IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 10, Issue 3 Ver. II (May. – June. 2018), PP 68-72
www.iosrjournals.org

Radioactivity of Surface Water Sources in Some Selected Local Government Areas of Benue State.

[*1] Sombo, T., [2] Tyovenda, A.A., [3] Bashiru, L., [4]Iheikhena, O.W and [5]Adejare, G.O

[1-3] Department of Physics, Federal University of Agriculture, P.M.B 2373 Makurdi, Benue State, North-Central, Nigeria.

*[*4]Department of Biology Education, Federal College of Education (Technical), Umunze, in Affliation with Nnamdi Azikiwe University, Awka, Anambra State.*

*[*5]Department of Industrial Education, Federal College of Education (Technical), Umunze, in Affliation with Nnamdi Azikiwe University, Awka, Anambra State.*

Corresponding auther: Sombo, T

Abstract: *This study assess the radioactivity of surface water sources in Oju, Otukpo and Ogbadibo Local Government Areas of Benue State, North-Central, Nigeria. A total of fifteen (15) surface water samples were collected from different locations within these selected local government areas. The activity concentrations of natural radionuclide's in the water samples were determined using gamma ray spectrometer comprising a 8.5 cm x 6.5 cm Nal (TI) detector (model: 802) coupled to a multichannel analyser. The mean activity concentration obtained in OJu LGA for ^{40}K, ^{238}U and ^{232}Th were found to be 3.864 ± 9.41 Bq/L, 2.13 ± 0.415 Bq/L and 1.634 ± 0.178 Bq/L. The mean activity concentration obtained in Otukpo LGA for ^{40}K, ^{238}U and ^{232}Th were found to be 3.534 ± 0.366 Bq/L, 2.703±0.372 Bq/L and 1.395 ± 0.138 Bq/L. While that of Ogbadibo LGA was 2.478 ± 0.316 Bq/L (for ^{40}K), 1.543 ± 0.324 Bq/L (for ^{238}U) and 2.024 ± 0.224 Bq/L (for ^{232}Th) respectively. The results revealed that the concentration of both radionuclides' fall within permissible safety limit 100 Bq/L set by Radiological Protection Adviser (RPA, 2000). This implies that the natural radionuclide content of the surface water sources within these study areas is within the tolerance level indicating minimal radiological health hazard to the public.*

Keywords: *Natural radionuclide, Surface water, radiological hazard, Exposure.*

Date of Submission: 29-05-2018 Date of acceptance: 14-06-2018

I. Introduction

Nuclear radiation is an inevitable part of our natural environment which is occasionally enhanced by human activities such as production of radioisotope or radiation sources for energy generation, research, medical applications as well as oil and gas extraction (Rashid-Nizam et al., 2014 Arogunjo et al., 2004). Despite the numerous benefits of radiations to mankind, accidental or over exposure to radiation during the above mentioned activities is capable of causing deleterious health hazard such as skin cancer, kidney failure, tumor, genetic effect and vascular diseases.

Natural radionuclide's found in our soil, water, food and air include ^{40}K, ^{238}U and ^{232}Th (Agbalagba et al, 2012). Water like any other components of the environment plays a vital role in sustaining life on planet earth. The quality of water is paramount factor determinant of public health (Sen et al., 2009; WHO, 2010). Water is easily accessible from lakes, rivers, streams and wells. Being a universal solvent, it dissolves various substances such as minerals ores and chemical as well as radioactive waste materials found in the soil through which they flow. These naturally occurring radioactive materials disintegrate and emit ionizing radiation in water (Fasunwon et al., 2010). The concentration of radionuclide in an area depends on the geological setting of the area.

Recent researches revealed that surface water sources contain measurable amount of natural radionuclide's such as ^{40}K, ^{238}U and ^{232}Th and their progeny (Jibiri et al., 1999; Avwiri, 2005; Ajayi et al., 1995 and Ajayi & Ajayi, 1999). Surface water sources in Africa and Nigeria in particular is serving as the major source of drinking water for man and his animals. In order to ascertain its quality with respect to radionuclide's contamination radioactivity monitoring is usually performed for the purpose of assessing the closeness to the general public from natural and man-made radiation sources (UNSCEAR, 2000).

II. Materials and methods

Sampling Sites

Table 1. Sampling Locations and their coordinates.

S/N	Location	Latitude	Longitude	POPULATION
1	Oju	6^0 51'0'' N	$8^0$25'0'' E	195,750
2	Otukpo	7^0 11' 35'' N	$8^0$8'47 ''E	309, 530
3	Ogbadibo	7^0 19'30'' N	8^0 14'63'' E	152, 190

Population: (Census, 2011)

Water samples were collected from five (5) surface water sources in each of the selected Local Government Areas. At each site, the water samples were collected near the bank of the river, 500 m away from the bank of the river and near the opposite side of the river, and then mix-up to obtain a common sample for the site.

The samples were analyzed at National Institute of Radiation Protection and Research centre (NIRPR), University of Ibadan. Gamma Ray Spectrometry using a thallium activated 3"x3" Sodium iodide [NaI (TI)] detector connected to amplifier (ORTEC 456). 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. Background measurement and efficiency calibration of the system was made possible using Cs-137 and Co-60 standard sources from IAEA, Vienna.

The activity concentration (A) of each radionuclide in the samples was determined by using the equation below;

$$A = \frac{cps}{E\ x\ I\ x\ W} \qquad 1$$

Where, A = activity concentration of the sample in $Bqkg^{-1}\ or\ BqL^{-1}$
cps = the net count per second
E = the counting efficiency of the gamma energy
I = Absolute intensity of the gamma ray and
W = net weight of the sample (in kilogram, kg or litre, L).

Radium equivalent activity

The measured values of Ra_{eq} were obtained by making use of the following equation (Huy, 2005 & Alharbi, 2011).

$$Raeq\ (Bq/L) = A_U + 1.43A_{Th} + 0.077A_k \qquad 3$$

Here A_U, A_{Th}, and A_K are the average activity concentrations of ^{238}U, ^{232}Th, and ^{40}K, respectively. In calculating Ra_{eq} values, the average activity concentrations of 370 Bq/L, 259 Bq/L, and 4810 Bq/L used for ^{238}U, ^{232}Th, and ^{40}K radionuclides, respectively, were assumed to produce the same gamma dose rate (Mahur, 2010)

Absorbed dose rate in air

The values of D_r in air and 1 m above the ground level are calculated from the measured activity concentrations of ^{238}U, ^{232}Th, and ^{40}K radionuclides using the following semiempirical formula (El-Shershaby, 2016 and Fatima, 2008).

$$D_r\ (nGyh^{-1}) = 0.427A_U + 0.662A_{Th} + 0.043A_K \qquad 4$$

Eq. (4) was modified to include the contributions of artificial radionuclides of cesium, ^{137}Cs, as well as cosmic radiation via the following equation (El-Shershaby, 2006).

$$D_y(nGyh^{-1}) = 0.427A_U + 0.662A_{Th} + 0.043A_K + 0.03A_{Cs} + 34 \qquad 5$$

Here 0.427, 0.662, and 0.043 are the dose rate conversion factors to convert the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K and ^{137}Cs radionuclides into absorbed dose rates as proposed by (UNSCEAR, 2003). Basically, these factors are representative of the absorbed dose rates in air per unit activity per unit of soil and water mass, in units of nGy h^{-1} per Bq/L

Annual effective dose equivalent

The annual effective dose equivalent (AEDE) received by individuals was calculated from the calculated values of D_r by applying the dose rate conversion factor of 0.7 Sv Gy^{-1} and the occupancy factors of 0.2 (5/24) and 0.8 (19/24) for outdoors and indoors, respectively (UNSCEAR, 2003). The annual effective outdoor doses, D_{out}; the annual effective indoor doses, D_{in}; and total annual effective doses, D_{tot}, were calculated

according to the following equations (Veiga, 2006).

$D_{out}\ (mSvy^{-1}) = D_r(nGyh^{-1}) \times 24h \times 365.25d \times 0.2 \times 0.7SvGy^{-1} \times 10^{-6}$ 6

$D_{in}\ (mSvy^{-1}) = D_r\ (nGyh^{-1}) \times 24h \times 365.25d \times 1.4 \times 0.8 \times 0.7SvGy^{-1} \times 10^{-6}$ 7

$Dtot\ (m\ S\ v\ y^{-1}) = D_{out} + D_{in}$ 8

External and internal radiation hazard indices

The external/ internal radiation hazard index, H_{ex}/H_{in} , corresponding to ^{238}U, ^{232}Th, and ^{40}K natural radionuclides, was calculated using the following equations (Shams, 2013 and Beretka, 1985).

$$H_{ex} = \frac{A_U}{370Bqkg^{-1}} + \frac{A_{Th}}{259Bqkg^{-1}} + \frac{A_K}{4810Bqkg^{-1}} \quad 9$$

$$H_{in} = \frac{A_U}{185Bqkg^{-1}} + \frac{A_{Th}}{259Bqkg^{-1}} + \frac{A_K}{4810Bqkg^{-1}} \quad 10$$

III. Results and Discussion

The result of activity concentration of ^{40}K, ^{238}U and ^{232}Th with their radium equivalent values in the water sample. The associated radiation hazard parameters calculated are presented in table 2-7 and figure 1 below;

Table 2: Activity Concentration (Bq/L) in different water Samples in Oju LGA

SAMPLE CODE	K-40	U-238	Th-232
AINU	1.28±0.12	1.66±0.34	1.30±0.14
IKACHI UKPA	8.33±0.82	1.75±0.35	1.30±0.16
IMOHO IBILLA IGEDE	3.75±0.35	2.05±0.4	0.93±0.09
OGENGENG	2.21±0.38	3.06±0.57	1.76±0.20
OMUDA	3.75±0.38	BDL	2.88±0.30
Average	**3.864±9.41**	**2.13±0.415**	**1.634±0.178**

Table 3: Activity Concentration in (Bq/L) of different water Samples inOtukpo LGA

SAMPLE CODE	K-40	U-238	Th-232
ALLAN AKPA	3.85±0.40	1.66±0.34	2.23±0.22
ASA-OTTO	4.01±0.43	BDL	BDL
OGBUOJI-ICHO	2.75±0.35	2.05±0.4	1.58±0.14
OKPOKU AKPA	3.21±0.28	3.06±0.57	0.56±0.06
OTOBI AKPA	3.85±0.37	4.04±0.55	1.21±0.13
Average	**3.534±0.366**	**2.703±0.372**	**1.395±0.138**

Table 4: Activity Concentration in (Bq/L) of different water Samples in Ogbadibo LGA

SAMPLE CODE	K-40	U-238	Th-232
ODOBA	3.01±0.42	BDL	1.11±0.12
OLAICHAGBAHA	1.75±0.34	2.16±0.44	2.23±0.26
OLAIGBENA	2.40±0.25	1.15±0.25	2.97±0.31
OROKAM 1	2.21±0.30	0.95±0.15	1.30±0.13
UGBOKPO	3.02 ±0.27	1.91±0.45	2.51±0.30
Average	**2.478±0.316**	**1.543±0.324**	**2.024±0.224**

Table 5:The absorbed dose Rate (D), annual effective dose rate (AEDR) (indoor and outdoor) index (external, H_{ex} and internal, H_{in}) and Radium equivalent Activity for Water Samples in Oju LGA

Sample Code	Absorbed dose ($nGyh^{-1}$	Annual Effective dose indoor (mSv y^{-1})	Annual Effective dose outdoor (mSv y^{-1})	Annual Effective dose total (mSv y^{-1})	External hazard Index (H_{ex})	Internal hazard Index (H_{in})	Radium Equivalent Activity (RAeq)
AINU	1.62446	0.00199	0.01156	0.01315	0.00977	0.01426	3.62
IKACHI-UKPA	1.96304	0.00241	0.01348	0.01589	0.01148	0.01621	4.25
IMOHO IBILLA-IGEDE	1.65226	0.00203	0.01135	0.01338	0.00991	0.01545	3.67
OGENGENG	2.56676	0.00315	0.01763	0.02078	0.01553	0.02381	5.75
OMUDA	2.06781	0.00254	0.01420	0.01674	0.01191	0.01191	4.40
AVERAGE	**1.97487**	**0.00242**	**0.01364**	**0.01599**	**0.01172**	**0.01633**	**4.34**

Table 6:The absorbed dose Rate (D), annual effective dose rate (AEDR) (indoor and outdoor) index (external, H_{ex} and internal, H_{in}),and Radium equivalent Activity for Water Sample in Otukpo LGA

Sample Code	Absorbed dose ($nGyh^{-1}$	Annual Effective dose indoor (mSv y^{-1})	Annual Effective dose outdoor (mSv y^{-1})	Annual Effective dose total (mSv y^{-1})	External hazard Index (H_{ex})	Internal hazard Index (H_{in})	Radium Equivalent Activity (RAeq)
ALLAN AKPA	2.35063	0.00288	0.01614	0.01902	0.01390	0.01838	5.14
ASA-OTTO	0.17243	0.00021	0.00118	0.00139	0.00083	0.00083	0.31
OGBUOJU-ICHO	2.03956	0.00250	0.01401	0.01651	0.01221	0.01775	4.52
OKPOKU	1.81537	0.00223	0.01247	0.01470	0.01110	0.01937	4.11
OTOBI-AKPA	2.69165	0.00033	0.01849	0.01882	0.01639	0.02731	6.07
AVERAGE	**1.81393**	**0.00163**	**0.01246**	**0.01409**	**0.01089**	**0.01673**	**4.03**

Table 7:The absorbed dose Rate (D), annual effective dose rate (AEDR) (indoor and outdoor) index (external, H_{ex} and internal, H_{in}), and Radium equivalent Activity for Water Samples in Ogbadibo LGA

Sample Code	Absorbed dose ($nGyh^{-}$	Annual Effective dose indoor (mSv y^{-1})	Annual Effective dose outdoor (mSv y^{-1})	Annual Effective dose total (mSv y^{-1})	External hazard Index (H_{ex})	Internal hazard Index (H_{in})	Radium Equivalent Activity (RAeq)
ODOBA	0.86425	0.00105	0.00594	0.00699	0.00491	0.00491	1.82
OLAICHAGBAHA	2.47383	0.00303	0.01699	0.02002	0.01481	0.02071	5.48
OLAIGBENA	2.56039	0.00314	0.01758	0.02072	0.01491	0.01718	5.58
OROKAM I	1.36128	0.00167	0.00935	0.01102	0.01064	0.01061	2.98
UGBOKPO	2.60705	0.00397	0.01790	0.02187	0.01548	0.02064	5.73
AVERAGE	**1.86605**	**0.01286**	**0.01355**	**0.01612**	**0.01215**	**0.01481**	**4.32**

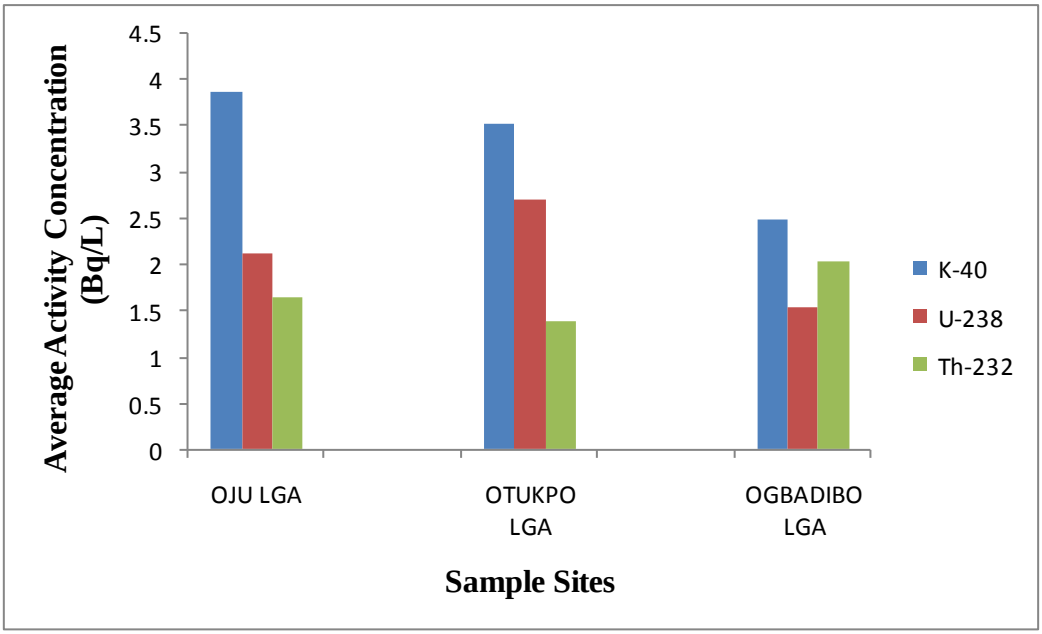

Fig. 1: Mean Concentrations of ^{40}K, ^{238}U and ^{232}Th in Surface Water of the Study Areas

IV. Discussion

Specific Activity concentration of ^{40}K, ^{238}U and ^{232}Th in the Soils.

The activity concentration of ^{40}K, ^{238}U and ^{232}Th in the water samples are determined and shown in Table 2-4 & Figure 1. The mean activity concentration of ^{40}K was found to be 3.864 ± 9.41 Bq/L; 3.534 ± 0.366 Bq/L, and 2.478 ± 0.316 Bq/L for Oju, Otukpo and Ogbadibo respectively. The mean activity concentration of ^{238}U was 2.13 ± 0.415 Bq/L; 2.703 ± 0.372 Bq/L and 1.543 ± 0.324 Bq/L for Oju, Otukpo and Ogbadibo. The

mean activity concentration of ^{232}Th was 1.634 ± 0.178 Bq/L; 1.395 ± 0.138 Bq/L, and 2.024±0.224 Bq/L for Oju, Otukpo and Ogbadibo respectively.

The slight variations of activity concentration of ^{40}K, ^{238}U and ^{232}Th in the surface water may be as a result of surface water movement through cracks in the bedrock that contain deposits of radioactive materials, the deposits may leach out into the surface water system. In all the sampling points, mean activity concentration of the natural radionuclide is of the order ^{232}Th < ^{238}U < ^{40}K. in Oju, ^{232}Th < ^{238}U < ^{40}K in Otukpo and ^{238}U < ^{232}Th < ^{40}K in Ogbadibo Local Government Area. The activity concentration of ^{238}U is high in Otobi-Akpa (Otukpo LGA) which may be due to the uranium concentration in bed rocks or surface soils that may be leached in the water sources (Kinyua, 2011). The increasing concentration of ^{232}Th may be due to the high content of monazite in the water body and may also related to the geological structure of the underground rocks in sea bed. The high values of ^{40}K recorded may be due to the leaching of radioactive elements from fertilizer use on farmlands into the water body. The activity concentration of ^{40}K, ^{238}U and ^{232}Th for all measured samples is less than the world mean value of 100 Bq/L reported by (RPA, 2000).

In order to assess the health effects, the quantities such as radium equivalent activity (Raeq), absorbed dose rate (D), annual effective dose (E) and external hazard index (Hex) have been calculated from the activity concentrations of ^{238}U, ^{232}Th and ^{40}K using equations (3), (4), (6 & 7), (9) and (10), respectively and the values are shown in Table 5-7. The results shown in Table 5-7 depict that all the radiological hazard indices are less than the world mean value recommended for water samples in the study areas (UNSCEAR, 2000).

V. Conclusion

The activity concentration of ^{40}K was found to be higher than the concentration of ^{238}U and ^{232}Th. The results showed that all the mean activity concentration values and radiological indices of all the surface water samples are within the recommended values by World Health Organization (WHO, 2010).

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Sombo, T "Radioactivity of Surface Water Sources in Some Selected Local Government Areas of Benue State. "IOSR Journal of Applied Physics (IOSR-JAP) , vol. 10, no. 3, 2018, pp. 68-72