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Excessive-life time cancer risks due to concentration of radionuclides and quantification of contamination of sediments from dredged portion of Niger River Nigeria

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► ***Original article***

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ABSTRACT

Background: River Niger is the principal river of Western African and is Africa's third longest river. The dredged project covers 572 km of the lower Niger, extending from Baro in Niger State to Warri Bifurcation in Delta State. ***Materials and Methods***: The current study estimated the activity concentrations of naturally occurring radionuclides and heavy metals concentrations in the sediment samples from Lower Niger River using gamma -ray and Atomic Absorption spectrometric techniques. ***Results***: The weighted activity concentrations of radionuclides ^{40}K (231± 21 Bq kg^{-1}), ^{232}Th (10±1 Bq kg^{-1}), ^{226}Ra (75±17 Bq kg^{-1}), were obtained in the sediment samples. The radium equivalent, absorbed dose rate, hazardous indices and excessive-life time cancer risk were compared with the international recommended limits. ***Conclusion***: The measured heavy metal concentrations, contamination factor, pollution load index and quantification of contamination indicated that sediment samples from the River were moderately contaminated.

Keywords: *Contamination factor, heavy metals, pollution load index, radionuclides, sediment, quantification of contamination.*

INTRODUCTION

Primordial radionuclides such as ^{40}K, ^{232}Th and ^{226}Ra are widely spread in the earth's environment and exist in various geological formations such as rocks, earth crust, plants, water and air [1]. Long-term exposures to radioactivity and inhalation of radionuclides have been ascertained to altering structure of the cells. River sediments when mixed with cement to form mortar are used for construction of houses and fixing of tiles. Activity concentrations of natural radionuclides in building materials affect the indoor absorbed dose [2] by contributing to the background level of radiation. Consequently dose rates in air indoors will be elevated due to the concentration of naturally occurring radionuclides in building materials such as sediments. Heavy metal are deemed as severe and high ecological and inorganic pollutants due to high enrichment factor (EF), slow removal rate, potential toxicity to aquatic life, persistent and bio-accumulate nature [3, 4, 5]. Heavy metals that enter into river system via weathering erosion of the earth, artificial activities such as mining, industrial waste at shipbuilding plants, agriculture, desalination facilities, coastal activities such as marinas, jetties, ports, harbors, fishing boats and sewage disposal [6, 7, 8] cannot be removed from water body by self-purification. Heavy metals are remobilized by sediment that acts as sinks for pollutants into aquatic systems. In as much they cannot be removed by water, they are consumed by aquatic animals and transfer to man via ingestion. Lower part of River Niger was dredged between Baro and Warri measures approximately 572 km in view of the enormous challenges of both riverine in terms of flooding and land transport in Nigeria. Sediment samples taken from widening and deepening of the lower Niger River were deposited some distance away from the River's bank. The knowledge about concentrations and distributions of radionuclides and heavy metals is of interest as a result of anthropogenic activities due to agricultural practices

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(irrigation and fertilizer application), domestic discharge and industrial operations on the river. The aforementioned activities are the major sources of radionuclides and heavy metals in the river sediments. Therefore, concentrations of naturally occurring radionuclides and heavy metals in the sediments of lower River Niger Nigeria were measured in order to achieve the following aims (1) the radiation health hazard indices (2) excessive lifetime cancer risk and (3) quality of contamination of the sediments to know dose accrued to the populace as a result of recent increase in usage of sediments for construction of buildings and other construction projects in Nigeria. These findings will contribute to the few available natural radioactivity level database obtained from the used of sediments for different purposes in Nigeria and provide information on any possible radiological hazard to mankind using sediments as raw materials.

MATERIALS AND METHODS

Study area

River Niger is the most popular and the longest River in Nigeria and West Africa [9]. It covers an area of about 2600 miles. The river has strong sinuous and meandering characters and has no regulating measures to guide the flow. Another significant characteristic of the river is its water level which varies up to 9 m between the dry season and the rainy season. During the rainy season (June till September) the output of the river increases from 1,800 m^3/ sec to more than 20,000 m^3/sec. This has a major impact on the current, which can peak to more than 3 m/sec [10]. It major tributaries are Kaduna River, Sokoto River and Bani River. It is joined by Benue River at Lokoja. Some significant dams on the River are Kainji Dam at new Bussa (Nigeria), Sotuba Dam (Mali), Markala Dam at Jebba (Nigeria) and Shiroro Dam (Kaduna tributary, Nigeria). There is large- scale irrigation and fish farming along the River's bank. The River serves as the main source of water for domestic and industrial uses in towns and villages along its course. The River has become polluted along its route to the Atlantic Ocean as a result of influential human activities such as fertilizers application in irrigation farming, washing, waste discharge [11] and series of dams built on it.

Sampling

The dredged areas covered Warri (where there is bifurcation) distance 70 km (Delta State), Onitsha distance 108 km (Anambra State), Idah distance 118km (Kogi State), Lokoja distance 116 (Kogi State) and Baro distance 154 km (Niger State) as seen in figure 1. At every sampling point, sediment samples were collected from the river's banks at distance between 20–50 m in dry season depending on the accessibility of sampling point. Surface sediments were collected from 0–0.20-m depth. A total of 305 and 210 sediment samples were collected for radioactivity and heavy-metal measurements, respectively. Points of collection based on the distance of each lot are shown in tables 1 and 2 respectively. Samples were collected into polythene plastics bags that are not radioactive and are well labeled for easy identification. Samples were then transported to laboratory for preparation and counting.

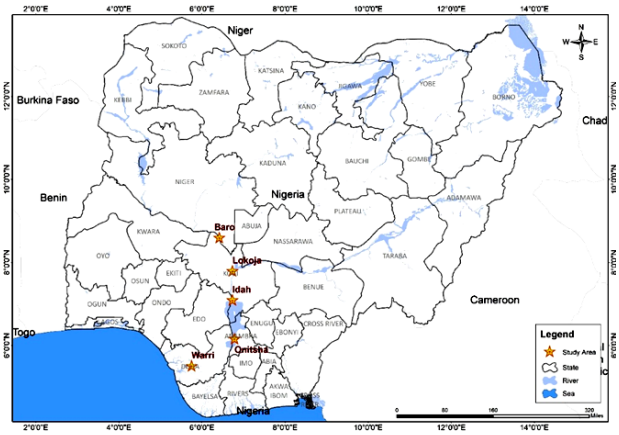


Figure 1. Map of Nigeria showing the flow of River Niger (Study Area).

Spectroscopic analysis

In order to remove the moisture content, samples were air dried in laboratory with a mean temperature 27^{0}C and mean relative humidity of about 70 % for 3 days [12] and thereafter they were oven-dried at a temperature of 105^{0}C to a constant mass. Foreign materials such as leaves, pebbles and other coarse materials were removed. Samples were passed through a 2-mm mesh sieve to

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remove stones and other materials [13]. Samples were then sieved through a 1-mm mesh sieve [14]. Each sample containing sediment grain weighing 200 g was stored in standardized radon impermeable polyethylene containers. These polyethylene containers were sealed tightly with vinyl tape around its screw neck to prevent possible escape of radon gases [15]. Samples were kept for a period of 4 weeks to allow secular radioactive equilibrium between ^{238}U (^{226}Ra) and ^{232}Th (^{228}Ra) and their progenies. Measurement of activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were carried out gamma-ray spectrometer consisting of NaI(Tl) (by Canberra Inc. USA) detector directly coupled to a pre-amplifier, a computer-controlled multichannel analyzer (MCA). Radium content of samples was determined from intensity of 1.76 MeV peak corresponding to ^{214}Bi, thorium content from 2.61 MeV gamma-ray peak corresponding to ^{208}Tl, and potassium content from 1.46 MeV gamma-ray peak following decay of ^{40}K. Spectrum of every sample was collected for 54,000 s (15 h). To reduce the background effect, the detector was shielded with lead.

Table 1. Mean concentration of radionuclides, exhaled radon, Excessive-lifetime cancer risks and other hazard parameters.

Lot	Town	Ds	S.No	^{40}K	^{232}Th	^{226}Ra	D_{out}	D_{in}	E_{out}	E_{in}	H_{ext}	H_{in}	Ra_{eq}	H_R	Risk x 10^{-3}		
		km		Bq kg^{-1}			nGy h^{-1}		mSv y^{-1}				Bq kg^{-1}	%	R_{out}	R_{in}	R_T
1	Baro	154	75	11-69 58±13	BLD-6 2±0.2	95-175 136±24	66.1	130.7	0.08	0.60	0.41	0.77	144	88	0.28	2.10	2.38
2	Lokoja	116	60	28-187 107±22	BLD-6 2±0.2	BLD-48 33±12	20.7	32.2	0.03	0.16	0.12	0.21	43	75	0.11	0.56	0.67
3	Idah	118	60	627-1045 857±43	8-66 30±1	93-104 99±18	100.1	134.7	0.12	0.66	0.66	0.83	206	26	0.42	2.31	2.73
4	Onitsha	108	60	46-167 124±23	BLD-9 4±0	15-27 21±13	16.9	31.9	0.02	0.16	0.09	0.15	35	67	0.10	0.56	0.66
5	Warri	70	50	4-26 17±4	BLD-29 14±2	25-148 74±14	43.3	42.6	0.05	0.21	0.14	0.18	44	29	0.18	0.74	0.92
	Weighted Mean			231±21	10±1	75±17	-	-	-	-	-	-	-	-	-	-	-

Table 2. Physico-chemical Properties of Sediment Samples from each Lot.

Lot	Town	Ds Km	S.No	Cu	Zn	Mn	Fe		C_f^i			PLI			QoC %	
				mg g^{-1}			Cu		Zn	Mn	Fe		Cu	Zn	Mn	Fe
1	Baro	154	60	0.19	0.43	0.22	52.92	4.22	4.53	0.26	1.13	1.78	76.3	77.9	-286.4	11.8
2	Lokoja	116	40	0.21	0.50	0.11	73.11	4.67	5.26	0.13	1.57	1.85	78.6	81.0	-672.7	36.1
3	Idah	118	40	0.24	0.49	0.91	118.76	5.33	5.16	1.07	2.54	1.94	81.3	80.6	6.6	60.7
4	Onitsha	108	40	0.14	0.28	0.50	66.70	3.11	2.94	0.59	1.43	1.69	67.9	66.1	-70.0	29.9
5	Warri	70	30	0.12	0.37	0.24	50.01	2.67	3.89	0.28	1.07	1.68	62.5	74.3	-254.2	6.6
	Mean			0.18	0.41	0.40	72.30	4.00	4.36	0.47	1.55	1.79	73.3	76.0	-255.3	29.0
	Average Shale			0.045	0.095	0.850	46.70	-	-	-	-	-	-	-	-	-

Analysis of Heavy-Metals

Samples were air dried and homogenized using pestle and mortar; they are passed through a 2-mm mesh screen and stored in polyethylene bags [16]. Two (2) g of fine powder sediment sample was digested using the high-quality concentrated (70 % w/v) nitric acid, hydrogen peroxide (35 %) and hydro-chloric acid (38 %) [17], the solution was then shaken for 1 h using a reciprocal shaker, and then filtered using filter paper. The beaker was then placed on hot plate and heated at 350^0C until frothing stops and HNO_3 is almost evaporated. Then watch glass was placed to cover the beaker and heating continued until perchloric reaction (copious fumes) appeared and the solution became colourless. The clear solution was then poured into sample bottles

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and was subjected to the Atomic Absorption Spectrophotometer (BUCK 210 VGP, USA) for analysis. The sample bottles were then put into the AAS machine one after the other. The mean concentrations for the samples taken in each lot are shown in table 2.

Radiation Hazard Parameters

Outdoor absorbed dose rate due to γ-radiation in air at 1 m above ground surface and the indoor absorbed dose in dwelling buildings were calculated using the equations (1 and 2) [18].

$$D_{out} = 0.462A_{Ra} + 0.621A_{Th} + 0.0417A_K \quad (1)$$

$$D_{in} = 0.908A_{Ra} + 1.06A_{Th} + 0.0767A_K \quad (2)$$

Where A_{Ra}, A_{Th}, A_K are the activity concentrations (Bq kg^{-1}) of radium, thorium and potassium concentrations in the samples.

People around the River depend strictly on the River for their livelihood. They excavate sediment for sales, buildings and various construction purposes. Therefore radium equivalent was estimated in order to estimate radiation hazard associated with the used of sediment samples from each lot. Since the distribution of ^{226}R, ^{232}Th and ^{40}K are not evenly in various matrices around the world, to ensure evenly distribution of these radionuclides, equation (3) was used.

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad (3)$$

Where A_{Ra}, A_{Th}, A_K are the activity concentrations (Bq kg^{-1}) of radium, thorium and potassium concentrations in the samples.

External hazards H_{ext} and internal hazard H_{in} were calculated using equations (4, 5) in order to quantified level of exposure when those working along the River's course are externally exposed and the residents are internally exposed.

$$H_{ext} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (4)$$

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (5)$$

To quantify dose rate in air from different combinations of the various radionuclides present in the sediment samples, activity utilization index was calculated using equation (6) [19].

$$AUI = \left(\frac{A_{Ra}}{50\ Bq\ kg^{-1}}\right)F_{Ra} + \left(\frac{A_{Th}}{50\ Bq\ kg^{-1}}\right)F_{Th} + \left(\frac{A_K}{500\ Bq\ kg^{-1}}\right)F_K \quad (6)$$

Where F_{Ra}, F_{Th}, F_K given as 0.0462, 0.604 and 0.041 the fractional contributions to the total dose rate in air from the sediment due to γ-radiation.

The hazard percentage and contribution due to exhaled radon in sediment samples were estimated using relation (7) [20].

$$H_R\ \% = 100 \times \left(\frac{Hin}{Hext} - 1\right) \quad (7)$$

The fishermen, consumers of aquatic species, tillers and residents could be prone to health challenges due ingestions of contaminated aquatic species and inhalation of radon in houses built by the sediment samples. Therefore outdoor and indoor dose rates were converted to effective dose rates using equations (8, 9) [18].

$$E_{out} = D_{out} \times 1.21 \times 10^{-3} \quad (8)$$

$$E_{in} = D_{in} \times 4.91 \times 10^{-3} \quad (9)$$

Where E_{out} and E_{in} are the annual effective dose rates and D_{out} and D_{in} are the dose rates.

The probability of developing cancer over a lifetime by fishermen and the residents along the River was estimated using relations (10, 11) [21].

$$Risk(outdoor) = E_{out} \times LE \times RF \quad (10)$$

$$Risk(indoor) = E_{in} \times LE \times RF \quad (11)$$

Where E_{out} and E_{in} are the annual effective doses, LE is the average lifetime duration of 70 years for fishermen and residents and RF is the factor 0.05 Sv^{-1} for stochastic effects.

Heavy-metals hazard parameters

Hakanson [22] revealed an equation to calculate a given toxic element in the primitive

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environment before civilization and industrialization such as the use of fertilizer in irrigation farming along the bank of the River and various dams built on it for hydroelectric power generation. He proposed formula for calculating contamination factor a seen in equation (12).

$$C_f^{\,i} = \frac{C^i}{C_n^{\,i}} \quad (12)$$

Where C^i is the mean content of element i in the sediment samples and C_n^i is the background level of the element. The four (4) - folds criteria used to describe the degree of contamination factor are $C_f^{\,i} < 1$ implies low contamination factor, $1 \leq C_f^{\,I} < 3$, moderate contamination factor, $3 \leq C_f^{\,I} < 6$, considerable contamination factor and $C_f^{\,I} \geq 6$ very high contamination factor. To determine the pollution load index of sediment samples from the River, the relation (13) proposed by Tomlinson [23] was used.

$$PLI = \left(C_{f1}^{\,i} \times C_{f2}^{\,i} \times C_{fn}^{\,i}\right)^{\frac{1}{n}} \quad (13)$$

Where n is the number of studied metals in the samples and C_f^i is the contamination factor. The pollution load index grouped in four (4)-folds are PLI <1, indicating no pollution, 1< PLI< 2, moderate pollution, 2<PLI<3, heavy pollution and 3< PLI 3 extremely pollution. The anthropogenic concentration of metals from various aforementioned activities ongoing on the River was estimated using the relation (14) as proposed by Asaah [24].

$$QoC\ \% = \left(\frac{C_i - C_c}{C_i}\right) \times 100 \quad (14)$$

Where C_i the average concentration of the metal in the investigated sediment samples is C_c is the background concentration of the metal.

RESULTS AND DISCUSSION

The activity concentration of ^{40}K obtained in this study ranged from 11-69 Bq kg^{-1}, 28-187 Bq kg^{-1}, 627-1045 Bq kg^{-1}, 46-167 Bq kg^{-1} and 4-26 Bq kg^{-1} with mean 53±13 Bq kg^{-1}, 107± 22 Bq kg^{-1}, 857±43 Bq kg^{-1}, 124±23 Bq kg^{-1} and 17±4 Bq kg^{-1} at Baro, Lokoja, Idah, Onitsha and Warri respectively. The weighted mean of ^{40}K was 231± 21 Bq kg^{-1}. The activity concentration of ^{232}Th oscillated from BLD (Below Detectable Limit)-6 Bq kg^{-1}, BLD-6 Bq kg^{-1}, 8-66 Bq kg^{-1}, BLD-9 Bq kg^{-1}, BLD-29 Bq kg^{-1} with mean 2± 0.2 Bq kg^{-1}, 2±0.2 Bq kg^{-1}, 30±1 Bq kg^{-1}, 4±1 Bq kg^{-1}, 14±2 Bq kg^{-1} at Baro, Lokoja, Idah, Onitsha and Warri respectively. The weighted mean concentration of ^{232}Th was 10±1 Bq kg^{-1}. The activity concentration of ^{226}Ra varied from 95-175 Bq kg^{-1}, BLD-48 Bq kg^{-1}, 93-104 Bq kg^{-1}, 15-27 Bq kg^{-1}, 25-148 Bq kg^{-1} with mean 136±24 Bq kg^{-1}, 33±12 Bq kg^{-1}, 99±18 Bq kg^{-1}, 21±13 Bq kg^{-1} and 74±14 Bq kg^{-1} at Baro, Lokoja, Idah, Onitsha and Warri respectively. The weighted mean concentration was 75±17 Bq kg^{-1}. The mean concentrations of the three naturally occurrence radionuclides are shown in columns 5, 6 and 7 of table 1. The weighted mean activities concentrations of ^{40}K and ^{232}Th were lower than the world average 420 Bq kg^{-1} and 45 Bq kg^{-1}, while the weighted mean activities concentration of ^{226}Ra in the sediment samples was (21 %) higher than 35 Bq kg^{-1} [2]. The highest mean and weighted mean concentrations were that of ^{40}K, which agreed with most findings in soil and sediments. The weighted mean of the three radionuclides resulted in AUI value of 0.21, which gives annual effective dose < 0.3 mSv y^{-1}. Columns 8 and 9 of table 1 show the estimated absorbed dose in the sediment samples. The mean outdoor absorbed dose rate ranged from 16.9 nGy h^{-1} at Onitsha to 100.1 nGy h^{-1} at Idah, while the mean indoor absorbed dose rate varied from 31.9 nGy h^{-1} at Onitsha to 134.7 nGy h^{-1} at Idah. The highest values of both outdoor and indoor dose rates at Idah were 1.72 times 58 nGy h^{-1} and 1.60 times 84 nGy h^{-1} world outdoor and indoor average respectively [18]. The mean outdoor annual effective dose was higher than the world average 0.07 mSv y^{-1} at Idah, while the mean indoor annual effective dose was higher than the world average 0.41 mSv y^{-1} at Baro and Idah respectively. All the values of H_{ext} and H_{in} were not higher than unity. Therefore, no radiological hazard is envisaged. The estimated radium equivalent was presented in column 14 of table

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1. The highest value 206 Bq kg^{-1} that corresponds to 0.84 mSv was below the recommended 370 Bq kg^{-1} (1.5 mSv) external gamma dose limit. In the present study, the highest radium equivalent obtained at Idah may be due to sedimentation materials from the River's Benue the largest tributary that meets River Niger at Lokoja the confluence town, before flown together on the same course to Idah, Onitsha and via Warri to Atlantic Ocean. The H_R % values obtained for each lot are shown in column 15 of table 1. The table revealed that Baro the starting lot with H_{ext} 0.41 and H_{in} 0.77 has the highest radon proportionate. Table 1 shows the values of outdoor, indoor and total risk. Outdoor risk ranged from $0.11x10^{-3}$ at Lokoja to 0.42×10^{-3} at Idah; while the indoor ranged from 0.56×10^{-3} to 2.31×10^{-3}. The total risk exposure values were higher than the world average 1.45×10^{-3} at Baro(1.45×10^{-3}) and Idah (1.45×10^{-3}) respectively. Except through weathering, sedimentation from its tributaries and flooding through heavy rainfall, cancer risk could increase with time of exposure in Baro and Idah.

The heavy metal worldwide average shale (WAS) values are 0.045 mg g^{-1} for Cu, 0.095 mg g^{-1} for Zn, 0.850 mg g^{-1} for Mn and 46.70 mg g^{-1} for Fe. The concentration of Cu, Zn and Fe are higher than the worldwide average. On the other hand concentration of Mn in all the towns was higher than the worldwide average except at Idah. The spread in concentrations of each metal in a particular lot was expressed in percentage of the total concentrations of all the studied metals in each lot along the River's course. The concentration of Cu was not evenly distributed along the River's course. The study revealed the concentration of Cu was in the order: Baro (31 %) > Lokoja (23 %) > Idah (16 %) while Onitsha (15%) and Warri (15 %) are equal. The distribution of Zn concentration in each lot compared to the total concentration of metals in each lot was in the order: Baro (27 %) > Lokoja (23 %) which was equal to Warri (23 %) > Idah (14 %) > Onitsha (13 %). The spread of Mn concentration was in the order; Idah (32 %) > Onitsha (28 %) > Warri (20 %) > Baro (16 %) >Lokoja (4 %) while Fe was evenly distribution in all the lots. The variations in concentrations of Cu, Mn and Zn in the sediment samples may be due meandering nature of the River in some points and anthropogenic activities on the River.

The contaminated factors of Cu ranged from 2.67 (Warri) - 5.33 (Idah) and Zn varied from 2.49 (Onitsha) - 5.26 (Idah), these corresponded to moderate contamination to considerable contamination level. On the other hand Mn ranged from 0.13 (Lokoja)- 1.07 (Idah) and Fe fell between 1.07 (Warri) -2.54 (Idah) which implied low contamination level to moderate contamination level. Figure 2 shows the variations in contaminations levels. The PLI values estimated for various lots were shown in the column 13 of table 2. The values indicated moderate contamination in all the studied towns along the River.

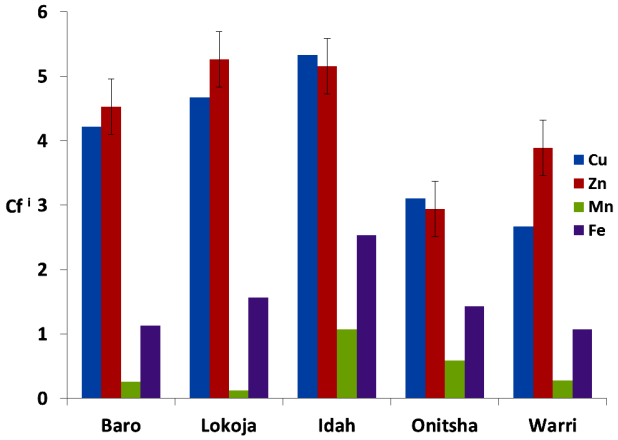


Figure 2. Contamination Factor In Each Lot

Therefore, River's Niger has moderate pollution status. Since the pollution index in all the lots was greater than unity, it suffices to say that sediment contamination was due to anthropogenic activities as reported by [25]. Quantification of contamination QoC for Cu, Zn, Mn and Fe was displayed in columns 14, 15, 16 and 17 of table 2. The results revealed that Cu, Zn and Fe for all the samples were majorly due to anthropogenic activities, while eighty (80 %) of the lots revealed geogenic sources and the remaining twenty (20 %) was anthropogenic. The negative values (green colour) of Mn in all the lots except lot 3 (Idah) revealed geogenic source of Mn, while the positive values in blue (Cu), red (Zn) and purple (Fe) revealed

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anthropogenic contamination (figure 3). Correlation coefficient was carried out between radionuclides and heavy metals concentrations. The correlation coefficients R^2= (0.51, 0.21, 0.77, 0.94), (0.14, 0.09, 0.68, 0.59) and (0.10, 0.14, 0.02, 0.00) were obtained between Cu, Zn, Mn, Fe with ^{40}K, ^{232}Th and ^{226}Ra respectively. These further revealed that Cu and Zn are from anthropogenic sources.

The present study with natural radionuclides weighted mean concentrations 231, 10, 75 Bq kg $^{-1}$ (total equal to 316 Bq kg^{-1}) fell within the global averages 400, 30 and 35 Bq kg^{-1} (total equal to 465 Bq kg^{-1}) for ^{40}K, ^{232}Th and ^{226}Ra respectively as seen in table 3. It implies no significant radiological hazard for human population that depends on sediments as raw materials used in building and other construction projects. The weighted mean value concentrations 0.18, 0.41, 0.40 and 72.30 mg g^{-1} was higher than the world average 0.045, 0.095, 0.850 and 46.70 mg g^{-1} for Cu, Zn, Mn and Fe respectively. These indicate that sediment samples were polluted with heavy metal.

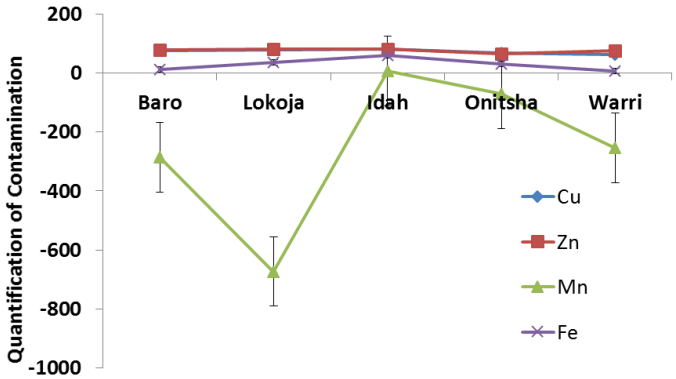


Figure 3. Fluctuations in the values of QoC in the sediment samples in each lot.

Table 3. Comparison of Radionuclides and Their Parameters with Other Countries of the World.

No	Country	^{40}K	^{226}Ra	^{232}Th	Total	Parameters D_{out} Ra_{eq}	E_{out}	H_{ex}	H_{in}	AUI
		Bq kg^{-1}			nGyh^{-1}		Bq kg^{-1} mSv			
1	Nigeria Present Study	231	75	10	316	49	94	0.06	0.28	0.43	0.21
2	China[26]	628	24	41	693	67	141	0.08	0.39	-	-
3	India[27]	387	4	37	428	42	85	0.05	0.22	0.23	-
4	India[28]	360	-	14	374	87	103	0.11	0.28	0.29	0.67
5	Bangladesh[29]	594	-	46	640	55	121	0.14	0.33	-	-
6	Ghana[30]	30	109	-	139	77	9	0.09	0.48	-	-
7	Egypt[31]	331	-	16	147	31	64	0.04	0.17	0.21	-
8	Global Average [32]	400	35	30	465	84	370	0.46	<1	<1	

CONCLUSION

The weighted mean activity concentration of ^{232}Th and ^{40}K for the sediment sample in lower Niger River was lower than international recommended limit, while that of ^{226}Ra was higher than the recommended limit. Therefore, this could be responsible for higher excessive cancer risk obtained in some of the lots. The result of mean radium equivalent in all the lots indicates that River's Niger sediment do not pose radiation hazard when used for various construction purposes. The estimated contamination factor, pollution load index and quantification of contamination revealed moderate contamination status of the River.

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