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ASSESSMENT OF RADIONUCLIDES IN WATER, SEDIMENT AND ALGAE IN RIVER BENUE AT JIMETA-YOLA, ADAMAWA STATE, NIGERIA

Physics

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ABSTRACT

Radioactivity levels in River Benue at Jimeta-Yola have been assessed by means of gamma ray spectrometry using sodium Iodide detector. The average values of activity concentration of 238U, 232Th and 40K were found to be 14.6±3.01Bq/kg, 47.0±4.03Bq/kg and 6714.7±487.34Bq/kg in sediments; 33.22±13.44Bq/kg, 25.48±2.54Bq/kg and 11256.99±865.44Bq/kg in Algae; 7.85±1.66Bq/l, 4.89±0.43Bq/l and 22.52±1.98Bq/l in water respectively. The average values of radium equivalent activity were 11.12Bq/l for water, 927.33Bq/kg for Algae and 587.9Bq/kg for sediment. The average value of representative gamma index were 0.08 for water, 7.92 for Algae and 4.97 for sediments. The average values of annual gonadal equivalent dose were 35.47mSv/y in water, 3717.21mSv/y in Algae and 2316.19mSv/y in sediments. The average values of external hazard index were 0.03 for water, 2.5 for Algae and 1.59 for sediment. The average values of internal hazard index were 0.05 for water, 2.59 for Algae and 1.6 for sediment. The average values of absorbed dose rate were 5.13nGy/h in water, 496.31nGy/h for Algae and 310.08nGy/h for sediment. The average values of excess lifetime cancer risk were 0.02×10-3 for water, 2.13×10-3 for Algae and 1.33×10-3 for sediments. The average values of annual effective dose equivalent (outdoor) were 6.29µSv/y for water, 608.67µSv/y for Algae and 380.29µSv/y for sediment. The average values of annual effective dose equivalent (indoor) were 25.17µSv/y for water, 2434.67µSv/y for Algae 1521.14µSv/y for sediment. The evaluation of radiation parameters has shown that, continuous usage of these samples will endanger the lives of humans by exposing them to various types of cancer and other ailments.

KEYWORDS

Radionuclides, Gamma spectrometry, water, Algae, Sediment, Radiation parameters.

1.0 INTRODUCTION

Ionising radiation in any environment is traceable to either natural or artificial sources (Faweya *et al*., 2013; Oni *et al.,* 2011; Kansal *et al*., 2010; Badawy *et al*., 2013). Many radionuclides (^{238}U, ^{232}Th, and ^{40}K respectively) occur naturally in soils and rocks and in materials made from them (Oni *et al*., 2011). The artificial sources are largely due to medical, industrial and commercial activities. The use of nuclear diagnostic and therapeutic medical procedures; indiscriminate discharge of petroleum products and some industrial wastes, the use of inorganic fertilizers in agricultural practices, among others account for artificial sources (CNSC, 2012; Oni *et al*., 2011).

Improper discharge of these radioactive materials of natural and artificial sources may pollute the terrestrial and aquatic environments. These radionuclides follow different pathways such as rain into the aquatic environment and may be found in water, sediments, aquatic plants and animal (Oni *et al*., 2011; Tchokossa *et al*., 2013).The exposure of man to various radiations from these radionuclides in aquatic environments may be internal due to ingestion, through the consumption of contaminated water and aquatic foods (Tchokossa *et al*., 2013). The seasons of the year determines largely the magnitude of contamination of different kinds of food. Vegetables, roots and tubers grown on the river sediments on the bank of rivers are prone to external contamination during the raining season. Contamination of meat is mainly the result of animals grazing and the consumption of contaminated drinking water. Contaminated plants and water is the direct pathway of radionuclides to animals and man through meat and milk (Tchokossa *et al*., 2013).

Studies on the effects of radiation on humans has shown that, exposure to radiation could lead to lung, pancreas, hepatic, bone, skin and kidney cancers; cataracts, sterility, atrophy of the kidney and leukemia (Avwiri *et al*., 2014).

2.0 THE STUDY AREA

Yola (Jimeta) the Adamawa state capital is located between longitude 12˚26' E and latitude 9˚16' N along the bank of river Benue one of the two major rivers in Nigeria. It has a population of 198,247 based on the 2006 census. It is the administrative capital of Adamawa state where the government house, ministries, and parastatals are located (Phanuel and Glanda, 2016).

3.0 MATERIALS AND METHODS

12 samples were collected at four different points (point 1 and 2 were collected before Jimeta bridge while points 3 and 4 were collected after Jimeta Bridge) at distances of between 100 and 300 metres from the study area with the help of the local fishermen. These samples comprised 4 samples of bed sediments, 4 samples of surface water, and 4 samples of Algae. The sediment and Algae samples were collected in black polyethylene bags while the water samples were collected in 2 litre plastic containers and tagged for identification. The sediment and Algae samples were sprayed in trays and air-dried for 48 hours under ambient temperature. The air-dried samples were subsequently oven dried in the laboratory at a temperature of 105˚C and then pulverized using mortar, pestle and 1mm standard sieve.

200g of the pulverized samples and 75cl of water samples were packed in labelled cylindrical and marinelli beakers of uniform base diameter of 5.0cm which could sit on the 7.6cm by 27.6cm NaI(Tl) detector. The cylindrical and marinelli beakers were tightly covered, sealed and left for 28days prior to counting, for attainment of secular equilibrium between ^{238}U and ^{232}Th and their respective progenies (Oni *et al*., 2011; Faweya *et al*., 2013).

The radionuclide concentration in the samples were then measured with a well calibrated low level gamma counting spectrometer consisting of a 7.6cm by 7.6cm NaI(Tl) detector (model 802 series) manufactured by Canberra Inc. The detector was coupled to a Canberra series 10 plus multi-channel analyzer (MCA) through a preamplifier base. The photo peak regions of ^{40}K (1.46MeV); ^{214}Bi (1.76MeV) and ^{208}Tl (2.165MeV) respectively were used for the analysis of ^{40}K, ^{238}U and ^{232}Th in the samples.

3.1 Theoretical Calculations of Radiation Parameters

3.1.1 Absorbed dose rate (D)

Absorbed dose is a measure of the energy deposited in a medium by ionizing radiation per unit mass. The absorbed dose rate (D) is calculated using the following expression:

$$D = 0.462C_U + 0.604C_{Th} + 0.0417C_K \quad (1)$$

Where, D is the absorbed dose rate in nGy/h, C_U, C_{Th} and C_K are the concentrations of Uranium, Thorium and Potassium respectively.

The world average value for gamma-absorbed rate is 55nGy/h for soil.

3.1.2 Annual effective dose equivalent (AEDE)

The annual effective dose equivalent received outdoor by a person is calculated from the absorbed dose rate by applying dose conversion factor of 0.7Sv/Gy. Taking into consideration that people on average, spent 20% of their time outdoors, Occupancy factor for outdoor and indoor are 0.2 and 0.8 respectively (Avwiri *et al.*, 2014; Bashir *et al.*, 2013; Al Mugren,2015).

AEDE (outdoor) (μSv/y) =
Absorbed dose (D) (nGy/h) × 8760h × 0.7Sv/Gy × 0.2 × 10^{-3} (2)
And also,
AEDE (indoor) (μSv/y) =
Absorbed dose (D) (nGy/h) × 8760h × 0.7Sv/Gy × 0.8 × 10^{-3} (3)

The AEDE (indoor) occurs within a house where by the radiation risk due to building materials only are taken into consideration while AEDE(outdoor) involves a consideration of the absorbed dose emitted from radionuclides in the environment such as ^{226}Ra (^{238}U), ^{232}Th and 40K.

The standard AEDE (outdoor) value is 70μSv/y and that for AEDE (indoor) is 450μSv/y. These indices measure the risk of stochastic and deterministic effect in the irradiated individual (Avwiri *et al.*, 2014).

3.1.3 Radium equivalent activity (Ra_{eq})

According to Avwiri et al. (2014) Radium equivalent activity (Bq/Kg) is estimated using the equation below:

$$Ra_{eq} = C_U + 1.43\,C_{Th} + 0.077C_K \quad (4)$$

Ra_{eq} is a single parameter used to represent the radionuclide concentration of ^{238}U, ^{232}Th and ^{40}K taking into account their respective radiation hazards. The maximum permissible standard value for Ra_{eq} is 370Bq/Kg (Pereira *et al.*, 2011; Hasan *et al.*, 2014;Al Mugren, 2015; Bashir *et al.*, 2013).

External hazard index (H_{ex})

Avwiri et al. (2014) defined external hazard index ((H_Ex) by the equation below:

$$(H_{Ex}) = \frac{C_U}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (5)$$

Where,C_U, C_{Th} and C_K are the radioactivity concentration in Bq/Kg or Bq/l of ^{238}U, ^{232}Th and ^{40}K. The value of this index must be less than unity for the radiation hazards to insignificant.

3.1.4 Internal hazard index (H_{In})

The internal hazard index is given as:

$$H_{In} = \frac{C_U}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (6)$$

H_{In}, should be less than unity for the radiation hazard to be insignificant. Internal exposure to radon and its daughter products are very hazardous and can lead to respiratory diseases like asthma and cancer (Avwiri *et al.*, 2014).

3.1.5 Excess lifetime cancer risk (ELCR)

ELCR is associated with the probability of developing cancer over a lifetime at a given exposure level. It is a value depicting the number of cancers expected in a given number of people on exposure to a carcinogen at a given dose.

An increase in the ELCR causes a proportionate increase in the rate at which an individual can get cancer of the breast, prostate or even blood. Excess lifetime cancer risk (ELCR) is given as according to Avwiri *et al.* (2014) as:

$$ELCR = AEDE \times DL \times RF \quad (7)$$

Where, AEDE is the annual effective dose equivalent, DL is the average duration of life/life expectancy (estimated as 70years), and RF is the risk factor (Sv)$^{-1}$, that is fatal cancer risk per Sievert. For stochastic effects; international commission on radiological protection (ICRP) use RF as 0.05Sv^{-1} for public (Avwiri *et al.*, 2014) with the ELCR UNSCEAR standard being 0.29×10^{-3}.

3.1.6 Annual gonadal equivalent dose (AGED)

The gonads, the bone marrow and the bone surface cells are considered as organs of interest because they are the most sensitive parts of human body to radiation. An increase in AGED has been known to affect the bone marrow and destroys the red blood cells that are then replaced by white blood cells. This situation results in a blood cancer (leukemia).

AGED is calculated with given activity concentration of ^{238}U, ^{232}Th and ^{40}K (in Bq/Kg) using the relation:

$$AGED\ (mSv/y) = 3.09C_U + 4.18C_{Th} + 0.314C_K \quad (8)$$

Where, C_U, C_{Th} and C_K the radioactivity concentration of ^{238}U, ^{232}Th and ^{40}K (in Bq/Kg) in soil samples respectively.

AGED has the world permissible threshold of 300mSv/y(Avwiri *et al.*, 2014).

3.1.7 Activity concentration index (Representative gamma index)

Activity concentration index (I_γr) is used to estimate the gamma radiation hazard associated with the natural radionuclides in specific investigated samples. The activity concentration index is given by Avwiri et al. (2014) as:

$$I_{\gamma r} = \frac{C_U}{150} + \frac{C_{Th}}{100} + \frac{C_K}{1500} \quad (9)$$

An increase in the representative gamma index greater than the universal standard of unity may result in radiation risk leading to the deformation of human cells thereby causing cancer.

Values of $I_{\gamma r} \leq 1$ corresponds to an annual effective dose of less than or equal to 1mSv, while $I_{\gamma r} \leq 0.5$ corresponds to annual effective dose less or equal to 0.3mSv (Avwiri *et al.*, 2014; Rafique *et al.*, 2011).

4.0 RESULTS

Table 1: Activity concentrations of the sediment samples obtained from gamma spectrometry analysis and UNSCEAR (2000) standard values.

Samples	U-238 (Bq/Kg)	Th-232(Bq/Kg)	K-40(Bq/Kg)
1	BDL	45.61±4.13	8648.93±633.88
2	BDL	32.16±3.06	8142.72±595.09
3	BDL	46.07±4.18	9346.29±681.4
4	14.6±3.01	64.19±4.76	720.86±38.98
standard value	33	45	420

BDL: Below detection limit

Table 2: Activity concentrations of the Algae samples obtained from Gamma spectrometry analysis and UNSCEAR (2000) standard values.

Samples	U-238 (Bq/Kg)	Th-232(Bq/Kg)	K-40(Bq/Kg)
1	40.94±18.39	20.90±2.17	14489.3±1083.17
2	33.47±15.57	BDL	8940.07±686.93
3	13.82±3.57	45.34±4.35	10012.35±767.82
4	44.63±16.23	10.20±1.10	11586.23±923.82
standard value	33	45	420

BDL: Below detection limit.

Table3: Activity concentrations of the water samples obtained from Gamma spectrometry analysis and UNSCEAR (2000) standard values.

Samples	U-238 (Bq/l)	Th-232(Bq/l)	K-40(Bq/l)
1	12.53±12.58	BDL	26.72±2.42
2	BDL	3.47±0.32	35.66±3.03
3	5.89±1.27	6.30±0.54	8.89±0.79
4	5.13±1.13	BDL	18.79±1.66
standard value	10	1	10

Table4: Radium Equivalent Activity (Ra_{eq}), Representative Gamma index ($I_{\gamma r}$), Annual Gonadal Equivalent dose (AGED), External hazard index (H_{EX}) and internal Hazard index (H_{In}) in water samples and world standard values.

Sample	Ra_{eq}(Bq/L)	$I_{\gamma r}$	AGED(mSv/y)	H_{EX}	H_{in}
1	14.59	0.10	47.11	0.04	0.07
2	7.71	0.06	25.7	0.02	0.02
3	15.58	0.11	47.33	0.04	0.06
4	6.58	0.05	21.75	0.02	0.03
Threshold	370	1	300	1	1

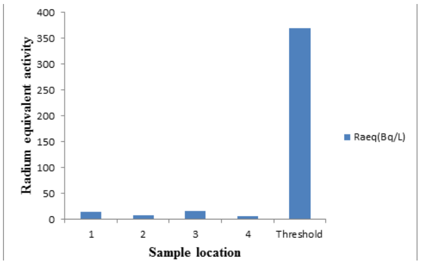


Figure1: Radium Equivalent Activity (***Ra****eq*) of water samples compared with the UNSCEAR (2000) Threshold for the locations.

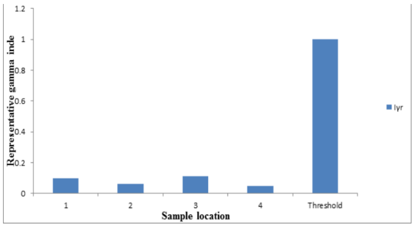


Figure2: Representative Gamma index ($I_{\gamma r}$) of water samples compared with the UNSCEAR (2000) Threshold for the locations.

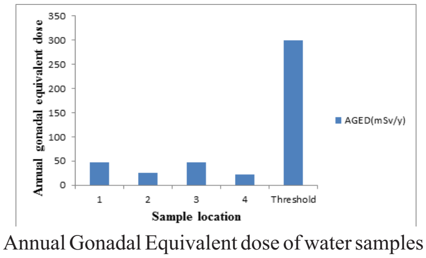


Figure3: Annual Gonadal Equivalent dose of water samples compared with the UNSCEAR (2000) Threshold for the locations.

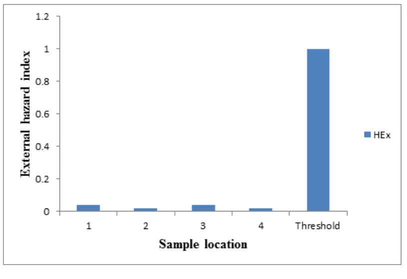


Figure4: External hazard index of water samples compared with the UNSCEAR (2000) Threshold for the locations.

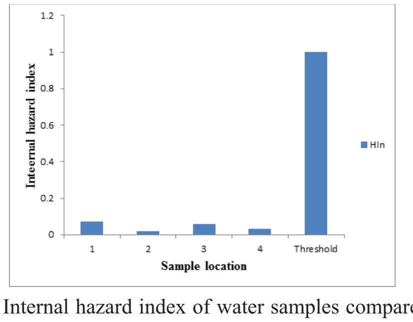


Figure5: Internal hazard index of water samples compared with the UNSCEAR (2000) Threshold for the locations.

Table5: Absorbed dose rate (D), Annual effective dose equivalent (AEDE) and Excess Lifetime cancer risk (ELCR) in water samples and world standard values.

Samples	D(nGy/h)	ELCR×10^-3	AEDE(outdoor)	AEDE(indoor)
1	6.9	0.0296	8.46	33.84
2	3.58	0.0125	4.39	17.56
3	6.9	0.0296	8.46	33.84
4	3.15	0.011	3.86	15.45
Threshold	55	0.29	70	450

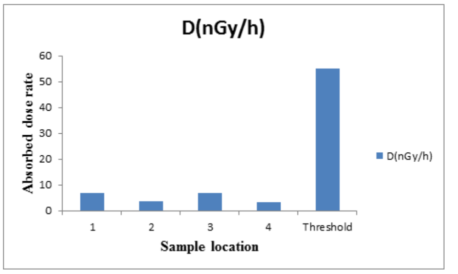


Figure6: Absorbed dose rate in water samples compared with the UNSCEAR (2000) Threshold for the location.

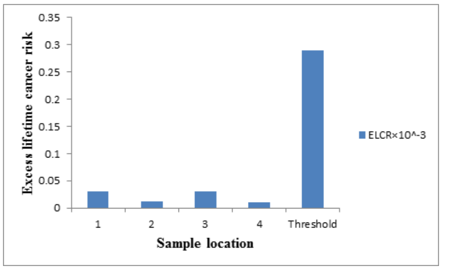


Figure7: Excess life time cancer risk in water samples compared with the UNSCEAR (2000) Threshold for the locations.

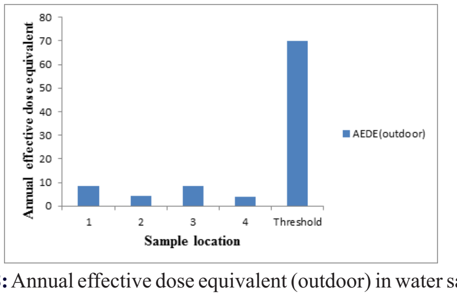


Figure 8: Annual effective dose equivalent (outdoor) in water samples compared with the UNSCEAR (2000) Threshold for the locations.

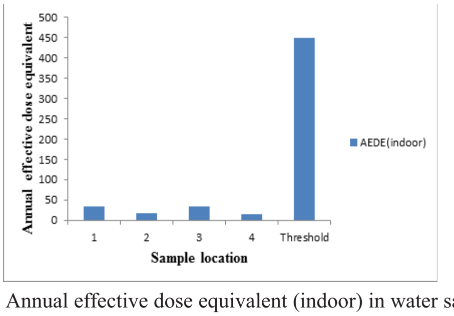
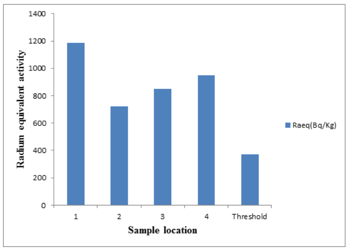


Figure9: Annual effective dose equivalent (indoor) in water samples compared with the UNSCEAR (2000) Threshold for the locations.

Table6: Radium Equivalent Activity (Ra_{eq}), Representative Gamma index ($I_{\gamma r}$), Annual Gonadal Equivalent dose (AGED), External hazard index (H_{EX}) and internal Hazard index (H_{In}) in Algae samples and world standard values.

Samples	Ra_{eq}(Bq/L)	$I_{\gamma r}$	AGED(mSv/y)	H_{EX}	H_{in}
1	1186.5	10.14	4763.51	3.2	3.31
2	721.86	6.18	2910.6	1.95	2.04
3	849.61	7.22	3376.1	2.29	2.33
4	951.36	8.12	3818.62	2.57	2.69
Threshold	370	1	300	1	1



Figurer10: Radium Equivalent Activity (Ra_{eq}) of Algae samples compared with the UNSCEAR (2000) Threshold for the locations.

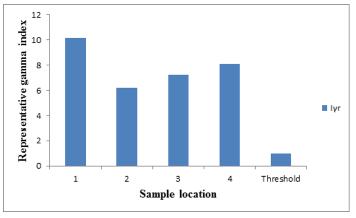


Figure11: Representative Gamma index of Algae samples compared with the UNSCEAR (2000) Threshold for the locations.

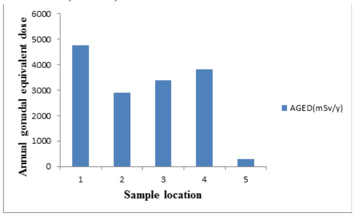


Figure12: Annual Gonadal Equivalent dose of Algae samples compared with the UNSCEAR (2000) Threshold for the locations.

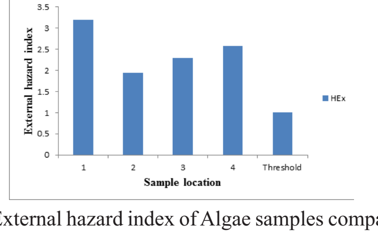


Figure13: External hazard index of Algae samples compared with the UNSCEAR (2000) Threshold for the locations.

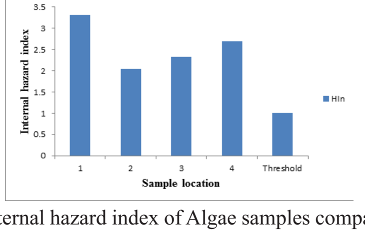


Figure14: Internal hazard index of Algae samples compared with the UNSCEAR (2000) Threshold for the locations.

Table7: Absorbed dose rate (D), Annual effective dose equivalent (AEDE) and Excess Lifetime cancer risk (ELCR) in Algae samples and world standard values.

Samples	D(nGy/h)	ELCR×10^-3	AEDE(outdoor)	AEDE(indoor)
1	635.74	2.7288	779.67	3118.68
2	388.26	1.6666	476.16	1904.65
3	451.29	1.9371	553.46	2213.85
4	509.93	2.1888	625.38	2501.51
Threshold	55	0.29	70	450

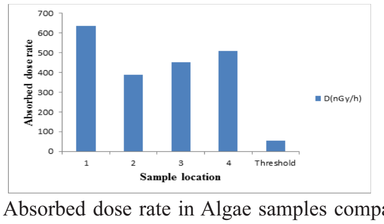


Figure15: Absorbed dose rate in Algae samples compared with the UNSCEAR (2000) Threshold for the locations.

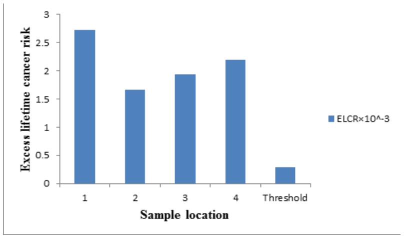


Figure 16: Excess life time cancer risk in Algae samples compared with the UNSCEAR (2000) Threshold for the locations.

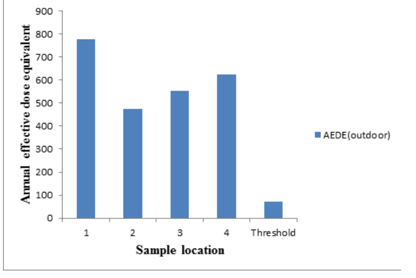


Figure17: Annual effective dose equivalent (outdoor) in Algae samples compared with the UNSCEAR (2000) Threshold for the locations.

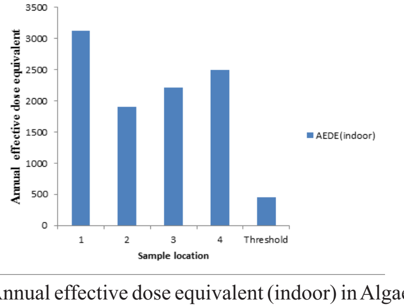


Figure18: Annual effective dose equivalent (indoor) in Algae samples compared with the UNSCEAR (2000) Threshold for the locations.

Table 8: Radium Equivalent Activity (Ra_{eq}), Representative Gamma index ($I_{\gamma r}$), Annual Gonadal Equivalent dose (AGED), External hazard index (H_{EX}) and internal Hazard index (H_{In}) in sediment samples and world standard values.

Samples	Ra_{eq}(Bq/Kg)	$I_{\gamma r}$	AGED(mSv/y)	H_{EX}	H_{in}
1	731.19	6.22	2906.41	1.97	1.97
2	672.98	5.75	2691.24	1.82	1.82
3	785.54	6.69	3127.31	2.12	2.12
4	161.9	1.22	539.78	0.44	0.48
Threshold	370	1	300	1	1

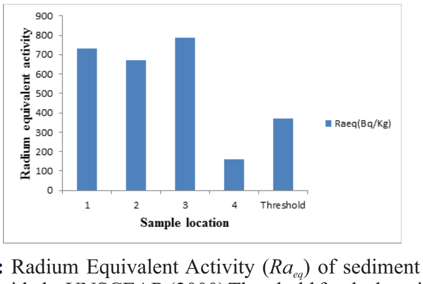


Figure 19: Radium Equivalent Activity (Ra_{eq}) of sediment samples compared with the UNSCEAR (2000) Threshold for the locations.

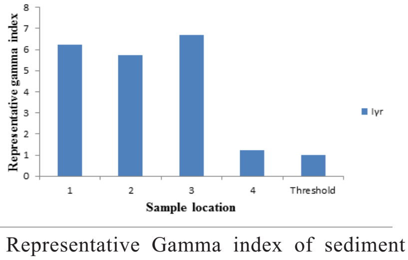


Figure20: Representative Gamma index of sediment samples compared with the UNSCEAR (2000) Threshold for the locations.

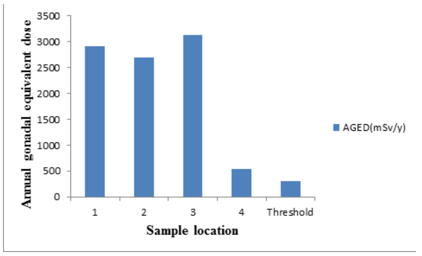


Figure21: Annual Gonadal Equivalent dose of sediments samples compared with the UNSCEAR (2000) Threshold for the locations.

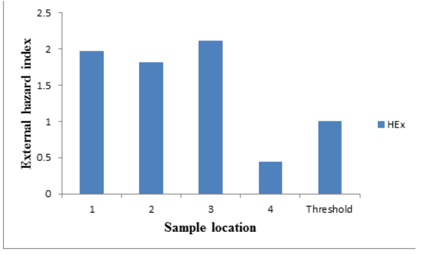


Figure22: External hazard index of sediments samples compared with the UNSCEAR (2000) Threshold for the locations.

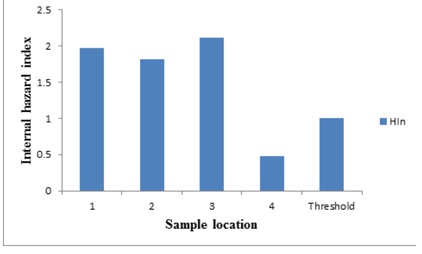


Figure23: Internal hazard index Equivalent dose of sediments samples compared with the UNSCEAR (2000) Threshold for the locations.

Table 9: Absorbed dose rate (D), Annual effective dose equivalent (AEDE) and Excess Lifetime cancer risk (ELCR) in sediment samples and world standard values.

Samples	D(nGy/h)	ELCR×10^-3	AEDE(outdoor)	AEDE(indoor)
1	388.21	1.6664	476.1	1904.4
2	358.98	1.5409	440.25	1761.01
3	417.57	1.924	512.11	2048.43
4	75.57	0.3244	92.68	370.72
Threshold	55	0.29	70	450

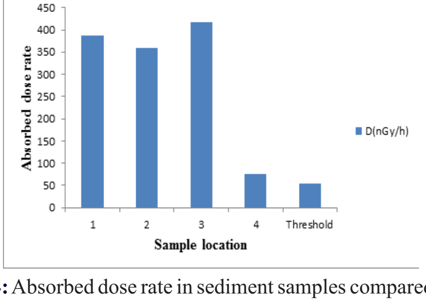


Figure 24: Absorbed dose rate in sediment samples compared with the UNSCEAR (2000) Threshold for the locations.

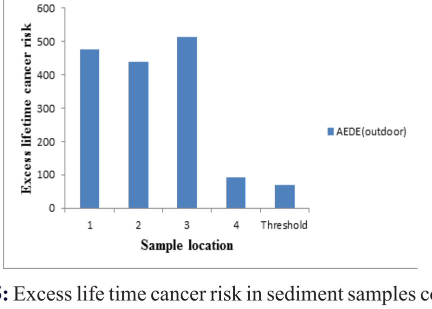


Figure 25: Excess life time cancer risk in sediment samples compared with the UNSCEAR (2000) Threshold for the locations.

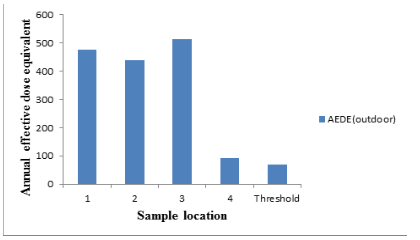


Figure26: Annual effective dose equivalent (outdoor) in sediment samples compared with the UNSCEAR (2000) Threshold for the locations.

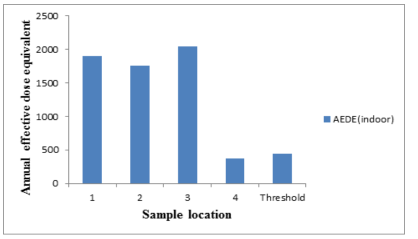


Figure27: Annual effective dose equivalent (indoor) in sediment samples compared with the UNSCEAR (2000) Threshold for the locations.

DISCUSSION

Activity concentration

Results of activity concentration for ^{238}U, ^{232}Th and ^{40}K nuclides in sediment samples is as presented in table 1 with the world average values. From table 1, the activity concentration of ^{238}U ranged from BDL to 14.6±3.01Bq/Kg with an average value of 14.6±3.01 Bq/Kg; ^{232}Th ranged from 32.16±3.06 Bq/Kg to 64.19±4.76Bq/Kg with an average value of 47±4.03Bq/Kg and ^{40}K ranged from 720.86±38.98Bq/Kg to 9346.29±681.40Bq/Kg with an average value of 6714.7±487.34Bq/Kg. These average values are above the world average values of 33Bq/Kg, 45Bq/Kg and 420Bq/Kg for ^{238}U, ^{232}Th and ^{40}K (Avwiri *et al*., 2014).

Results of activity concentration for ^{238}U, ^{232}Th and ^{40}K nuclides in Algae samples is as presented in table 2 with the world average values. From table 2, the activity concentration of ^{238}U ranged from 13.82±3.57Bq/Kg to 44.63±16.23Bq/Kg with an average value of 33.22±13.44Bq/Kg; ^{232}Th ranged from BDL to 45.34±4.35Bq/Kg with an average value of 25.48±2.54Bq/Kg; ^{40}K ranged from 8940.07±686.93Bq/Kg to 14489.3±1083.17Bq/Kg with an average value of 11256.99±865.44Bq/Kg. These values when compared with the world average standard values showed that the values of ^{238}U and ^{232}Th were within the world standard values. ^{40}K had values above the set limits.

Results of activity concentration for ^{238}U, ^{232}Th and ^{40}K nuclides in water samples is as presented in table 3with the world average values. From table 3, the activity concentration of ^{238}U ranged from BDL to 12.53±2.58Bq/l with an average value of 7.85±1.66Bq/l; ^{232}Th ranged from BDL to 6.30±0.54Bq/l with an average value of 4.89±0.43Bq/l; ^{40}K ranged from 8.89±0.79Bq/l to 35.66±3.03Bq/l with an average value of 22.52±1.98Bq/l. These average values when compared with the world average values of 10Bq/l, 1Bq/l, 10Bq/l for ^{238}U, ^{232}Th and ^{40}K showed that, all the average values are above the world standard values except for ^{238}U.

Radium equivalent activity

Results of radium equivalent activity for water, Algae and sediments is as presented in tables 4, 6, 8 and figures 1, 10, 19 with the world average value of 370Bq/Kg or Bq/l. Tables 4,6 , 8 and figures 1, 10, 19 showed that the radium equivalent activity ranged as follows: 6.58Bq/l to 15.58Bq/l with an average value of 11.12Bq/l for water; 849.61Bq/Kg to 1186.50Bq/Kg with an average of 927.33Bq/Kg for Algae; 161.90Bq/Kg to 785.54Bq/Kg with an average of 587.90Bq/Kg for sediment. These values when compared with the world standards showed that the radium equivalent activity for water samples were within the standard value while Algae and sediment samples showed values that were above the standards.

Representative gamma index

Results of representative gamma index for water, Algae and sediment is as presented in tables 4, 6, 8 and figures 2, 11, 20 with the world average value of 1. Tables 4, 6, 8 and figures 2, 11, 20 showed that the representative gamma index ranged as follows: 0.05 to 0.11 with an average value of 0.08 for water; 6.18 to 10.14 with an average value of 7.92 for Algae; 1.22 to 6.69for sediment. These values when compared with the world average value of 1 indicate that, they are above the world average value.

Annual gonadal equivalent dose

Results of annual gonadal equivalent dose for water, Algae and sediment is as presented in tables 4, 6, 8 and figures 3, 12, 21 with the world average value of 300mS/y. Tables 4, 6, 8 and figures 3, 12, 21 showed that the annual gonadal equivalent dose ranged as follows: 21.75mSv/y to 47.33mSv/y with an average value of 35.47mSv/y in water samples; 2910.60mSv/y to 4763.51mSv/y with an average value of 3717.21 for Algae samples; 539.78mSv/y to 3127.31mSv/y with an average value of 2316.19mSv/y. The results showed that water samples had values within the world average values while Algae and sediment had values above the world standards.

External hazard index

Results of external hazard index for water, Algae and sediment is as presented in tables 4, 6, 8 and figures 4, 13, 22 with the world average value of 1. Tables 4, 6, 8 and figures 4, 13, 22 showed that, the external hazard index ranged as follows: 0.02 to 0.04 with an average value of 0.03 for water samples; 1.95 to 3.20 with an average value of 2.50 for Algae samples; 0.44 to 2.12 with an average value of 1.59 for sediment samples. The results showed that, water samples had values within the world average standard while Algae and sediment had values above the world standard values.

Internal hazard index

Results of internal hazard index for water, Algae and sediment is as presented in tables 4, 6, 8 and figures 5, 14, 23 with the world average value of 1.Tables 4, 6, 8 and figures 5, 14, 23 showed that, the internal hazard index ranged as follows: 0.02 to 0.07 with an average value of 0.05 for water samples; 2.04 to 3.31 with an average value of 2.59 for Algae samples; 0.48 to 2.12 with an average value of 1.60 for sediment samples. Water samples had values within the world average values while Algae and sediments had values above the standard values.

Absorbed dose rate

Results of absorbed dose rate for water, Algae and sediments is as presented in tables 5, 7, 9 and figures 6, 15, 24 with the world average value of 55nGy/h.Tables 5, 7, 9 and figures 6, 15, 24 showed that the absorbed dose rate ranged as follows: 3.15nGy/h to 6.90nGy/h with an average value of 5.13nGy/h in water sample; 388.26nGy/h to 635.74nGy/h with an average value of 496.31nGy/h for Algae samples; 75.57nGy/h to 417.57nGy/h with an average value of 310.08nGy/h for sediment samples. The values of absorbed dose rate for water were within the world standard value while the values for Algae and sediments were above the standard values.

Excess lifetime cancer risk

Results of excess lifetime cancer risk for water, Algae and sediment is as presented in tables 5, 7, 9 and figures 7, 16, 25 with the world average value of 0.29×10^{-3}.Tables 5, 7, 9 and figures 7, 16, 25 showed that, the excess lifetime cancer risk ranged as follows: 0.01×10^{-3} to 0.03×10^{-3} with an average value of 2.13×10^{-3} for Algae samples; 0.32×10^{-3} to 1.79×10^{-3} with an average value of 1.33×10^{-3} for sediment samples. These values when compared with the world standard values showed that water samples had values within the world standard value while Algae and sediments had values above the stated standard.

Annual effective dose equivalent (outdoor)

Results of annual effective dose equivalent (outdoor) for water, Algae and sediments is as presented in tables 5, 7, 9 and figures 8, 17, 26 with the world average value of 70µSv/y. Tables 5, 7, 9 and figures 8, 17, 26 showed that, the annual effective dose equivalent (outdoor) ranged as follows: 3.86µSv/y to 8.46µSv/y with an average value of 608.67µSv/y in Algae samples; 92.65µSv/y to 512.11µSv/y with an average value of 380.29µSv/y for sediment. This results when compared with the world standard values indicates that water had values within the set limits while Algae and sediment were above the set limits.

Annual effective dose equivalent (outdoor) annual effective dose equivalent (indoor) for water, Algae and sediments is as presented in tables 5, 7, 9 and figures 9, 18, 27 with the world average value of 450µSv/y.Tables 5, 7, 9 and figures 9, 18, 27 showed that, the annual effective dose equivalent (indoor) ranged as follows: 15.45µSv/y to 33.84µSv/y with an average value of 25.17µSv/y for water; 1904.65µSv/y to 3118.68µSv/y with an average value of 2434.67µSv/y for Algae; 370.72µSv/y to 2048.43µSv/y with an average of value 1521.14µSv/y for sediment. This value when compared with the standard value indicates water to be within the set limits while Algae and sediment were above the set limits.

CONCLUSION

The calculated values of activity concentration showed that the values of ^{238}U, ^{232}Th and ^{40}K are above the world average values for sediment samples. The calculated values of activity concentration in Algae were within the world average values except for ^{40}K. The values of activity concentration for water were within the world average values except for ^{238}U. The calculated values of radium equivalent activity for water samples were within the standard value while Algae and sediment samples showed values above the threshold value. The calculated values of representative gamma index for water, Algae and sediment showed values above the world average values. The calculated value of radium equivalent activity, absorbed dose rate, excess lifetime cancer risk, annual effective dose (outdoor and indoor), annual gonadal equivalent dose, external and internal hazard indices showed that water samples had values within the world average values while Algae and sediments had values above the world standard values.The study has shown from the evaluation of radiation parameters that, continuous usage of these samples will endanger the lives of humans by exposing them to various types of cancer and related ailments.

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