity concentrations due to ^{238}U is not significantly different from that ^{232}Th in both soil and rock samples, while that of ^{40}K is about 2 times greater than that of either ^{238}U and ^{232}Th in soil samples and considerably higher in the bedrock samples. Therefore, the dominant source of γ-radiation measured in samples from all locations must have been from ^{40}K. The higher concentrations of the radionuclides in the surface soil within the premises and at the Quarry of the cement factory may be due to the various activities of the cement factory. This may result in some negative effects on the plant growth in the two areas. Radionuclide concentrations in the surface soil of the two nearby communities Papalanto and Lapeleke are lower than that of the subsurface soil. This may be as a result of the less industrial activities in these areas compared to the Ewekoro, the premise of the cement packing plant and quarry of the cement factory.

The results have also shown that the activity concentrations of the radionuclides in the bed rock samples are generally higher than in the soil samples. This may therefore, portend the geogenic provenance of the radionuclides in the soil samples. The data shows that both the packing plant area (i.e., Ewekoro) and quarry of the cement factory have higher absorbed dose rate than a nearby communities (Papalanto and Lapeleke). The higher than expected dose rates in Lapeleke community may be due to its geology and the human activities in the area (Fasasi *et al*., 1999). The values obtained for ^{238}U in both surface and subsurface soil samples fall within the wide range of values (5 to 71 Bq kg^{-1}) reported for the soils of Kalpakkam, India (Kannan *et al*., 2002), Savor, Bangladesh (Mollah *et al*., 1986) and 23.6 to 33.4 Bq kg^{-1} reported in the soil of Ile-ife, Nigeria (Olomo *et al*.,1994). The average activity concentration of 7.78±2.74 Bq kg^{-1} of ^{238}U obtained for the soils of the study area is lower than 24 Bq Kg^{-1} obtained in the soils of Tehran Iran (Hafezi *et al*., 2005) and 43.2 Bq Kg^{-1} obtained for the soils of Udagamandalam, India (Salvasekarapandian *et al*., 1999). The values obtained for ^{232}Th in both surface and subsurface soil samples in this study however fall within the wide range of values of 15 to 776 Bq kg^{-1} reported for the soils of Kalpakkam, India (Kannan *et al*., 2002). The average activity concentration of 8.99±3.70 Bq kg^{-1} in this work obtained for ^{232}Th is lower than 28 Bq Kg^{-1} obtained for the soils of Tehran Iran (Hafezi *et al*., 2005), 41 Bq kg^{-1} obtained for the soils of Punjab, Pakistan (Tahir *et al*., 2005) and 114.6 Bq kg^{-1} obtained for the soils of Udagamandalam, India (Salvasekarapandian *et al*., 1999). ^{232}Th concentration for the soil of ile-ife, Nigeria is about a factor of 2 greater than those obtained for this work. The average activity concentrations 17.63±1.98 Bq Kg^{-1} for ^{40}K in the soil samples obtained in this study is lower than the 131.8 Bq kg^{-1} in the soil of Ile-ife, Nigeria (Olomo *et al*., 1994), 135.75 Bq kg^{-1} reported in the soil of Pradesh, India (Asha and Singh, 2005), 274.6 Bq kg^{-1} reported for the soils of Udagamandalam, India (Salvasekarapandian *et al*., 1999), 615 Bq kg^{-1} for the soils of Punjab, Pakistan (Tahir *et al*., 2005) and 635 Bq kg^{-1} for the soils of Tehran Iran (Hafezi *et al*., 2005).

The gamma absorbed dose rates obtained in the soils of the study area ranged from 5.52 to 17.8 nGy h^{-1} with a mean of 9.87 nGy h^{-1} (Table 6). These values are lower than the 34.5 to 97.6 nGy h^{-1} with a mean of 6.68 nGy h^{-1} for the soils of Serbia and Montenegro (Dragovic *et al*., 2006). The dose equivalent (0.05-0.16 mSv y^{-1}) obtained for the soil samples is lower than the mean dose equivalent of 0.26 mSv y^{-1} obtained for the soils of the Tirunelrali district, India (Brahmanandhan *et al*., 2005). The mean activity concentrations of 5.79±2.36 and 35.86±7.06; 5.95±2.26 and 348.20±61.82 obtained for ^{232}Th and ^{40}K, respectively in limestone and shale rock samples are lower than 60.8 and 928 Bq kg^{-1} of ^{232}Th and ^{40}K obtained, respectively for limestone samples in Bangladesh (Alam *et al*., 1999). Similarly, the mean activity concentration of both radionuclides obtained for both the limestone and shale bedrock samples in this study were generally found to be lower than the range obtained in the limestone and shales in the Nordic region (Table 5). The mean dose equivalent (0.39 mSv y^{-1}) obtained for the studied limestone rock sample is higher than the 0.1739 mSv y^{-1} for the limestone from both Anz and Sarai, Egypt (Abbady, 2004). The activity concentration obtained for the soils and rocks in this work were compared with those in either regions of the world and also compared with the world average values as shown in Table 4 and 5. from the results, it is evident that despite the various activities of the cement factory, Ewekoro and its neighboring communities could be considered as areas of low concentrations of the naturally occurring radionuclides with low γ-radiation (except probably for Uranium in limestone and shale). The absorbed dose rates obtained for the soil and rock samples fall within the world average (Table 6, 7). The dose equivalents of all samples all fall within those reported in literatures (Myrick *et al*., 1983; Ajayi *et al*., 1995) and the same with 0.4839 mSv y^{-1} reported for the soil samples around cement factory in Port Harcourt, Nigeria by Avwiri (2005). However, the values of the dose equivalents of the soil and rock samples obtained are lower than the maximum permitted limits of 1 mSv y^{-1} for the general public and 20 mSv y^{-1} for occupational exposure, recommended by the International Commission on Radiological Protection (ICRP, 1992) as shown in Tables 6. Investigation has shown that ^{40}K is significantly and positively correlated to % sand however, it is both negatively and non-significantly correlated to silt % and clay %, this trend is in conformity with this work. Similarly, ^{40}K also has negative and non-significant correlations with organic carbon, organic matter and pH of the soil samples in the study area. However, the concentrations are lower in the surface soils than in the subsurface soils of the two nearby communities Papalanto and Lapeleke communities. The radionuclide concentrations are also observed to be so much higher in the bedrock samples from the study area compared with the concentration obtained from the soil surfaces. This confirmed the geogenic nature of the radionuclide in this area. Similarly, the higher concentrations in the surface soils at the packing plant at Ewekoro and Quarry site of the cement factory may be as a result of the contributions from both the bedrocks during excavations, mining and crushing at the Quarry site. The determination of radiation effects achieved by comparing the calculated equivalent dose and the absorbed dose rates with appropriate standards and limits revealed that, the radiological heath burden or adverse radiological effects due to the operations of the cement factory on the human populace and the entire environment is very insignificant.

CONCLUSION

The assessment of radionuclide concentrations and their possible health effects in and around Ewekoro Cement Factory has been carried out. The mean dose equivalent of 0.09 mSv y^{-1} for soil and 0.39 mSv y^{-1} for rock samples were obtained. These values are

lower than the maximum permitted limits of 1 mSv y^{-1} (public) and 20 mSv y^{-1} (occupational), hence, may not have serious health implications or adverse effects on the populace and the environment. However, there may be increase in the values obtained with longer period of operation. It is therefore, recommended that there should be occupational and public awareness on the presence of natural radiations especially of limestone mining and cement production in the environment and their possible health hazards. Background radiation and proper health monitoring should also be part of environmental assessment for industrial and mining projects.

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