



## Radioisotope and Metal Concentrations in Borehole Water Samples of Umuahia and Umudike, Nigeria

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**ABSTRACT:** The study examined metal and radioisotope concentrations in boreholes water samples collected from the neighbouring towns of in Umuahia and Umudike, Abia State, Nigeria. Triplicate samples were collected from seventeen functional boreholes and were analyzed with standard methods for physicochemical parameters. Metal concentrations were analyzed with Graphite furnace Atomic Absorption Spectrophotometer (AAS) while radioisotopes were determined with gamma ray spectrometry. Results showed that mean values for conductivity, total solids, total dissolved solids, hardness and nitrates were lower than recommended values by the World Health Organization (WHO) and Standards Organization of Nigeria (SON). However, mean values for pH (range:  $3.05 \pm 0.11 - 4.51 \pm 0.08$ ) were in the acidic region and outside the recommended values. Mean metal concentrations had ranges of: calcium  $1.255 \pm 0.037 - 1.967 \pm 0.078$  mg/L; magnesium  $0.286 \pm 0.057 - 0.608 \pm 0.094$  mg/L; sodium  $0.030 \pm 0.005 - 0.102 \pm 0.029$  mg/L; iron  $0.012 \pm 0.001 - 0.019 \pm 0.004$  mg/L; cadmium  $0.001 \pm 0.000 - 0.011 \pm 0.003$  mg/L and lead (Pb)  $0.077 \pm 0.005 - 0.198 \pm 0.040$  mg/L. The mean concentrations of calcium, sodium, magnesium and iron were all below the NSDWQ limits. However, while mean cadmium concentrations exceeded SON limits in 13 locations, mean lead concentrations were above the limits set by WHO and SON in the samples from all the boreholes. The mean activity concentrations K-40, U-238 and Th-232 had ranges of below detection limit (BDL) –  $21.94 \pm 2.50$  Bq/L; BDL –  $7.85 \pm 1.80$  Bq/L and BDL –  $5.76 \pm 0.53$  respectively. The SON maximum level for radionuclides in water is 0.1 Bq/L while the WHO limits for U-238 and Th-232 are 10 and 1 Bq/L respectively. The activity concentrations of U-238 were below the WHO limits but the limits were exceeded for Th-232 in water samples from eight locations. The NSDWQ limits were exceeded in samples from most of the locations for K-40.

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Water is a crucial resource for the existence and survival of mankind and the importance of good quality drinking water cannot be over emphasized. A large portion of the world's population depends on groundwater (i.e. wells, bore holes) for their survival (Lenntech, 2004). The over exploitation of ground water resources and both natural and anthropogenic processes lead to the degradation of groundwater quality. Natural processes include the absorption of contaminants like heavy metals and naturally occurring radioactive materials (NORMs) from the soil while anthropogenic processes include seepage or direct migration of wastes generated from human activities from the soil into groundwater. Heavy metals are serious pollutants because of their toxicity, persistence and non degradability in the environment (Jarup, 2003). They are usually present in trace amounts in natural water but many of them are toxic even at very low concentrations. NORMs emits alpha, beta and gamma radiations but their activity concentrations depend on the water source; their activity concentration are typically low in surface

water but drinking water from deep wells and boreholes usually have higher concentrations arising from the absorption of NORM when water passes through fractures in bedrocks or soil which may have mineral deposits with radioactive constituents (Gyuk *et al.*, 2017). The major radionuclides that are naturally introduced into surface water and groundwater include uranium, thorium, radium-226, radium-228, radon, potassium-40, tritium, and carbon-14. It is estimated that over 80% of the radiation doses received by humans arise from natural radiation sources especially the naturally occurring radioactive isotopes of U-238 and Th-232, their progeny and also K-40 (Shetty and Narayana, 2010; UNSCEAR, 1993).

The major source of drinking water in Umuahia and Umudike is mechanized boreholes. Therefore, this study both analyzes the physicochemical, metal and radionuclide concentrations in water samples from boreholes in both areas in order to determine their suitability for drinking.

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**MATERIALS AND METHODS**

*Study Area:* The study was carried out in Umuahia and Umudike, Abia State, Nigeria. Umuahia is the capital of Abia State and is divided into Umuahia North and Umuahia South Local Government Areas (LGAs). Geographically, Umuahia is located within latitude: 5° 32' N and longitude: 7° 29' E. and is within the forest belt. The area is characterized by high temperatures of about 29 – 31°C and has double maximal rainfall peaks in July and September. It has an area of 245 km<sup>2</sup> and a population of 359,230 according to the 2006 National Population Census (NPC, 2006). Geologically, Umuahia is within the Benin formation which comprises of shale/sand sediments with intercalation of thin clay beds. It is a part of the coastal

plain sands of the Cenozoic Niger Delta region of Nigeria.

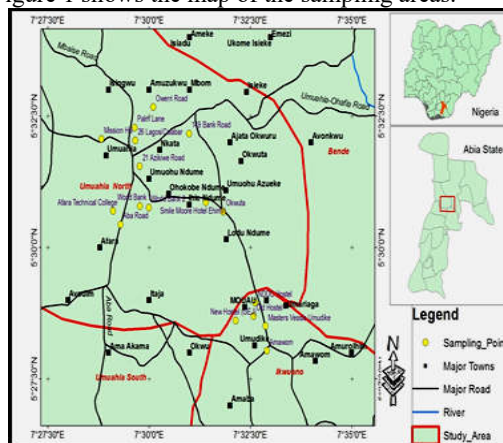
Umudike is about 10 km southeast of Umuahia. It is in Ikwuano LGA which is endowed with rich agricultural land. Umudike is located between latitude 5° 28'33"N and longitude: 7° 32'56" E and it hosts the Michael Okpara University of Agriculture (MOUAAU) and the National Root Crops Research Institute (NRCRI). The town is surrounded by other neighbouring communities which it shares its common beliefs and socio-cultural ethics with. These communities include Umuariaga, Amaoba, Amawom, Nnono, Ndro and Ahuwa which accommodate a large percentage of the students of MOUAAU. Major occupations include agriculture, trading and civil service.

**Table 1.** Sampling Point Description and Location

Sample ID	Sampling Location	GPS Coordinates	Town
1	NDDC Hostel (MOUAAU)	5.480969N, 7.543423E	Umudike
2	New Hostel (MOUAAU)	5.480359N, 7.539178E	
3	Old Hostel (MOUAAU)	5.480666N, 7.542379E	
4	Master Vessel, Umuariaga, Ikot-Ekpene Road	5.475138N, 7.547809E	
5	Amawom Village	5.467268N, 7.548389E	
6	Ehimmiri (beside Smilemoore Hotel), Ikot-Ekpene Road	5.512794N, 7.525433E	Umuahia
7	No. 7 Aghazuruike St., World Bank Housing Estate	5.514894N, 7.503257E	
8	No. 1 Ndoki Health Centre Road, World Bank Housing Estate	5.514319N, 7.500580E	
9	117 Aba Rd. (opposite Apricot Hotel)	5.507337N, 7.488238E	
10	Afara (Opp. Technical College)	5.511531N, 7.485180E	
11	No 21 Azikiwe Road	5.525740N, 7.496130E	
12	26 Lagos Street/Calabar Street	5.533935N, 7.494303E	
13	No. 20 Palm Lane	5.538036N, 7.494018E	
14	Opposite All Saints Church, Ezizama Ossa	5.534399N, 7.480370E	
15	Obowo/Owerri Road	5.544526N, 7.501661E	
16	No. 149 Bende Road	5.536120N, 7.516460E	
17	Okwita Village	5.511882N, 7.529805E	

*Sampling, Sample Pre-treatment and Preservation:* A pre-sampling survey of the sampling areas (Umuahia North and Ikwuano LGAs) was conducted prior to sampling and this enabled the identification of functional boreholes. A Functional borehole was conceptualized as one that is regularly used by a minimum of 50 persons daily. Thirty-five functional boreholes were identified and stratified random sampling was applied in the selection of sampling points in order to achieve a fair representation of drinking water sources in both LGAs. Triplicate water samples were collected from each sampling point (borehole) with acid washed 2L polyethylene containers. Samples for heavy metal and radionuclide determination were acidified with 2 ml/L concentrated HNO<sub>3</sub>. The containers were tightly corked, labeled, put in an ice chest and immediately taken to the laboratory for analysis. The description and location of

the sampling points are outlined in Table 1 while Figure 1 shows the map of the sampling areas.



**Fig 1.** Map showing the Sampling Points

*Analyses of Water Samples:* Exttech DO/temperature meter (model SDL 150) was calibrated with electrolyte filling solution and used for DO determination. Hanna portable pH/temp/EC/TDS meter (model HI991300) was calibrated with buffer 4, 7 and 9 solutions (for pH) and 0.01 moldm<sup>-3</sup> potassium chloride solution (for electrical conductivity, EC). It was then used to determine pH, temperature, EC and total dissolved solids (TDS) by inserting the probe into a pre-washed 250 ml beaker containing each water sample at the point of collection after the beaker was rinsed thrice with the particular water samples.

Standard methods for the examination of water and wastewater (APHA, 2012) were used for other physicochemical parameters including total solids, hardness, alkalinity, nitrate and phosphate. Total Solids was determined by evaporation to dryness of 100ml of water sample while total hardness was determined with the ethylene diamine tetra acetic acid (EDTA) titrimetric method. Total alkalinity was determined with the titrimetric method using 0.02 M H<sub>2</sub>SO<sub>4</sub> and methyl orange indicator. The colorimetric method using a spectrophotometer was used for nitrate and phosphate determinations.

*Metal Analysis:* The metals of interest were sodium, calcium, magnesium, cadmium, lead and iron. Aqueous stock solutions were prepared with the appropriate metallic salts and five working standards were prepared in triplicate for each metal by serial dilution of the appropriate stock solutions. These and blank solutions were aspirated into an Atomic Absorption Spectrophotometer (model 210/211VGP) with a 220GF Graphite furnace 220 AS Autosampler. Absorbance readings obtained from Atomic Absorption Spectrophotometer (AAS) for each standard was used in plotting calibration curves for each metal. The samples were digested according to APHA (2012). 100ml of sample was transferred into a 250ml conical flask. 5ml of concentrated HNO<sub>3</sub> and a few boiling chips were added. The solution was boiled slowly and evaporated on a hot plate to about 20ml, before precipitation occurs. Heating and addition of concentrated HNO<sub>3</sub> was continued until a clear solution was obtained. The sample was not allowed to dry during digestion. The wall of the flask was washed with distilled-deionised water and solution filtered through Whatman no. 42 filter paper into a 50ml volumetric flask with two 5ml portions of deionised water. The solution was cooled, made up to mark and mixed thoroughly. Portions of this solution were used for metal determinations with the AAS.

*Determination of Radioisotopes by Gamma Ray Spectrometry:* The gamma ray spectrometry analysis

was carried out at the National Institute of Radiation Protection and Research (NIRPR), University of Ibadan, Nigeria. This was done using a Canberra NaI detector (model UNISPEC, serial no 22060316). Energy Calibration Sources were Am-241, Cs-137 and Co-60. The complete electronic instrumentation was connected to a PC-based multichannel analyser for gamma spectrum evaluation.

The energy and efficiency calibration of the NaI detector was carried out with IAEA Mixed Sediment Standard consisting of K-40, U-238 and Th-232 using the 1.33 MeV gamma line of Co-60 resulting to energy resolution of 2.3 keV (Full Width at Half Maximum, FWHM) with a relative yield of 1.73%.

Each sample was put into an acid washed Marinelli beaker (cylindrical plastic container) which was firmly sealed for a minimum of 28 d in order for secular equilibrium to be attained. They were then counted for 10800s (3h) each after they had attained secular equilibrium. The gamma spectrum peak area analysis and quantification was done with Genie 2000 software.

The activity concentrations of the radionuclides (K-40, U-238 and Th-232) were determined using the equation:

$$A_c = \frac{C_n}{P_\gamma V \epsilon}$$

(A<sub>c</sub> = activity concentration of the radionuclide in the sample in Bq/L; C<sub>n</sub> = net count under the corresponding peak; P<sub>γ</sub> = absolute transition probability of the specific gamma ray; V = volume of the sample (L); ε = detector efficiency at the specific gamma ray energy).

The data generated were converted to conventional units with calibration factors for actual determination of the activity concentrations the radionuclides. In order to determine the specific activity concentrations in the samples, the IAEA mixed standard which contains the radionuclides of the same dimension as the samples were also subjected to the same experimental procedures followed by subtraction of background counts. Generation of activity concentration in Bq/L was then carried out via the conversion of the count per second with the conversion factors which were different for each nuclide.

## RESULTS AND DISCUSSION

*Physicochemical Analysis:* The physico-chemical parameters of the groundwater samples are shown in Table 2. Temperature ranged from 26.41±0.27 in Sample 1 to 29.20±0.09 °C in Sample 8. This suggests

that the groundwater temperature is generally ambient and good for consumers who prefer cool to warm water. High temperature negatively impacts water quality by enhancing the growth of certain microorganisms which may increase taste, odour, colour and corrosion problems (UNICEF, 2008). Electrical conductivity (EC) values had a range of 37.09±2.50 – 601.00±15.30 µS/cm. Electrical conductivity gives an indication of the amount of total dissolved ions in water (Yilmaz and Koc, 2014). Mean values for EC in all the samples were low compared to the standard value 1000 µS/cm set by and the World Health Organization, WHO (2017). The pH values of all the water samples were in the acidic region and ranged from 3.05±0.11 in sample 5 to 4.51±0.08 in sample 14. WHO recommends a pH range of 6.5-8.5 for drinking water though a pH above 8.0 would be disadvantageous in the treatment and disinfection of drinking water with chlorine (UNICEF, 2008). Water samples gotten from various locations in Umuahia and Umudike were acidic and much lower than the WHO guideline values. Possible implication of this scenario is that low pH levels can encourage the solubility of heavy metals in water from piping and storage

systems. Acidic water can also impart sour or metallic taste on drinking water and lead to staining of laundry and sinks.

Mean total solid (TS) content had a range of 40.23±3.50 – 410.93±12.88 mg/L while mean total dissolve solids (TDS) ranged from 18.13±1.24 in Sample 1 to 301.58±6.35 mg/L in Sample 13. Mean TDS values in all the samples were below the WHO and Nigeria Standards for Drinking Water Quality (SON, 2015) recommended values of 1000 and 500 mg/L respectively. The dissolved oxygen (DO) is oxygen that is dissolved in water. Dissolved oxygen analysis measures the amount of gaseous oxygen (O<sub>2</sub>) dissolved in an aqueous solution. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis. Mean DO values of the samples ranged from 3.84±0.17 to 7.45±0.92 mg/L. A high DO level in a community water supply is good because it makes drinking water taste better. However, high DO levels may enhance corrosion in water pipes. For this reason, industries use water with the least possible amount of dissolved oxygen.

Table 2. Mean Physicochemical Parameters of Borehole Water Samples

Sample ID	Temp (°C)	EC (µS/cm)	pH	TS (mg/L)	TDS (mg/L)	DO (mg/L)	Hardness (mgCaCO <sub>3</sub> /L)	Alkalinity (mg/L)	NO <sub>3</sub> <sup>-</sup> (mg/L)	PO <sub>4</sub> <sup>3-</sup> (mg/L)
1	26.41±0.27	37.09±2.50	4.35±0.18	40.23±3.50	8.13±1.24	7.45±0.92	9.20±1.27	181.05±7.49	0.06±0.00	2.33±0.82
2	26.64±0.16	123.20±3.22	3.66±0.45	113.56±5.81	61.27±3.28	4.82±0.61	22.56±2.70	163.11±4.57	0.01±0.00	1.57±0.07
3	27.43±0.50	233.15±1.71	3.35±0.07	200.42±11.12	116.52±5.71	5.10±0.33	241.18±10.15	26.94±1.88	0.12±0.01	2.10±0.11
4	27.40±0.22	343.22±5.86	3.12±0.03	295.21±10.77	169.11±8.20	4.68±0.11	153.25±7.71	30.72±2.99	0.18±0.02	2.59±0.08
5	26.91±0.63	350.06±9.25	3.05±0.11	301.63±15.36	169.70±4.29	4.63±0.15	20.49±1.83	150.83±4.11	0.01±0.00	1.53±0.07
6	27.12±0.11	187.24±6.14	3.32±0.04	164.28±9.83	94.38±5.82	4.86±0.63	212.84±12.10	26.15±2.74	0.11±0.02	3.22±0.41
7	28.15±0.04	347.81±2.88	3.09±0.02	311.84±11.90	174.21±9.18	4.25±0.09	128.39±5.81	18.50±1.90	0.14±0.01	1.60±0.08
8	29.27±0.09	111.25±7.83	4.27±0.61	101.20±14.89	56.88±6.41	4.49±0.13	18.77±1.95	115.32±5.18	0.19±0.05	1.92±0.21
9	27.73±0.39	113.70±4.72	4.23±0.07	116.05±6.44	56.19±2.77	4.42±0.07	11.96±1.33	180.22±7.59	1.81±0.34	2.10±0.14
10	28.52±0.62	127.55±3.11	4.25±0.19	123.19±12.70	64.26±1.90	4.37±0.15	23.14±4.09	170±11.28	0.02±0.00	2.05±0.35
11	27.48±0.18	134.74±7.94	4.06±0.02	103.68±4.61	67.35±5.21	4.82±0.31	25.42±2.70	149.56±6.44	0.29±0.04	3.06±0.77
12	27.33±0.19	484.19±10.11	3.91±0.02	357.28±25.26	248.17±4.99	4.89±0.20	115.74±13.67	15.99±3.27	0.57±0.01	1.84±0.69
13	28.41±0.80	601.20±15.30	3.89±0.11	410±12.88	301.58±6.35	3.84±0.17	169.33±8.31	370.14±14.22	0.03±0.00	1.50±0.23
14	28.15±0.07	89.52±5.29	4.51±0.08	100.29±5.45	45.29±1.22	4.72±0.02	29.17±2.88	177.35±12.16	0.21±0.01	0.98±0.03
15	26.95±0.21	63.26±1.88	3.46±0.03	59.48±2.19	32.60±0.76	4.46±0.33	20.11±1.85	139.46±3.22	0.08±0.00	1.81±0.50
16	27.53±0.54	45.85±1.53	3.54±0.01	45.33±2.30	22.94±0.93	5.81±0.86	10.28±1.13	180.09±10.55	0.04±0.00	2.36±0.47
17	27.11±0.49	62.10±3.44	4.08±0.04	73.27±3.15	31.71±0.88	4.39±0.19	17.59±2.82	215.73±17.38	1.07±0.03	0.85±0.04
WHO limits (2017)	Cool	-	6.5 - 8.5	-	1000	-	-	-	50	-
SON limits (2015)	Ambient	-	6.5 - 8.5	-	500	-	150	-	50	-

WHO = World Health Organization recommended Values; SON = Standards Organization of Nigeria

**Metal Analysis:** The results for the mean concentrations of metals (Na, mg, Ca, Fe, Pb and Cd) in the water samples collected from the 17 boreholes in Umuahia and Umudike are presented in Table 3. Mean calcium concentration ranged from 1.255±0.037 mg/L in location 1 (NDDC Hostel, MOUAU) to 1.967±0.078 mg/L in location 3 (Old Hostel, MOUAU). These values were all below the guideline

values of WHO. Calcium occurs in water naturally and one of the main reasons for its abundance in water is its natural occurrence in the earth's crust. Calcium is an important determinant of water hardness, and it also functions as a pH stabilizer, because of its buffering qualities. Calcium also gives water a better taste but in addition to its contribution to water hardness, several epidemiological investigations have demonstrated the

relation between risk for cardiovascular disease, growth retardation, reproductive failure, and other health problems is caused by drinking water having large Ca content. Mean cadmium concentrations of the borehole water samples from the seventeen different sampling locations ranged from 0.001±0.000 in location 10 to 0.011±0.003 mg/L in location 7.

**Table 3.** Mean Metal Concentrations in Borehole Water Samples

Sample ID	Metals concentrations (mg/L)					
	Ca	Cd	Fe	Pb	Na	Mg
1	1.255±0.037	0.009±0.000	0.012±0.001	0.191±0.028	0.048±0.011	0.286±0.057
2	1.360±0.101	0.006±0.001	0.014±0.003	0.171±0.033	0.038±0.007	0.401±0.082
3	1.967±0.078	0.008±0.002	0.014±0.001	0.149±0.017	0.084±0.015	0.348±0.071
4	1.867±0.211	0.005±0.000	0.017±0.003	0.155±0.022	0.051±0.018	0.309±0.029
5	1.298±0.065	0.002±0.000	0.015±0.002	0.144±0.019	0.065±0.009	0.554±0.095
6	1.783±0.127	0.009±0.001	0.015±0.000	0.077±0.005	0.041±0.006	0.359±0.037
7	1.647±0.311	0.011±0.003	0.012±0.002	0.164±0.026	0.043±0.010	0.464±0.085
8	1.464±0.094	0.006±0.001	0.019±0.004	0.160±0.044	0.057±0.018	0.413±0.038
9	1.366±0.072	0.003±0.000	0.012±0.001	0.127±0.011	0.102±0.029	0.379±0.077
10	1.300±0.088	0.001±0.000	0.015±0.003	0.189±0.063	0.068±0.007	0.572±0.062
11	1.779±0.116	0.004±0.001	0.012±0.002	0.194±0.071	0.083±0.027	0.409±0.016
12	1.271±0.240	0.005±0.001	0.019±0.004	0.198±0.040	0.073±0.013	0.499±0.022
13	1.496±0.129	0.006±0.000	0.013±0.001	0.174±0.029	0.082±0.024	0.347±0.028
14	1.385±0.447	0.005±0.001	0.014±0.003	0.158±0.016	0.062±0.018	0.497±0.011
15	1.462±0.097	0.007±0.002	0.015±0.004	0.168±0.032	0.086±0.030	0.518±0.103
16	1.265±0.046	0.000±0.000	0.014±0.001	0.200±0.047	0.078±0.017	0.608±0.094
17	1.353±0.085	0.008±0.002	0.017±0.002	0.128±0.009	0.030±0.005	0.478±0.045
WHO limits (2017)	–	0.003	–	0.01	–	–
SON limits (2015)	–	0.003	0.3	0.01	200	20

The maximum permissible limits set by WHO and SON is 0.003mg/L and this values is exceeded in water samples from locations 1, 2, 3, 4, 6, 7, 8, 11, 12, 13, 14, 15 and 17. High concentration of cadmium in water for drinking and domestic purpose can cause severe damage to lungs and also cause diarrhea, severe stomach pain and vomiting (NAS, 1977). The mean concentrations of iron in the samples varied from 0.012±0.001 to 0.019±0.004 mg/L which was lower than the SON guideline value of 0.03mg/l. WHO considers iron to be a secondary contaminant in drinking water which is not of health concern at levels causing acceptability problems. Mean lead concentrations had a range of 0.077±0.005 – 0.198±0.040 mg/L. all the values exceed the permissible limit of 0.01 mg/L set by SON and WHO. Lead is a confirmed carcinogen which also interferes with the functions of vitamin D as well as damages the nervous system and causes brain disorder Jarup, 2003; Barbee and Prince, 1999). Mean sodium and magnesium concentrations had ranges of 0.030±0.005 – 0.102±0.029 mg/L and 0.286±0.057 – 0.608±0.094 mg/L respectively. These concentrations were below the standards set for sodium (200 mg/L) and magnesium (20 mg/L) by SON. Magnesium, like calcium, causes hardness of water. It is more difficult for hard water to form lather with soap. The most common effects of hard water on the human skin is dryness and difficulty in rinsing away soap from the surface of the skin which leaves the skin dry and potentially irritated.

**Radionuclides Concentrations:** The activity concentrations arising from the presence of three naturally occurring radionuclides, <sup>40</sup>K, <sup>238</sup>U and <sup>232</sup>Th were determined in Umuahia and Umudike and the results are shown in Table 4. This serves as baseline data since no such previous work was found with respect to Umudike and Umuahia. According to WHO, natural radionuclides, including potassium-40, and those of the thorium and uranium decay series especially radium-226, radium-228, uranium-234, uranium-238 and lead-210 are found in water due to natural processes or technological processes involving naturally occurring radioactive materials (NORM). K-40 is a naturally occurring radioactive isotope of potassium which is present in mineral waters, brines, feldspar, saltpetre and greensand (Norse Decom, 2003). It had a range of below detection limit (BDL) to 21.94±2.50 Bq/L in the water samples. The values were lower than those obtained by Jibiri *et al.* (2010) who analyzed radionuclides in water samples from high background radiation areas of Abeokuta, Nigeria. U-238 and Th-232 had ranges of BDL – 7.85 ±1.80 Bq/L and BDL – 5.76 ±0.53 respectively. The SON maximum level for radionuclides in water is 0.1 Bq/L while the WHO limits for U-238 and Th-232 are 10 and 1 Bq/L respectively. The activity concentrations of U-238 were below the WHO limits but the limits were exceeded for Th-232 in water samples from locations 2, 3, 4, 8, 10, 12, 14 and 15. The SON limits were exceeded in samples from most of the locations

for K-40. The radiation impact risk on biota depends on factors like the type of radiation involved, energy of radiation, activity level, the chemical and physical

properties of the nuclides and the contaminated material (NAS, 1977).

**Table 4.** Mean Activity Radionuclide Concentrations in of Borehole Water Samples

Sample ID	K-40 (Bq/L)	U-238 (Bq/L)	Th-232 (Bq/L)
1	10.95 ±0.98	7.85 ±1.80	BDL
2	1.59 ±0.14	4.64 ±1.01	4.11 ±0.37
3	21.79 ±1.89	5.73 ±1.28	5.76 ±0.53
4	12.68 ±1.06	4.76 ±1.19	1.56 ±0.17
5	BDL	5.45 ±1.22	BDL
6	BDL	BDL	BDL
7	BDL	BDL	0.78 ±0.08
8	2.99 ±0.27	4.24 ±0.95	4.24 ±0.95
9	29.68 ±2.25	BDL	BDL
10	2.19 ±0.18	3.50 ±0.80	1.19 ±0.12
11	2.10 ±0.18	BDL	BDL
12	6.57 ±0.56	5.27 ±1.21	1.23 ±0.12
13	13.14 ±1.05	0.23 ±0.07	BDL
14	5.99 ±0.51	BDL	1.53 ±0.05
15	21.94 ±2.50	4.82 ±0.64	1.53 ±0.09
16	8.70 ±0.75	7.11 ±1.62	BDL
17	1.73 ±0.15	BDL	BDL
WHO limits (2017)	–	10.00	1.00
SON (2015) maximum level for radionuclides			0.1

The United Nations Scientific Committee on Effects of Atomic Radiation, UNSCEAR, reported that the average worldwide exposure to natural sources in foods and drinking water (ingestion exposure) is 0.29 mSv/y i.e. approximately 0.17 mSv/y from K-40 and 0.12 mSv/y from Uranium and Thorium (UNSCEAR, 2000). Minute traces of radioactivity normally exist in all drinking water but concentrations depend on the radiochemical composition of soils and rocks strata through which raw passes and this makes compositions in water to vary from place to place (NAS, 1977).

*Conclusion:* Water samples from boreholes in Umuahia and Umudike were all acidic and may need to be treated to bring pH up to the recommended range before consumption. Of greater concern are the values for mean cadmium concentrations which were above recommended limits in 13 out of the 17 sampled boreholes and lead concentrations which exceeded both national and international standards in all the samples. The limit set for Th-232 in water samples by WHO was also exceeded in eight locations while SON limit for K-40 was also exceeded in samples from most of the boreholes.

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