

# EFFECT OF GRAIN SIZE ON RADIONUCLIDE CONTENT IN SEDIMENT SAMPLES FROM KOLO CREEK, BAYELSA STATE, NIGERIA

## Abstract

### Abstract

The effect of grain sizes on radionuclide concentration in soil and sediment samples from Kolo creek, Bayelsa State was investigated using gamma spectroscopy. Eight (8) samples of sediment were collected around the oil spill site of the creek. All the samples were separated into four different grain sizes, A (0.5mm), B (1mm), C (1.5mm) and D (2mm), making a total of 32 sediment. The activity concentration in sediment samples of grain sizes 0.5 mm, 1.0mm, 1.5mm and 2mm were determined. In sediment samples of grain sizes 0.5mm(A),  $^{226}\text{Ra}$  activity concentration ranges from  $2.24 \pm 1.54$  Bq/kg (Imiringi) to  $20.03 \pm 2.43$  Bq/kg (Otuasega 2), while that of  $^{232}\text{Th}$  and  $^{40}\text{K}$  varies from  $3.21 \pm 1.01$  Bq/kg (Otuasega 2) to  $5.59 \pm 1.32$  Bq/kg (Ibelebiri 1) and  $24.46 \pm 4.06$  Bq/kg (Imiringi 2) to  $795.99 \pm 6.20$  (Kolo) respectively. For grain size of 1.0mm (B) the activity concentration of  $^{226}\text{Ra}$  varies from  $2.66 \pm 1.30$  Bq/kg (Ibelebiri 2) to  $26.64 \pm 4.23$  Bq/kg (Emeyal) while that of  $^{232}\text{Th}$  and  $^{40}\text{K}$  varies from  $2.19 \pm 0.95$  Bq/kg (Imiringi) to  $33.47 \pm 3.97$  (Emeyal) and  $43.38 \pm 3.00$  Bq/kg (Ibelebiri 2) to  $739.21 \pm 6.20$  Bq/kg (Kolo) respectively. The mean activity concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in sediment samples are  $14.68 \pm 3.4$ ,  $8.49 \pm 1.6$  and  $189.1 \pm 4.0$  Bq/kg respectively. The result obtained shows there was no clear trend in variation of activity concentration with grain sizes. The mean values obtained are below the world average of 35, 30 and 400 Bq/kg for  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  for grain sizes of 0.5, 1.0, 1.5 and 2.0 mm respectively in all the communities except samples from Kolo that recorded  $471.36 \pm 6.12$  to  $795.99 \pm 6.44$  Bq/kg in all the grain sizes. Radiological risk parameters such as Absorbed Dose Rate, Annual Effective Dose Equivalent, Annual Gonadal Dose Equivalent, Annual Utility Index, Radioactivity Level Index, Hazard Indices and Excess Life Cancer Risk were estimated and values were found to be within the world average. From this study, the sediment of the given grain sizes will pose no radiological health risk if used in farming and in building construction.

## 1. Introduction

Man is exposed to varying degrees of radiation on earth, through the air we breathe, the soil we use for farming and construction, mining of minerals, sediments we use for building, even the food we consume [1]. Despite efforts to ensure safety, radionuclide is introduced into land and water environment of coastal areas which are mainly network of rivers and creeks through leaks, mishandling of equipment, improper discharge, loss and theft [2], Following different pathways through erosion, run-off, flooding, wind etc, large quantity of radionuclide may end up at river sediments and farm lands.

However, the exposure to radiation is not limited to internal exposure from the consumption of terrestrial and aquatic foods alone, sediments found in creeks and rivers with high radionuclide concentration used as building material has the probability of increasing external exposure level.

It has been studied that the highest radionuclide content is found in building materials such as sand, stone, bricks and sediments [3], and their concentration are widely distributed in the environment which may vary from one place to another based on geological setting [4].

The distribution of grain sizes in soil is important characteristic factor which can influence the radionuclide distribution in the environment during transport process. Sediments from water bodies (creeks, rivers etc) are made of minerals of different sizes of grain which may serve as a reliable indicator of radionuclide pollution when deposited, and may emit gamma radiation which could be fatal if of high concentration when used in construction of buildings [5]. The predominant radionuclide mostly found are that of Uranium-238, Thorium-232 series and their progenies and Potassium-40 which may be of potential threat if found in high concentration, it is therefore imperative for proper environmental monitoring to know the radiological status of soil and sediment and its associated risks.

Recent radiological studies revealed high gamma concentration on sediments in Nigeria around oil and gas production facilities and the environments, hence study of radionuclide distribution provides knowledge on the radiological implication of exposure and irradiation to various internal organs of the body [6].

The activity concentration of natural radionuclides in river sediment depends on mineralogical features in the catchment area and the chemistry of the river as a whole [7]. The major sources of natural radionuclides in sediments have different origins. These include weathering and recycling of terrestrial minerals and rocks (igneous or metamorphic) containing  $^{40}\text{K}$  and radionuclides of the uranium and thorium radioactive series, rainfall and other depositional phenomena such as gravitational settling and precipitation. In stream sediments U and Th may be found incorporated into the existing minerals or they may be adsorbed directly from river water onto clay minerals or organic debris. Occasionally, U may be removed from river water to sediments directly if reducing bottom conditions exist [8].

Artificial radionuclides can be introduced into rivers for direct and indirect inputs. Directly through the aqueous discharges from nuclear installations and indirectly from wash-off of land deposited activity within the river catchment following nuclear weapon testing or nuclear accidents. Most of the radioactivity deposited on surface soils, depending on the radionuclide's geochemistry, is washed out by rains and drained in to the rivers. After reaching the river ecosystem, radionuclides may be transferred through the water-sediment-biota pathways [9] to humans, by using the river water as drinking water or for irrigation and by the consumption of contaminated fish.

River sediments, consisting of mineral particles with different sizes, are considered long term reliable indicators of river pollution by radionuclides because water pollution components are deposited in the sediments. Long-term radioactive pollution may accumulate and whenever the sediments are re-suspended the radionuclides re-enter the sediment-biota chain [5]. Therefore, the

knowledge of the concentrations and distribution of the radionuclides in the river sediments are of great interest since it provides useful information on the background and on the temporal changes in radionuclide activity concentrations within the river.

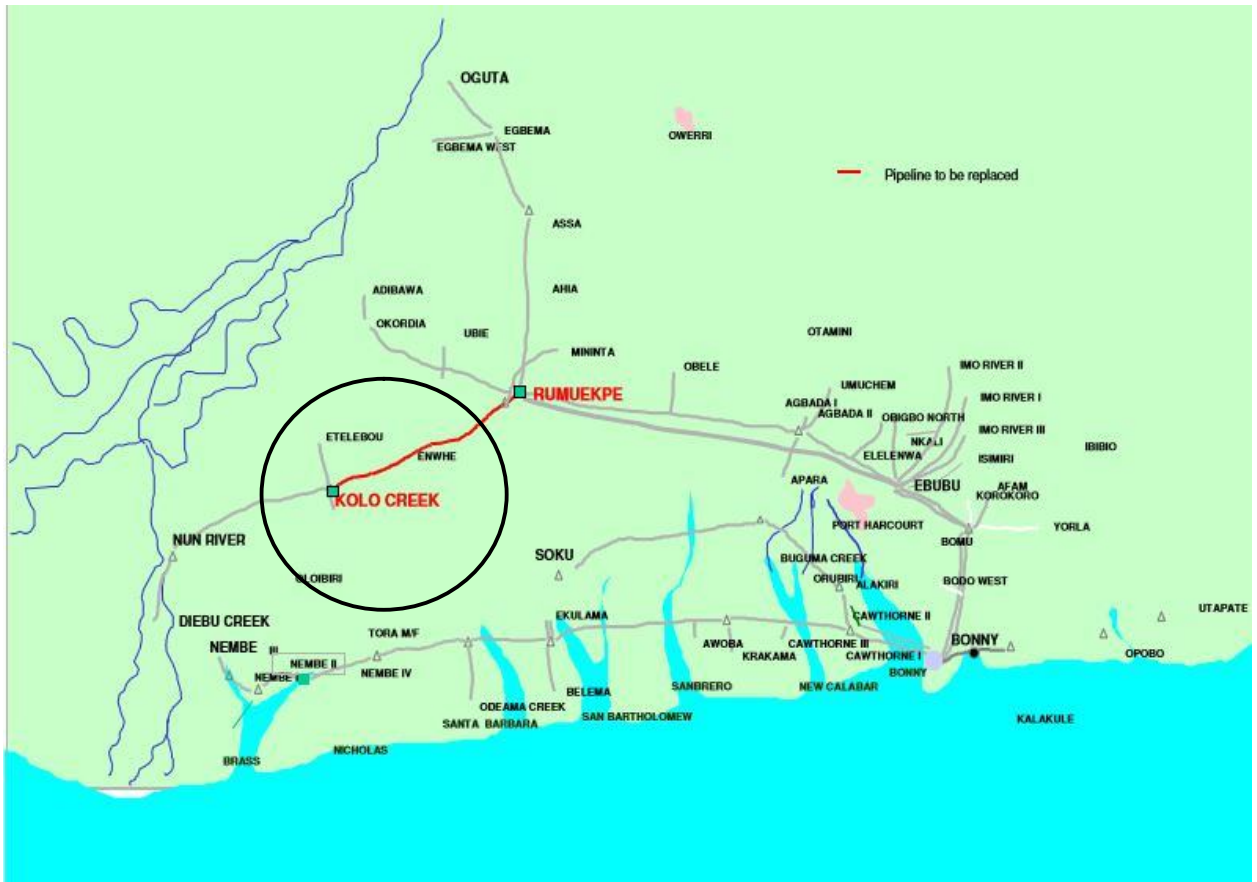
The main objective of this study is to assess, the activity distribution of natural  $^{228}\text{Ra}$ ,  $^{226}\text{Ra}$ ,  $^{40}\text{K}$  in sediments collected from oil spill River sediment from oil spill areas of the creek and the influence of the sediment particle sizes on radionuclide concentrations. Besides, the knowledge of radionuclide concentrations and distribution in River sediments can be useful for the radiological mapping of the studied area. Bottom sediments consist of particles that have been transported by water, air or glaciers from the sites of their origin in a terrestrial environment and have been deposited on the floor of a river, lake, or ocean [5]. In addition to these particles, bottom sediments will contain materials precipitated from chemical and biological processes. Natural processes responsible for the formation of bottom sediments can be altered by anthropogenic activities. Many man-made wastes have entered bodies of water through atmospheric deposition, runoff from land, or direct discharge into the water. Most hydrophobic organic contaminants, metal compounds, and nutrients, which enter the water become associated with particulate matter. This particulate matter then settles and accumulates in the bottom sediments. Under certain conditions the contaminants in the bottom sediments may be released back into water or enter the food chain [8].

Consequently, bottom sediments are a sink as well as a source of contaminants in the aquatic environment. These contaminants may pose a high risk to the environment on a large scale and hence need to be monitored at regular intervals. Environmental monitoring includes sampling and analyses of the sediments based on grain sizes is of great importance. Hence the need for this research work.

## 2. Materials and Methods

### 2.1 Study Area

Kolo Creek is situated in Ogbia Local Government Area of Bayelsa State, in the Niger Delta. The study area lies within Latitudes  $4^{\circ}47'40''$  and  $4^{\circ}56'31''$  N and Longitudes  $6^{\circ}19'15''$  and  $6^{\circ}25'8''$  E, Northwest of Yenagoa, within the lower delta plain. It is a non-tidal freshwater environment that empties into the river Nun [10]. It is host to oil and gas fields with noticeable presence of oil exploration and related activities that have attracted the influx of people and businesses. It has a history of oil spillage that has affected farmlands and sources of domestic water of the inhabitants. It is also host to the Kolo creek flow station and a gas turbine plant which supplies electricity to neighboring communities and parts of the state. The inhabitants of Ogbia (Ijaw) extraction whose major occupations are farming of cassava, plantain, banana, coco yam, sugarcane and fishing.



**Fig. 1: Study Area (Shell, 2004).**

Twelve (12) samples of sediment and soil samples were collected in five (5) communities (Immiringi, Kolo, Ibelebiri, Emeyal And Otuosega) of the study area. Soil samples were collected at a depth of 5cm from the ground surface using a hand-held auger, sediment samples were collected at low tide from the Creek. All the samples were put in a black cellophane bag that is well labeled. The samples were air dried for two weeks and debris removed before taking them to radiation laboratory. Each sample was separated into four different grain sizes: 0.5mm, 1.0mm, 1.5mm and 2mm and labeled A, B, C and D respectively by passing them through a mesh. The 48 samples were then weighed and filled into Marinelli beakers with labels and sealed to avoid the escape of radon ( $^{222}\text{Rn}$  and  $^{220}\text{Rn}$ ) [11] and then stored for about a month, in order to reach the radioactive equilibrium between  $^{222}\text{Rn}$  with its parent,  $^{226}\text{Ra}$  (secular equilibrium) before gamma ray spectroscopy was done.

## 2.2 Gamma ray analysis

The samples were analyzed at Radiation Laboratory of the department of Physics, Federal University of Agriculture, Abeokuta, Ogun State. Gamma Ray Spectrometry using a thallium activated 3"x3" Sodium iodide [NaI(Tl)] detector connected to ORTEC 456 amplifier was used.

The detector, enclosed in a 100mm thick lead shield, was connected to a computer program SAMPO 90 window that matched gamma energies to a library of possible isotopes. Since the accuracy of the quantitative measurements is dependent on the calibration of the spectrometry system and adequate energy. Background measurement and efficiency calibration of the system was made possible using Cs -137 and Co-60 standard sources from IAEA, Vienna. Spectrum were accumulated for background for 29000s at 900volts to produce strong peaks at gamma emitting energies of 1460 keV for  $^{40}\text{K}$ ; 609 keV of 214 Bi and 911 keV of  $^{228}\text{Ac}$ , which were used to estimate the concentration of  $^{238}\text{U}$  ( $^{226}\text{Ra}$ ) and  $^{232}\text{Th}$ , respectively. The energy resolution of the detector using Cs -137 and Co-60 standards is 39.5% and 22.2% respectively while the activity of the standards at the time of calibration is 25.37 KBq for Cs - 137 and 4.84 KBq for Co- 60. The background spectra, measured under the same conditions for both the standard and sample measurements, were used to correct the calculated sample activities concentration in accordance with Arogunjo et al., [12]. The activity concentration (C) in Bq/kg of the radionuclides in the samples was calculated after subtracting decay correction using the expression:

$$C_s = \frac{NE_\gamma}{\varepsilon E_\gamma \chi M_v \chi t_c \chi P_\gamma} \quad (1)$$

Where  $C_s$ = Sample concentration,  $NE_\gamma$ = net peak area of a peak at energy,  $\varepsilon E_\gamma$ = Efficiency of the detector for a  $\gamma$ -energy of interest,  $M_v$ =Sample volume,  $t_c$ = total counting time,  $P_\gamma$ =Emission probability of radionuclide of interest.

## 2.3 Radiological parameters

### 2.3.1 Radium equivalent (Raeq)

Due to non- uniformity of radionuclide distribution in a material which contains  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$ , Radium equivalent activity concentrations are employed to represent the concentration of radionuclides in a material. It represents the net effect of radionuclide present in a material. It is determined by to the equation [14].

$$\text{Raeq} = A_{\text{Ra}} + 0.143A_{\text{Th}} + 0.077A_{\text{K}} \quad (2)$$

Where  $A_{\text{Ra}}$ ,  $A_{\text{Th}}$  and  $A_{\text{K}}$  are activity concentration of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in Bq/kg respectively assuming 370Bq/kg of  $^{226}\text{Ra}$ , 259 Bq/kg of  $^{232}\text{Th}$  and 4810 Bq/kg of  $^{40}\text{K}$  that will produce the same gamma dose rate.

### 2.3.2 Absorbed Dose Rate (DR)

For a uniform radionuclide distribution, the absorbed dose rate due to gamma radiation in air 1meter above the ground for  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  isa measure of the energy deposited in a medium by ionizing radiation from the nuclides. The conversion factor for a unit activity concentration for dry weight of the radionuclides is  $0.462 \text{ nGyh}^{-1}$  for  $^{226}\text{Ra}$  ,  $0.604 \text{ nGyh}^{-1}$  for  $^{232}\text{Th}$  and  $0.042 \text{ nGyh}^{-1}$  for  $^{40}\text{K}$ . The value is determined by the equation [15].

$$D(\text{nGh}^{-1}) = 0.462A_{\text{Ra}} + 0.604A_{\text{Th}} + 0.042A_{\text{K}} \quad (3)$$

Where  $A_{\text{Ra}}$ ,  $A_{\text{Th}}$  and  $A_{\text{K}}$ , represents the activity concentration of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  respectively.

### 2.3.3 Internal hazard index ( $H_{\text{in}}$ )

This represents the internal radiation. It is important due to the present of radon gas and its short-lived products and the hazard they pose to the respiratory organ [16]. For it to be insignificant, the index must be less than unity. It is determined according to the equation:

$$H_{\text{in}} = \frac{A_{\text{Ra}}}{185} + \frac{A_{\text{Th}}}{259} + \frac{A_{\text{K}}}{4810} \leq 1 \quad (4)$$

Where  $A_{\text{Ra}}$ ,  $A_{\text{Th}}$  and  $A_{\text{K}}$  are the activity concentration of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in Bq/kg respectively

### 2.3.4 External Radiation Index ( $H_{\text{ex}}$ )

This value also must be less than unity for it to be insignificant. Both internal and external hazard index is determined from  $R_{\text{aeq}}$  expression through the superposition that the maximum value will be equal to 1 corresponds to the upper limit of  $R_{\text{aeq}}$  (370 Bq/kg). The external radiation hazard index is determined according to the equation [14].

$$H_{\text{Ex}} = \frac{A_{\text{Ra}}}{370} + \frac{A_{\text{Th}}}{259} + \frac{A_{\text{K}}}{4810} \leq 1 \quad (5)$$

### 2.3.5 Annual Effective Dose Equivalent (AEDE)

It represents a measure of deterministic or stochastic risk due to irradiation. This parameter converts the absorbed dose in air given in  $\text{nGyh}^{-1}$  with a factor of  $0.7 \text{ SvGy}^{-1}$  to effective dose rate in milliSv per year ( $\text{mSvyr}^{-1}$ ). The time of stay is 20% of 8760 hr in a year for indoor annual effective dose and 80% for outdoor annual effective dose. The value should not exceed  $1 \text{ mSv/yr}$  [15], the world average value is  $0.48 \text{ mSv/yr}$ . It is determined according to the equation [15].

$$\text{AEDE} = DR(\text{nGyh}^{-1}) \times 8760 \text{ hr}^{-1} \times 0.7 \text{ SvGy}^{-1} \times \frac{10^3 \text{ mSv}}{10^9 \text{ nGy}} \times 0.2 \quad (6)$$

### 2.3.6 Annual Gonadal Dose (AGD)

The organs of interest are the gonad, active bone marrow and the bone surface cells. They are radiosensitive and when affected may cause significant damage. High values of AGDE can cause damage to the red blood cells and bone marrow due to their sensitive nature, which may result to cancer [6].

The annual gonadal dose equivalent due to  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  are determined by the equation [17].

$$AGDE(mSv\text{y}^{-1}) = 3.09A_{Ra} + 4.18A_{Th} + 0.0314A_K(7)$$

Where  $A_{Ra}$ ,  $A_{Th}$  and  $A_K$  are activity concentration of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in Bq/kg respectively.

### 2.3.7 Gamma Representative Index

Also called gamma radioactivity level index, is concerned with the radioactivity associated with different concentration of some specific nuclides. It is given by Eshiemomoh et al., [14].

$$RLI = \frac{A_{Ra}}{150\text{Bqkg}^{-1}} + \frac{A_{Th}}{100\text{Bqkg}^{-1}} + \frac{A_K}{1500\text{BqK}^{-1}} \leq 1 \quad (8)$$

Where  $A_{Ra}$ ,  $A_{Th}$  and  $A_K$  are the activity concentration of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in Bq/kg respectively.  $RLI \leq 1$  corresponds to  $AEDE \leq 1\text{mSv/yr}$ .

### 2.3.8 Activity Utilization Index (AUI)

This is used as criteria for building construction, to calculate the dose rate in air arising from  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$ , since sediments and soil are used in building construction. A wall made up of soil (sandy, muddy or coarse grains) can be a source of radiation and can also serve as a shield against outdoor radiation [15].

The Activity Utilization Index is defined by applying appropriate conversion factors [19].

$$AUI = \left(\frac{A_{Ra}}{50}\right)F_{Ra} + \left(\frac{A_{Th}}{50}\right)F_{Th} + \left(\frac{A_K}{50}\right)F_K \leq 2(9)$$

Where  $F_{Ra}(0.462)$ ,  $F_{Th}(0.604)$  and  $F_K(0.041)$  represents the various fractional contribution to the total gamma dose in air from actual concentration of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$ . The recommended safe limit is 2.

### 2.3.9 Excess Life Time Cancer (ELCR)

At certain exposure level (rate), there is the possibility of developing cancer over time from exposure. The excess life time cancer risk gives that probability.

The ELCR is calculated by Degerlieret al.,[20].

$$ELCR = AEDE \times DL \times RF(10)$$

Where AEDE, DL and RF are the annual effective dose equivalent, duration of life (life expectancy of 70yrs) and fatal risk factor per Sievert. For stochastic effect a value of  $0.05\text{Sv}^{-1}$  was given by ICRP 60 for the public [21].

## 3. Results

**Table 1: Activity concentration of Radionuclides according to their grain size and radium equivalent in sediment samples**

S/ N	Sample location	GPS reading	Grain size	Activity Concentration (Bqkg <sup>-1</sup> )			Raeq(B qkg <sup>-1</sup> )
				<sup>226</sup> Ra	<sup>232</sup> Th	<sup>40</sup> K	
1	Ibelebiri 1	N4°56'3.2"	A	13.08±3.51	5.59±1.32	69.58±3.46	26.4
			B	4.40±1.09	3.45±0.74	88.51±4.24	14.7
		E6°25'8.1"	C	17.14±2.74	3.11±1.17	97.24±2.74	29.0
			D	5.56±3.54	2.87±1.33	113.25±2.74	18.3
2	Ibelebiri 2	N4°56'05"	A	13.08±2.87	3.70±1.20	55.47±2.74	22.6
			B	2.66±1.30	5.30±0.81	43.38±3.00	13.5
		E6°25'7.5"	C	4.40±1.09	3.45±0.74	39.90±3.54	12.4
			D	4.86±1.23	3.84±0.78	43.38±3.00	13.7
3	Otuasega1	N4°55'6.4"	A	10.19±4.62	4.37±1.52	57.94±3.32	20.9
			B	17.14±4.03	4.76±1.42	116.17±3.74	32.8
		E6°23'52.8"	C	33.93±3.65	3.79±1.35	53.57±3.61	43.4
			D	20.03±3.68	5.30±1.36	39.01±4.00	30.6
4	Otuasega2	N4°55'5.4"	A	20.03±2.43	3.21±1.10	197.69±4.53	39.8
			B	15.40±3.12	4.18±1.25	196.23±4.30	36.4
		E6°23'53.6"	C	7.76±4.35	4.62±1.47	331.61±5.43	39.9
			D	4.86±3.78	4.71±1.37	207.88±3.94	27.6
5	Imiringi 1	N4°52'46'	A	3.24±1.54	3.21±0.88	140.91±4.00	18.6
			B	2.66±1.81	2.19±0.95	121.99±4.30	15.1
		E6°22'32.8"	C	8.45±5.95	2.14±1.72	223.89±3.54	28.7
			D	32.19±3.95	2.19±1.40	60.85±2.83	40.0
6	Imiringi2	N4°52'45"	A	7.76±4.93	4.81±1.57	24.46±4.06	16.5
			B	17.14±4.03	5.30±1.42	91.42±4.53	31.7
		E6°22'32.3"	C	30.45±3.75	4.91±1.37	219.52±5.00	54.3
			D	40.29±2.50	4.67±1.12	76.86±4.42	52.8

7	Emeyal	N4°50'31"	A	13.67±5.59	13.92±5.3	212.53±2.68	49.9	
			E6°20'19"	B	26.64±4.23	33.47±3.9	285.32±2.50	96.4
			C	23.76±5.85	26.15±5.3	243.63±3.61	79.9	
			D	21.59±5.07	83.20±3.9	96.08±4.15	147.9	
8	Kolo	N4°47'40"	A	11.51±3.63	5.39±1.35	795.99±6.44	80.50	
			E6°19'15'	B	21.77±4.59	4.62±1.51	739.21±6.20	85.2
			C	9.49±4.70	5.35±1.53	471.36±6.12	53.4	
			D	4.81±1.84	3.94±0.96	497.56±5.87	48.7	

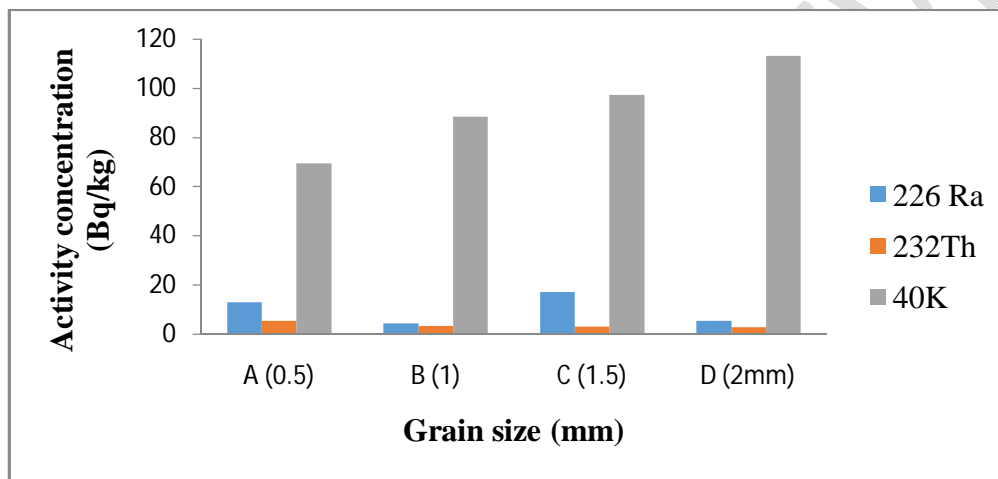


Fig.2: Variation of activity concentration with grain size for Ibelebiri1 sediment samples

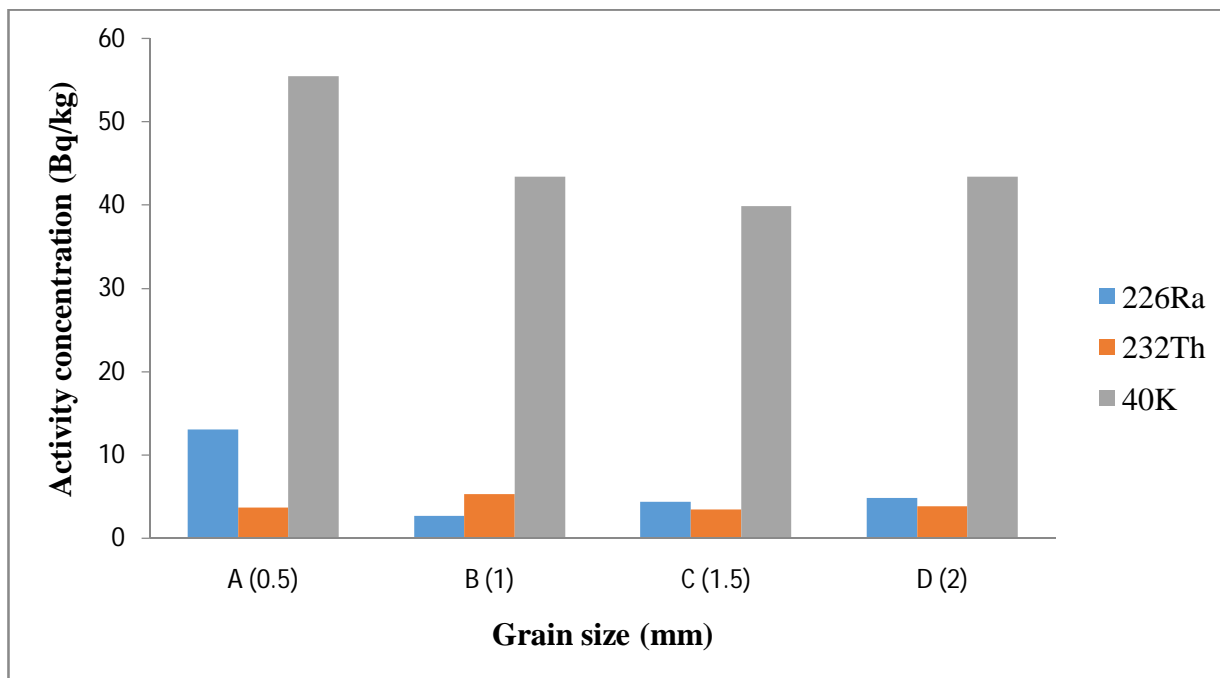


Fig.3: Variation of activity concentration with grain size for Sediment from Ibelebiri 2 samples

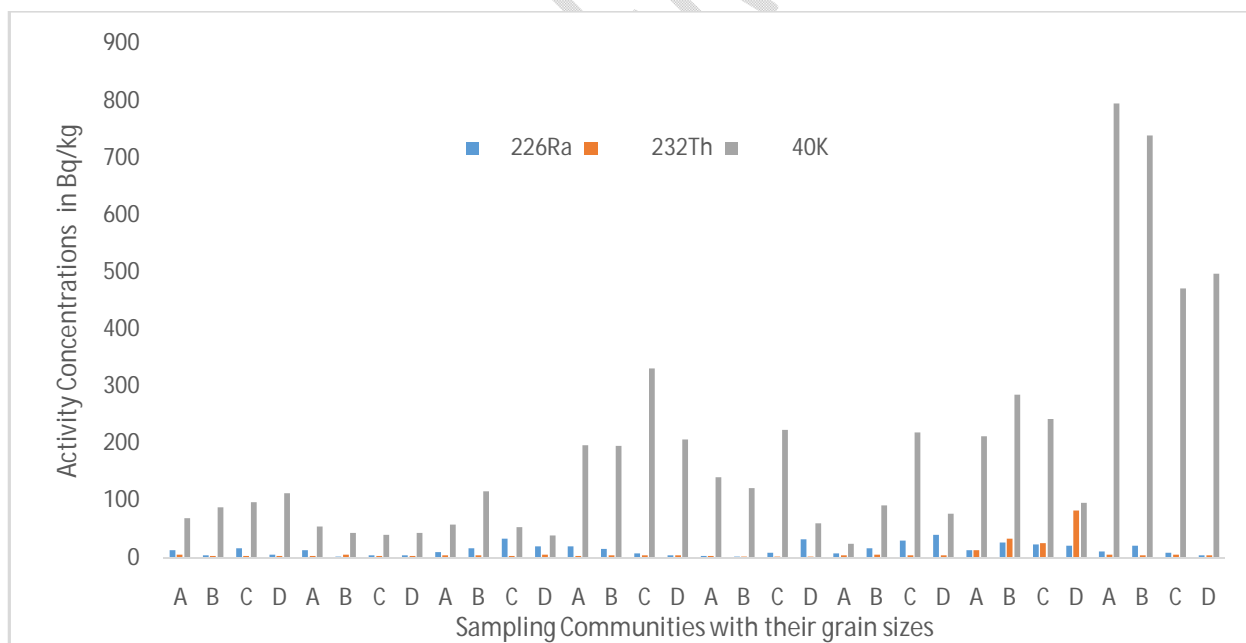


Fig 4: Variations of activity concentration of  $^{226}\text{Ra}$ ,  $^{40}\text{K}$  and  $^{232}\text{Th}$  with grain sizes

**Table 2: Radiological risk parameters in sediment samples from Kolo creek**

S/N	Sample location	grain size	DR (nGyh <sup>-1</sup> )	AEDE (mSvh <sup>-1</sup> )	AGD (mSvh <sup>-1</sup> )	AUI	RLI	H <sub>ex</sub>	H <sub>in</sub>	ELCR x 10 <sup>-3</sup>
1	Ibelebiri 1	A	12.34	0.015	89.04	0.245	0.189	0.071	0.106	0.053
		B	7.834	0.009	55.80	0.154	0.122	0.043	0.055	0.032
		C	13.88	0.017	96.46	0.275	0.210	0.078	0.124	0.059
		D	9.058	0.011	64.73	0.178	0.141	0.049	0.064	0.038
2	Ibelebiri 2	A	10.60	0.014	73.30	0.211	0.161	0.050	0.096	0.049
		B	6.252	0.008	43.99	0.124	0.099	0.036	0.043	0.028
		C	5.792	0.007	40.54	0.115	0.090	0.033	0.045	0.025
		D	9.058	0.008	44.68	0.126	0.099	0.036	0.050	0.028
3	Otuasega1	A	9.780	0.012	67.94	0.194	0.150	0.056	0.083	0.042
		B	15.67	0.019	109.3	0.311	0.239	0.088	0.135	0.066
		C	20.04	0.024	138.1	0.403	0.299	0.117	0.209	0.084
		D	14.09	0.017	96.24	0.281	0.212	0.082	0.136	0.059
4	Otuasega2	A	19.46	0.024	137.3	0.385	0.297	0.107	0.161	0.084
		B	17.88	0.022	126.6	0.353	0.275	0.098	0.140	0.077
		C	20.30	0.025	147.4	0.399	0.319	0.107	0.128	0.087
		D	13.83	0.017	99.97	0.272	0.218	0.074	0.087	0.059
5	Imiringi 1	A	9.35	0.011	67.67	0.184	0.147	0.050	0.059	0.038
		B	7.675	0.009	55.67	0.151	0.120	0.041	0.048	0.032
		C	14.59	0.018	105.3	0.287	0.226	0.077	0.166	0.063
		D	18.74	0.023	127.7	0.373	0.277	0.187	0.195	0.081
6	Imiringi 2	A	7.517	0.009	51.57	0.149	0.116	0.044	0.065	0.032
		B	14.95	0.018	103.8	0.297	0.228	0.085	0.132	0.063

		C	26.25	0.032	183.5	0.520	0.398	0.146	0.229	0.112
		D	24.66	0.030	168.1	0.491	0.366	0.142	0.251	0.105
7	Emeyal	A	23.61	0.029	167.1	0.468	0.372	0.134	0.171	0.102
		B	44.50	0.055	311.0	0.884	0.705	0.260	0.332	0.193
		C	36.99	0.045	259.2	0.735	0.582	0.215	0.279	0.157
		D	64.26	0.078	444.6	1.283	1.039	0.399	0.457	0.273
8	Kolo	A	41.52	0.051	308.0	0.824	0.661	0.217	0.248	0.178
		B	43.89	0.054	318.6	0.863	0.684	0.230	0.289	0.189
		C	27.41	0.034	199.6	0.538	0.431	0.144	0.169	0.119
		D	25.49	0.031	187.5	0.050	0.403	0.131	0.144	0.108
		<b>MEAN</b>	<b>19.91</b>	<b>0.024</b>	<b>140.3</b>	<b>0.378</b>	<b>0.308</b>	<b>0.113</b>	<b>0.153</b>	<b>0.085</b>

#### 4. Discussion

In sediment samples of grain sizes 0.5mm(A),  $^{226}\text{Ra}$  activity concentration ranges from  $2.24 \pm 1.54$  Bq/kg (Imiringi) to  $20.03 \pm 2.43$  Bq/kg (Otuasega 2), while that of  $^{232}\text{Th}$  and  $^{40}\text{K}$  varies from  $3.21 \pm 1.01$  Bq/kg (Otuasega 2) to  $5.59 \pm 1.32$  Bq/kg (Ibelebiri 1) and  $24.46 \pm 4.06$  Bq/kg (Imiringi 2) to  $795.99 \pm 6.20$  (Kolo) respectively. For grain size of 1.0mm (B) the activity concentration of  $^{226}\text{Ra}$  varies from  $2.66 \pm 1.30$  Bq/kg (Ibelebiri 2) to  $26.64 \pm 4.23$  Bq/kg (Emeyal) while that of  $^{232}\text{Th}$  and  $^{40}\text{K}$  varies from  $2.19 \pm 0.95$  Bq/kg (Imiringi) to  $33.47 \pm 3.97$  (Emeyal) and  $43.38 \pm 3.00$  Bq/kg (Ibelebiri 2) to  $739.21 \pm 6.20$  Bq/kg (Kolo) respectively.

For grain sizes 1.5mm (C),  $^{226}\text{Ra}$  activity concentration ranges from  $4.40 \pm 1.09$  Bq/kg (Ibelebiri 2) to  $33.93 \pm 3.65$  Bq/kg (Otuasega 1) while that of  $^{232}\text{Th}$  and  $^{40}\text{K}$  varies from  $2.14 \pm 1.72$  Bq/kg (Imiringi 1) to  $26.15 \pm 5.37$  Bq/kg (Emeyal) and  $39.90 \pm 3.54$  Bq/kg (Ibelebiri 2) to  $471.36 \pm 6.12$  (Kolo) respectively. For grain sizes 2.0mm (D)  $^{226}\text{Ra}$  activity concentration ranges from  $4.81 \pm 1.84$  Bq/kg (Kolo) to  $40.29 \pm 2.50$  Bq/kg (Emeyal) while that of  $^{232}\text{Th}$  and  $^{40}\text{K}$  varies from  $2.19 \pm 1.40$  Bq/kg (Imiringi 1) to  $83.20 \pm 3.91$  Bq/kg (Emeyal) and  $39.01 \pm 4.00$  Bq/kg (Otuasega 1) to  $497.56 \pm 5.87$  (Kolo) respectively. Mean value of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  for all sediment samples are  $14.68 \pm 3.4$  Bq/kg,  $8.49 \pm 1.6$  Bq/kg and  $189.1 \pm 4.0$  Bq/kg respectively. The results show that only sample with grain size of 2

mm from Imirigi recorded higher value of 40.29 Bq/kg for  $^{226}\text{Ra}$  while other values obtained for all the radionuclides are below their permissible values of 35, 30 and 400Bq/kg. The activity concentration of  $^{40}\text{K}$  in samples from Kolo community of varying grain sizes exceeded the permissible limit of 400.0 Bq/kg. However, the variation of activity concentration of radionuclides with grain size though not uniform, increases with increase in grain size in some samples. Figures 2-4 showed the variation of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  with different grain sizes of sediment samples. Activity concentration of  $^{40}\text{K}$  were higher in all the grain sizes from all the communities along the Kolo creek.

The average activity concentration values of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  obtained in the study area are lower than the average values of 16.82Bq/kg, 32.84 Bq/kg and 743.52 Bq/kg recorded in Bangladesh by Nizamet *al.*, [22], 189.62, 53.47 and 725.62 Bq/kg in Ndokwa east of Delta state recorded by Ononugbo and Ofuonye [6]. The radiological risk parameters estimated in the samples were lower than their safe values. The activity utilization index was lower than unity which means that sediment from Kolo creek is suitable for building purposes since the radiological risk of exposure is minimal.

## 5. Conclusion

Gamma Spectrometry using Sodium Iodide (Thallium) will continue to be popular for delineating the activity concentration of primordial isotopes  $^{40}\text{K}$ ,  $^{232}\text{Th}$ , and  $^{226}\text{Ra}$  present in sediment samples from Kolo Creek. Findings shows that the average activity concentrations of  $^{40}\text{K}$  increased with increase in grain size in some samples but overturned in samples from Kolo community where  $^{40}\text{K}$  values recorded in grain size 0.5 (A) was the highest ( $795.99 \pm 6.44$  Bq/kg) while  $^{226}\text{Ra}$  and  $^{232}\text{Th}$  activities varied randomly with grain sizes. The estimated radiological health risk parameters also showed random variation with grain sizes and are within their safe limits. This result showed that the activity concentration of radionuclides in sediment samples from Kolo creek does not depend on grain sizes.

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