Original Research Article

EVALUATION OF RADIONUCLIDE CONCENTRATION IN SUSPENDED PARTICULATE MATTER FROM TWO QUARRY SITES IN NIGERIA

Abstract

Evaluation of Radionuclide contents of suspended particulate matter from two quarry sites in Nigeria, have been carried out using High Volume air sampler and Gamma ray spectrometer NaI(Tl) Detector. The results obtained showed the mean value for ^{226} Ra, ^{232}Th and ^{40}k for Ishiagu sampleswere 2.76, 1.57 and 5.29 Bq/Kg respectively while that obtained in Okpella sampleswere 1.84, 2.21 and 6.2 Bq/kg respectively. The values obtained were higher than their control values but lower than the world recommended safe values. The results obtained in Okpella are slightly higher than that obtained in Ishiagu sites. This could be due to different geological constituents and other mining activities going on at Okpella that might have contributed to the slight change. All the radiological health risk parameter estimated were within their safe values as recommended by UNSCEAR. Comparison of results with other similar works shows positive correlation. We therefore conclude that inhalable suspended particulate matter within quarry sites does not constitute immediate radiological health hazard though precaution should be taken to avoid long term accumulation that can lead to stochastic health risk.

***Keywords*:** Radionuclide, suspended particulate matter, Quarry sites, Gamma spectrometer.

1. Introduction

"The earth crust is endowed with solid mineral ores, rocks and soil" [1]. "These materials are primary hosts of naturally occurring radioactive materials (NORMs) containing the natural radionuclides ^{40}K, ^{236}Th, and ^{238}U and their various progenies. These geological materials together with sediments and groundwater are strongly enriched with NORMs and due to local geology of an area, the activities and concentrations of the NORMs vary from place to place" [2]. "With respect to environmental radioactivity monitoring and radiation safety, solid minerals, rocks and soil are of particular interest in that in the event of any activities of exploration, mining, quarrying, crushing and processing, radionuclides and toxic elements contained in them can be re-suspended in air with dust particles and dispersed from the mining site to the immediate environment through various mechanisms that can even contaminate the air, water bodies and the food chain causing significant exposure to radiation levels" [3].

“With the large mass of mineral ore deposits and rocks fairly spread across different regions of Nigeria, many local mining and rock quarrying outfits have been set up in these regions” [2]. “Rock quarrying which involves excavation of deep buried and outcrop rocks followed by crushing into various sizes can redistribute radionuclides in quarry dust, soil and air, and have the capability of increasing the exposure levels and radiation dose rates of workers and inhabitants of immediate environment. Particulate matter within these quarrying sites may contain varying concentration of radionuclides.Natural radionuclides and potential toxic elements contained in the rocks during quarrying can find their way to the human internal organs through inhalation of dust particles suspended in air (particulate matter) and ingestion of contaminated water and food crops cultivated in soil of immediate environment” [4].

“Naturally occurring primordial radioactive nuclides in ambient environment are of great concern for their hazardous impacts on human-health through ionizing radiations. Various types of physiological problems, for example, lung cancer, renal failure, kidney dysfunction, and bone deformities may be caused by exposure to NORMs” [5, 6, 7]. “NORMs distributions in differential environmental constituents (e.g., dust (particulate matter), sediment, soil, water) mostly depend on climatic conditions, local geology, & weathering processes” [8,9,10]. “NORMs' occurrence in soil and/or sediment is mostly correlated with external exposure to radiation if the inhalation of gaseous radon is overlooked. Though the NORMs' impacts by water having various exposure routes, the impacts seem trivial due to the very low abundances of NORMs in the natural resources of water” [11, 12]. “Moreover, like water, radioactivity abundance in dust cannot be disregarded. Additionally, like soil or sediment, exposures of radiation through dust-NORMs are not limited merely through external-route (ignoring the inhalation of radon). Rather dust can have the probability of entering in lungs through the inhalation route [13] along with its radionuclides. since radionuclides are not evenly distributed, in the air components of the quarrying environment, the knowledge of their distributionin the atmosphere plays an important role in radiation protection and measurement”. Radiation exposure arising from the mining and mineral processing industries results from three principal pathways; external gamma radiation from ores, inhalation of dust containing long-lived alpha-emitting radionuclides and inhalation of short-lived decay products of radon.

Quarrying activities have lots of challenges on the environments as all stages emit a lot of dust and radioactive elements [14]. Dust (particulate) of about 20 – 500 microns found in the atmosphere can be carried away easily by wind.Dust from quarry spread along large areas through wind, rain and are accumulated on soils, plants and animals and can adversely affect humans that inhale the duststhat might contain naturally occurring radioactive materials [15]. Air pollutants are major environmental problems affecting both the developed and developing countries. The various environmental impacts due to quarrying activities are both particle sizes and location dependent, manifesting itself in specific impacts on air, soil, water, human, flora and fauna when the particulate are suspended in air for long period[16]. Particulate matters having

significant number of radionuclides in them can be carcinogenic in nature [17]. Based on these detrimental effects, this study aimed at evaluating the level of radionuclide content of inhalable particulate matter from two quarry sites in order to ascertain the radiological risks of the workers and host community dwellers.

2. Material and Methods

2.1 Study Area

This study was carried out in two different states where Quarrying activities are going on: Okpella Edo State and Ishiagu Ebony State.Okpella – is a clean situated along Benin – Abuja Federal high way located at coordinate of 7.272^0N latitude, 6.3465^0E Longitude. It plays host to BUA cement processing plant. Okpella is endowed with natural sedimentary rock based mineral resources, which include limestone, calcium, granite, feldspar, talc, clay, marbles and so on. In view of the abundance of other solid minerals it is home for several granite and marble-making industrial which gives the community a vibrant industrial outlook (Figure 1a).

Ishiagu Quarry site islocated at latitude is $5^052^1 – 6^000^1$N and longitude $7^030^1 – 7^035^1$(figure 1b). “It is part of the geologic complex called Benue trough, a deep linear sediment filled basin which extends to Niger Delta for over 700km toward the North – Eastern part of Eke, Isikwuato by South and Lokpa and Lekwensi by West” [5]. “Ishiagu area is generally a dominant low lying to gentle undulating shaly terrain of 85 – 100km above sea level and punctuated by few isolated low hills. The land surface is usually marshy in wet season which prevails from April – October yielding annual rainfall of between 1200 – 2000mm” [11]. According to Eburua and Ezeribe [12] “Ishiagu has many mineral deposit, making the inhabitants prominently farmers and miners”.

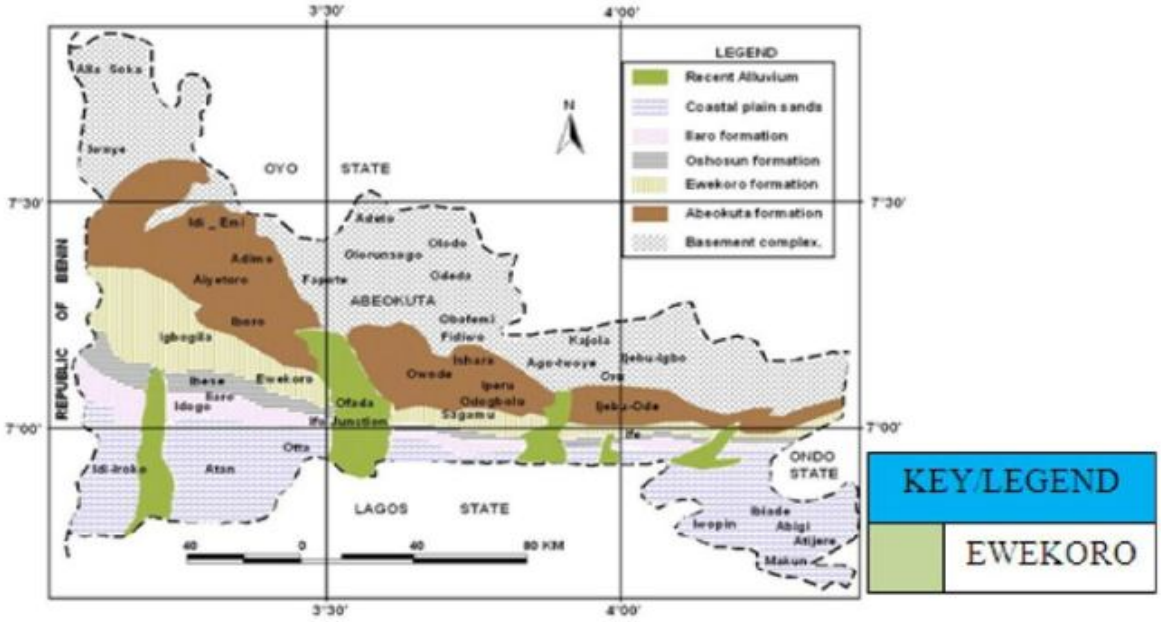

Fig.1a: Geological Map of the Study Area (Okpella)

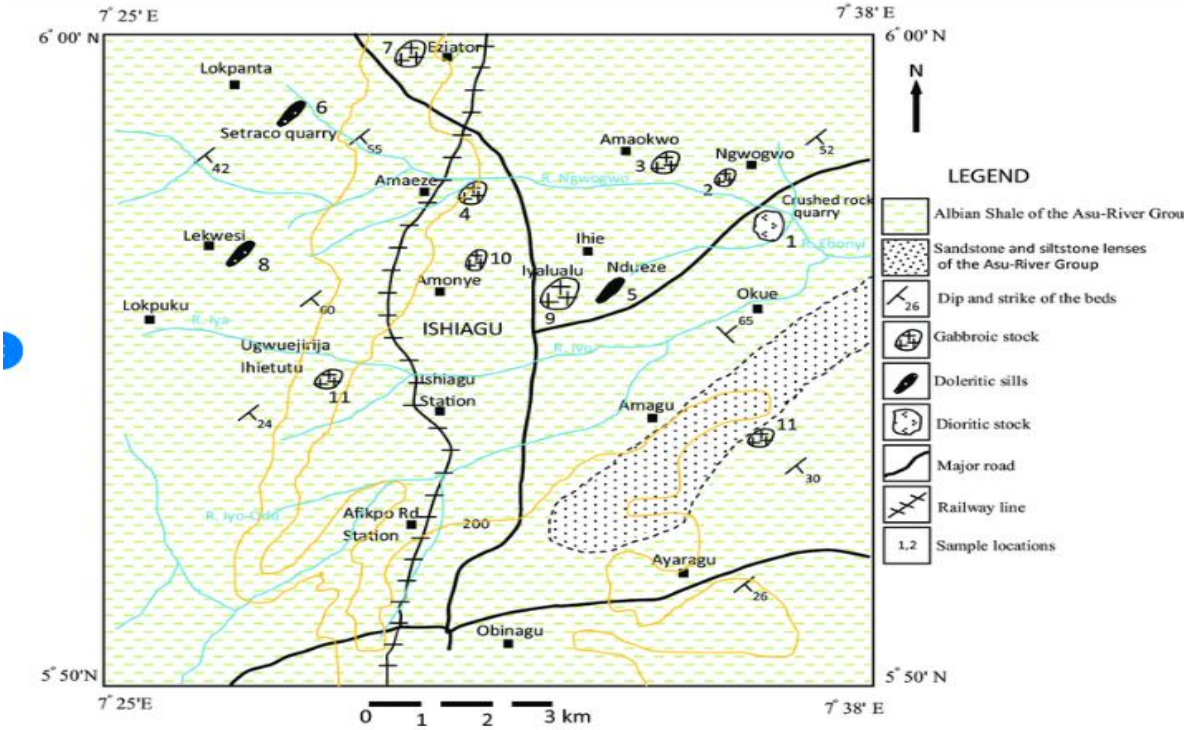

Fig.1b: Geological map of Ishiagu Quarry site in Ebonyi State.

2.2 **Sample Collection and Preparation**

A total of sixteen samples were collected from two quarry sites in Niger Delta region, Nigeria. Airborne particulate matter was collected on a filter using high volume sampler. The filter is processed and then subjected to gamma spectrometric analysis.Each filter sample was inserted in 500ml beaker, 100ml of conc. H_2SO_4, 20ml per chloric acid and 20ml of aqua rigia (3ml of Hcl, 1ml of HNO_3) were added and beaked on hot plate for eight hours. At the end of the digestion, 100ml of each digested sample was transferred into 100ml Marinelli beaker for gamma spectrometry and sealed for 30day to reach secular equilibrium between the parent and progeny nuclide before counting using sodium iodide NaI(TI) detector [13, 14, 15].

2.3 **Gamma ray Spectroscopy**

The gamma-ray counting of the samples are performed on a lower gamma-beam spectrometer comprising of a detector called sodium iodide thallium activated Canberra vertical high purity 2" x 2" sodium iodide coupled with ORTEC 456 digibase amplifier, which amplifiers the incoming signals and integrates them to volts (0 – 10v). "This detector is connected with computer - multichannel analyzer model MCA2500R and serial 25066" [16]. "The used lead shield (100 mm thick) and copper shield (0.3 mm thick) helped reduce background radiation. The system was calibrated using standard sources [15, 17] and measured the detector's background for 24 hours to accumulate a spectrum. The Minimum detectable activity was calculated from the background under the same conditions of measurements for ^{226}Ra, ^{232}Th, and ^{40}K and equal 0.04, 0.08, and 0.44 Bq/kg respectively using equation (1) approved by Chao et al., [17].

The measured activity concentration (Bq/kg) of individual radionuclides was counted after 24 hours, and the obtained accumulated count used to get the measured activity according to the following equation (2) [18, 15].

$$MDA\ (Bq/kg) = (2.71 + (4.65 * \sqrt{N_B t_m}))/(t_m \varepsilon_m) \quad (1)$$

Where N_B is the count per minute for background, tm is the counting time per minute, ε is photopeak detection efficiency for the interested activity per natural radionuclides, and m is the sample weight per volume [17].

$$A(Bq/kg) = [(Ns/ts) - (N_B/T_B)]/[\varepsilon * P * M] \quad (2)$$

Where A(Bq/kg) is the activity of individual radionuclides, (Ns /ts) is the count per second for sample, (N_B/T_B) is the count per second for background, ε is photopeak efficiency, P is the emission probability, and M is the mass of the sample.

3. Radiological Health Risk Parameters

The radiological parameters calculated in this work are as seen below:

Radiation Absorbed Doseis a measure of the energy deposited in a medium by ionizing radiation. It is equal to the energy deposited per unit mass of medium, and so has the unit J/kg or gray (Gy) where 1Gy = $1Jkg^{-1}$. The absorbed dose rates (D) due to gamma radiations in the air at 1m above the ground surface for the uniform distribution of the naturally occurring radionuclides ^{238}U, ^{232}Th, and ^{40}K is calculated using

$$D(nGyh^{-1}) = 0.462A_{Ra} + 0.621A_{Th} + 0.0417A_k \quad (3)$$

Where A_{Ra}, A_{Th}, and A_k are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}k respectively [3].

Annual Effective Dose Equivalent (AEDE)

This is a measure of the risk of long- term effects of ionizing radiation on the human body, organs and tissues, accounting for their sensitivity. "It is evaluated from the absorbed dose rate (D) using the conversion factor of 0.7sv/Gy and the outdoor occupancy factor 0.2" [19]. "The annual effective dose equivalent ($mSvy^{-1}$) was calculated using the formula below" [4].

$$\text{Annual effective dose rate } (mSvy\text{-}^{1}) = D(nGyh^{-1}) \text{ X } 8760hyr^{-1} \text{ x } 0.7Gy/h$$

$$AEDE = D \times 1.2264 \times 10^{-3} \quad (4)$$

Excess Life Cancer Risk

"is the probability of developing cancer over life time at a given radiation exposure level. It is presented as a value representing the number of extra cancers expected in a given number of people on exposure to a carcinogen at a dose. It is calculated as" [5].

$$ELCR = AEDE \times DL \times RF \quad (5)$$

Where AEDE is Annual effective dose equivalent, DL is average duration of life (estimated to be 70 years) and RF is the risk factor (Svy^{-1}), i.e. final cancer risk per sievert for stochastic effect ICRP uses RF as 0.05 Svy^{-1} for the public exposure [16].

Radium Equivalent Activity (Raeq)

equivalent is used to assess the hazard associated with materials hot contain ^{226}Ra, ^{232}Th and ^{40}k in Bqll and is mathematically defined by Mujahid et al.,[20]

$$Raeq\ (Bqlkg) = A_{Ra} + 1.43\ A_{Th} + \ 0.077Ak \quad (6)$$

Where A_{Ra}, A_{Th} and A_k are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}k respectively.

The External hazard Index (Hex)/ Internal hazard index (Hin)

is a criterion use for the evaluation of external exposure to gamma radiation in the outdoor air. This widely used hazard index was calculated using equation 7 [21]

$$H_{ex} = = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (7)$$

Where A_{Ra}, A_{Th} and A_k are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}k respectively.

Internal hazard index

Radon and its short-lived products are radiologically hazardous when inhaled. Internal exposure to radon and its daughter products is very hazardous and can lead to respiratory diseases like asthma and cancer. The internal hazard index (Hin) can be used to determine the internal exposure of living cell to radon and its products[5]. Exposure to radon and its daughter products is quantified by the internal hazard index (H_{in}), which is given equation 8 [22]

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (8)$$

The values of the indices (H_{in} and H_{ex}) must be less than unity for the reduction hazard to be negligible.

Gamma Index (I_γ)

It is a form of radiation hazard index proposed by the European Commission [23]. It is usually calculated from the activity concentration of ^{226}Ra, ^{232}Th and ^{40}k in the samples collected.

$$I_\gamma = = \frac{A_{Ra}}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \qquad (9)$$

Materials with Iy >1 should be avoided in building construction as such will deliver an effective dose rate higher than 1msvyr^{-1} to occupants of such building [24].

Annual Gonadal Equivalent Dose (AGED)

The gonads (organ in which eggs or sperms are produced especially the ovary and testis), the active bone marrow and the bone surface cells are considered as the organs of interest. An increase in Annual Gonadal Equivalent Dose (AGED) has been known to affect the bone marrow, causal destruction of the red blood cells that are then replaced by white blood cells. The AGED (μsvy^{-1}) for the residents of the study area due to specific activities of ^{226}Ra, ^{232}Th and ^{40}k was calculated using the equation given by [19, 15] as :

$$AGED(mSvy^{-1}) = 3.09\,A_{Ra} + 4.18A_{Th} + 0.314A_k \qquad (10)$$

Activity Utilization Index (Au)

is a parametric model that enables us to determine the dose ratio in air of Radionuclides (k, Ra and Th) from samples

$$Au == \frac{A_{Ra}}{500}F_{Ra} + \frac{A_{Th}}{50}F_{Th} + \frac{A_K}{5000}F_K \qquad (11)$$

F_{Ra}, F_{Th} and F_k are the fractional conurbations to the total does rate in air due to gamma radiation from the actual concentration as of these radionuclides [26]. The value of F_{Ra}, F_{Th} and F_k are given as 0.462, 0.604 and 0.041 for uranium, thorium and potassium respectively [26]less than 2 corresponds to an annual effective dose of 1 mSvyr which is safe for the environment.

4. Results

The results of specific activity concentration of ^{226} Ra, ^{232}Th and ^{40}K in particulate matter samples and their radiological risk parameters from Ishiagy in Eboyi State and Okpella Edo state Quarrying sites are presented in Table 1 to 4 respectively.

Table 1: Specific Activity Concentration of ^{226}Ra, ^{232}Th and ^{40}K in particulate samples from Ishiagu Quarry Sites

Sample Code	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	Raeq(Bq/kg)
Ishi 1	1.91 ± 0.32	1.40 ± 0.15	1.89 ± 0.08	4.06
Ishi 2	6.41 ± 0.78	0.94 ± 0.21	8.16 ± 0.20	8.38
Ishi 3	0.89 ± 0.06	0.63 ± 0.05	1.65 ± 0.07	1.92
Ishi 4	2.22 ±0.36	1.86 ±0.30	7.71 ± 0.19	5.47
Ishi 5	2.91 ± 0.51	2.22 ± 0.40	5.82 ± 0.15	6.53
Ishi 6	5.08 ± 0.72	4.08 ± 0.46	10.87 ± 0.24	11.75
Ishi 7	1.87 ± 0.23	0.84 ± 0.22	4.31 ± 0.15	3.4
Ishi 8	0.76 ± 0.05	0.56 ± 0.06	1.82 ± 0.07	1.7
Mean	**2.76 ± 0.38**	**1.57 ± 0.23**	**5.29 ± 0.14**	**5.41**
Min	0.76 ± 0.05	0.56 ±0.06	1.65 ± 0.07	1.7
Max	6.41 ± 0.78	4.08 ± 0.46	10.87 ± 0.24	11.75
MDA	**0.04**	**0.08**	**0.44**	

Table 2: Radiological health Risks estimated in samples from Ishiagu

Sample Area	DR ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	AGDE (μsvy^{-1})	AUI	H_{ex}	H_{in}	I_γ	ELCR x 10^{-3}
Ishi 1	1.81	0.002	12.35	0.02	0.01	0.02	0.05	0.01
Ishi 2	3.87	0.005	26.3	0.03	0.02	0.04	0.14	0.02
Ishi 3	0.86	0.001	5.9	0.02	0.01	0.01	0.03	0.00
Ishi 4	4.13	0.005	17.06	0.04	0.01	0.02	0.07	0.02
Ishi 5	2.93	0.004	20.1	0.05	0.02	0.03	0.08	0.01
Ishi 6	5.26	0.006	36.16	0.10	0.03	0.05	0.15	0.02
Ishi 7	1.55	0.002	10.64	0.03	0.01	0.01	0.05	0.01
Ishi 8	0.77	0.001	5.26	0.01	0	0.01	0.07	00.0
Mean	**2.52**	**0.003**	**16.72**	**0.04**	**0.01**	**0.02**	**0.02**	**0.01**
Min	0.77	0.001	5.26	0.01	0.01	0.01	0.02	0.00

Max	5.26	0.006	36.16	0.1	0.03	0.05	0.15	0.02

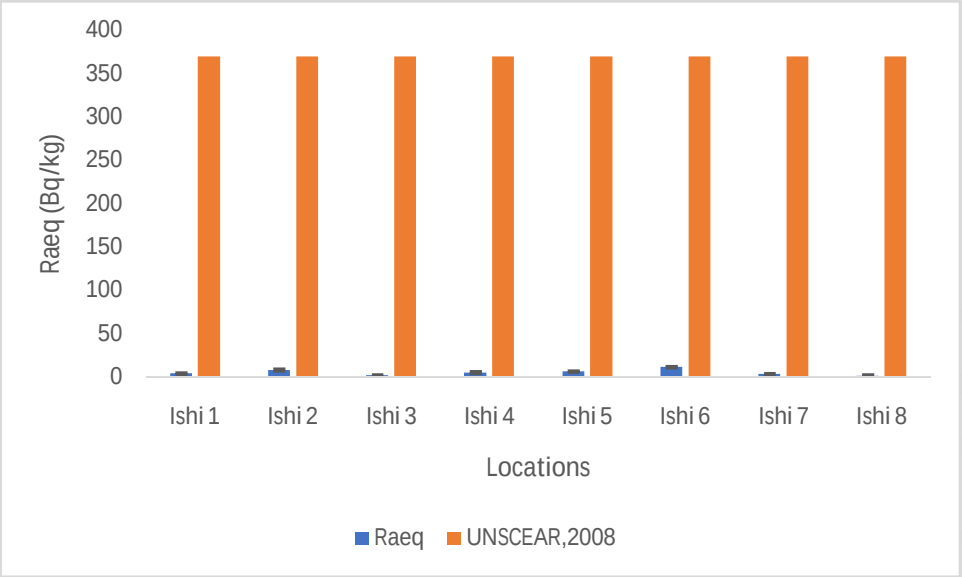

Figure 2: Comparison of radium equivalent activity with UNSCEAR, 2008 safe value

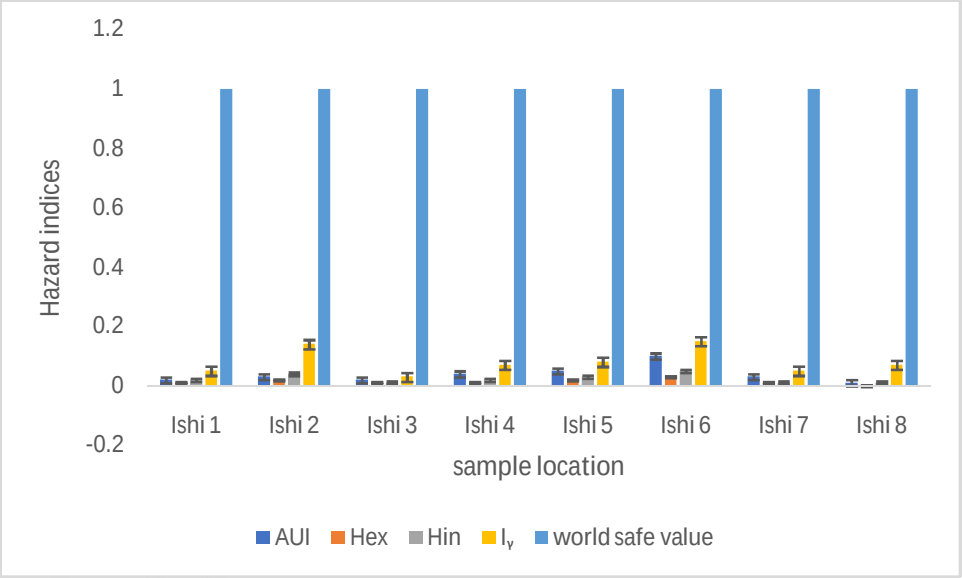

Fig. 3: comparison of all the hazard indices with UNSCEAR, 2008 Recommended value

Table 3:Specific Activity Concentration of ^{226}Ra, ^{232}Th and ^{40}K in particulate samples from Okpella Quarry Sites

Sample Code	**^{226}Ra (Bq/kg)**	**^{232}Th(Bq/kg)**	**^{40}K (Bq/kg)**	**Raeq (Bq/kg)**
Okp 1	1.45 ± 0.39	1.68 ± 0.29	6.76 ± 0.18	4.37

Okp 2	2.18 ± 0.48	2.42 ± 0.34	8.06 ± 0.20	6.26
Okp 3	0.53 ± 0.23	0.81 ± 0.21	8.77.65 ± 0.21	2.41
Okp 4	1.25 ±0.31	1.91 ±0.24	7.09 ± 0.19	4.53
Okp 5	1.72 ± 0.12	2.04 ± 0.39	3.20 ± 0.13	4.83
Okp 6	4.61 ± 0.76	4.97 ± 0.43	11.47 ± 0.26	12.6
Okp 7	1.86 ± 0.41	2.44 ± 0.48	3.47 ± 0.10	5.62
Okp 8	1.11 ± 0.78	1.39 ± 0.66	1.13 ± 0.11	3.18
Mean	**1.84 ± 0.44**	**2.21 ± 0.38**	**6.24 ± 0.20**	**5.48**
Min	0.53 ± 0.23	0.81 ±0.21	1.13 ± 0.25	2.41
Max	4.61 ± 0.76	4.97 ± 0.43	11.47 ± 0.264	12.6
MDA	**0.04(Rq)**	**0.08(Th)**	**0.44(k)**	

Table 4:Radiological health Risks estimated in samples from Okpella

Sampling Area	DR ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	AGDE (μSvy^{-1})	AUI	H_{ex}	H_{in}	I_γ	ELCR ($x\ 10^{-3}$)
Okp 1	1.96	0.002	13.63	0.03	0.07	0.02	0.03	0.01
Okp 2	2.80	0.003	19.38	0.05	0.01	0.03	0.04	0.01
Okp 3	1.10	0.001	7.78	0.02	0.01	0.01	0.02	0.00
Okp 4	4.13	0.002	14.07	0.04	0.07	0.02	0.03	0.01
Okp 5	2.93	0.003	14.85	0.04	0.01	0.02	0.03	0.01
Okp 6	5.61	0.007	38.62	0.1	0.03	0.05	0.09	0.02
Okp 7	2.48	0.003	17.04	0.05	0.02	0.02	0.04	0.01
Okp 8	1.40	0.002	9.59	0.03	0.01	0.01	0.02	0.01
Mean	2.44	0.003	16.87	0.05	0.02	0.02	0.04	0.01
Min	1.10	0.001	7.78	0.01	0.01	0.01	0.02	0.01
Max	5.61	0.007	36.62	0.05	0.03	0.05	0.09	0.02

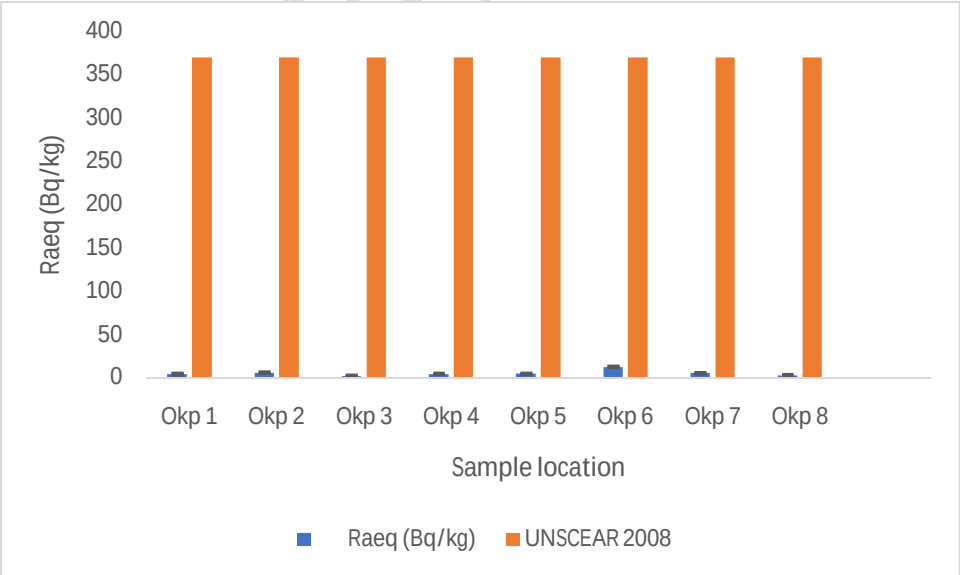

Fig.4:**Comparison of radium equivalent activity with UNSCEAR, 2008 safe value in Okpella site**

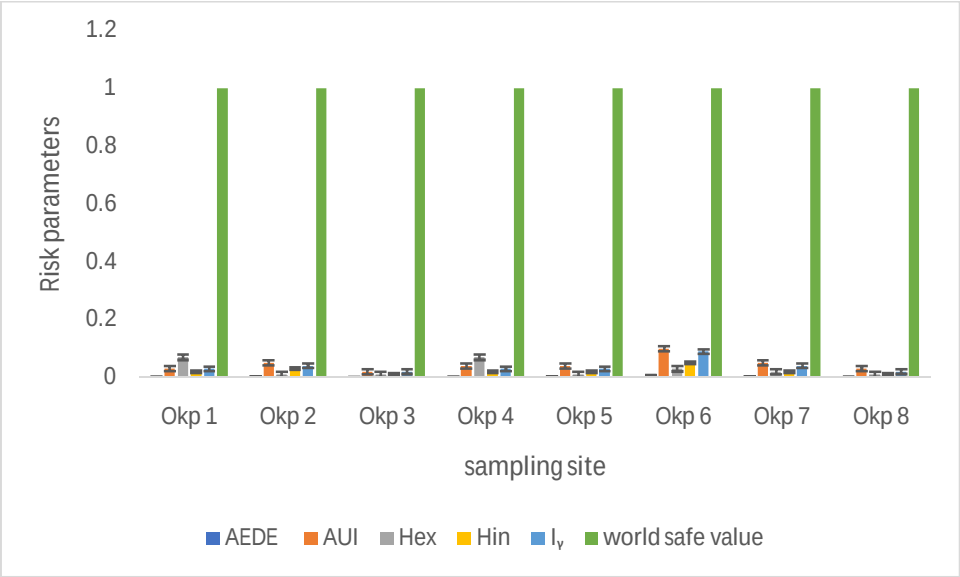

Figure 5: Comparison of all the risk parameters with UNSCEAR, 2008 Recommended value

5. Discussion

Evaluation of activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in suspended particulate matter collected from two quarry sites have been done using gamma spectroscopy. The minimum activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in inhalable particulate matter from Ishiagu quarry site are 0.76±0.05, 0.56±0.06 and 1.65±0.10 Bq/kg while the maximum activity concentration values are 6.41 ±0.78, 4.08±0.46 and 10.87±0.24 Bq/kg respectively. The minimum activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in inhalable particulate matter from Okpella Bua cement quarry site are 0.53±0.23, 0.81±0.21 and 1.13±0.25 Bq/kg respectively while the maximum activity concentration values are 4.61 ±0.76, 4.97±0.43 and 11.47±0.26 Bq/kg respectively.The relative contribution to the absorbed dose in Ishiagu site equals 29%, 16%, and 55% for ^{40}K, ^{226}Ra, and ^{232}Th, respectively, while the relative contribution to the absorbed dose in Okpella site equals 18%, 21%, and 61% for ^{40}K, ^{226}Ra, and ^{232}Th, respectively. The result show that ^{232}Th contributed more to the total absorbed dose.

The hazard levels of gamma-ray were measured through different calculations such as Radium equivalent, internal and external hazard indexes, absorbed dose, annual effective dose, and lifetime risk, as is listed in (Tables 1, 2) and (Figures 2,3, 4 and 5). The calculated resultsof radium equivalent activity (Raeq) (Bq/kg) in Ishiagu site varied between 1.7 to11.75 with an average of 5.41 and 2.41 to 12.6 with mean value of 5.48 Bq/kg for Okpella site, used equation approved by [27, 28, 29], So the obtained value is lower than the global values approved by UNSCEAR, [20]. The external and internal hazards were calculated according to the equation

[30, 31,32]. As mentioned in (Table 2 &4). It is clear that (Hex) fluctuated between 0.01 to 0.003 with an average of 0.10 Bq/kg, and (Hin) varied between 0.01 to 0.05 with an average of 0.01 Bq/kg. These results were within the safe limits and less than unity. The represented level index (Iγ) was calculated using the equation approved by[33,34]. It is clear that the lower value of (Iγ) is 0.02, and the upper value is 0.15 with a mean of 0.02, which is also presented in (Table 2 and 4) and (Figure 5). This magnitude less than unity. The results compared well with results of other similar works [35, 36, 37].

Table 2 and 4 and (Figures 2 and 5) represent the calculated environmental radiation hazard index (absorbed dose, Radium equivalent, annual effective dose, and lifetime risk). All of these variables shew the health risks that affect human beings. The current research used the equation mentioned by [13] to calculate these variables. The absorbed dose (nGy/h) varied between 0.77 to 5.26 with an average of 2.52 nGy/h, which are lower than the recommended public limits (ICRP, 2012). Effective dose per year (mSv/y) for outdoor radiation varied from 0.001 to 0.006 with mean value of 0.003 for Ishiagu site and 0.001 to 0.007 with mean value of 0.004 $mSvy^{-1}$ for Okpella site.

The result of the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in the samples from Ishiagu quarry site are comparable with that from Okpella Bua cement quarry site with slight variation. All the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K obtained are higher than the activity concentration obtained in the control samples and other related works [38,39]. This implies that the quarry mining activities slightly impacted on the concentration of radionuclides in those sites, the activities of ^{226}Ra, ^{232}Th and ^{40}K obtained are also within the permissible safe limit.

All the radiation risk parameters estimated were lower than the World safe values of 55 $nGyh^{-1}$, $0.07mSvy^{-1}$, 0.29 x $10^{-3}$and 300 $mSvy^{-1}$ for absorbed dose, annual effective dose, excess lifetime cancer risks and annual gonadal dose respectively in all locations studied. Also, all the estimated radiation hazard indices A_{uI}, H_{ex}, H_{in}, 1_{yr}, ELCR ($x10^{-3}$) were lower than the world means of ≤ 1 for the three locations. These results are similar to the ones obtained in similar work [23, 40]. The results of this study shows that there will be no immediate radiation risk due to inhalable particulate matter within the quarry sites to the workers and the inhabitants of these communities, though long-term effect might be envisaged.

Conclusion

The evaluation of radionuclide content of suspended particulate matter from some quarry sites have been carried out. The result showed that the particulate matter in the quarries sites has low radionuclide content since the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in the suspended particulate matter were lower than the recommended safe values.

The estimated radiological risk parameters of all the sites were lower than their safe values. Hazard indices estimated were lower than 1 which is the recommended safe value. Therefore, quarrying activities in the two areas Okpella and Ishiagu mining sites have not impacted radiologically the air of the communities hosting the companies.Hence, constant radiological screening of the suspended particulate matter SPM is therefore recommended to keep the possible radiation hazard as low as reasonably achievable (ALARA). The result can as well serve as baseline for further radiological studies for the two states.

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