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NATURAL RADIONUCLIDES IN DRINKING WATER AVAILABLE IN SECONDARY SCHOOLS OF SOUTHERN PART OF DELTA STATE, NIGERIA

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ABSTRACT

Water is required by people of all ages. Therefore it is pertinent to be armed with basic knowledge to help in the evaluation of certain parameters required in the choice of the water consumed by people. This study employed gamma spectrometry using NaI (TI) detector to measure the activity concentrations of natural radioactivity in water samples available in some secondary schools within the southern part of Delta State, Nigeria. To examine the radiological safety of the water samples in this study, committed annual effective dose was estimated for the age groups 12 – 17 years (students) and >17 years (teachers). A total of 30 samples of water were analyzed. Results obtained showed that the average activity concentrations of the samples of water ranged from129.89 ± 11.37 - 256.60 ± 9.60 Bql^{-1}, 5.39 ± 1.04 - 9.01 ± 1.87 Bql^{-1} and 1.60 ± 0.02 - 7.35 ± 1.87 Bql^{-1} for ^{40}K, ^{238}U and ^{232}Th, respectively. The derived total combined annual effective dose received by the two groups was obtained as 7.60 mSvy^{-1} and 2.85 mSvy^{-1}, respectively, with ^{238}U having higher values than ^{40}K and ^{232}Th in all the samples in the order, ^{238}U >^{40}K >^{232}Th.The values clearly exceeded the values recommended by regulating agencies like World Health Organization (WHO) with reference value of 0.1 and ICRP and IAEA with reference value of 1.0 indicating a state of radioactivity contamination. In view of this, consumption of the water in the studied locations may pose a serious public health challenge, with the group 12 – 17 years being more susceptible.

Keywords: Activity concentration, Drinking water, Radiological safety, Health risk, Delta South

Introduction

Water experts (Living-Water, 2021) recommend that humans as a matter of practice should drink water regularly. Water content of the human body they submit is nearly 70% and there is the need to ensure that this balance is maintained. The function of water in the body are lubrication of the joints, formation of mucus and saliva, conveyance of oxygen round the body and boosting of the beauty and healthiness of the skin.

The best water for drinking they submit should satisfy at least any three of the properties. i) Have alkaline pH greater or equal to 7.0 but less or equal to 9.5 and should contain sufficient proportions of alkaline minerals. ii) Should be ionized to ensure that the ‘oxidation reduction potential’ is negative. This makes it capable of neutralizing free radicals which is a plus in the slowing down of the aging process.iii) Should contain the necessary occurring minerals .iv) Should be free of contaminants. These pollutants could be toxic metals, viruses, radioactive materials, toxin.

O’Rourke (2002) indicated that an important factor in maintaining the overall health and wellbeing of teens is ensuring that they are hydrated. Some hydrating agents for children from literature are water, milk, soup, health drinks and fruit juice (Parenting healthy babies, 2017). Of these the most easily sourced by the generality of the teens in the secondary schools in Delta State and in fact Nigeria is water. The advantage of good hydration is the prevention of a number of health issues such as kidney stone, headaches, confusion, pressure ulcers, constipation and infections of the urinary tract (UTIs). It is fundamental then that these teens should have good sources of drinking water in their schools. If they are healthy, then they can focus in their academics all other factors being held constant. In fact Akingbulu (2017) had asserted that school attendance in Nigeria has been promoted by easy access to water. The ‘United Nations Children’s Fund (UNICEF)’ has also submitted that clean water amongst other facilities are vital if the development of children must survive (UNICEF, 2018). This explains why this has been assisting most State Governments in Nigeria in addressing this problem. The FederalGovernment of Nigeria is not left out. She provided boreholes and other items to 54 secondary schools across the country through her Victims Support Programme (VSF) by way of combating the Corona virus pandemic (COVID-19). The effort of the Delta State Government in the past years towards providing boreholes in a number of her public schools is commendable.

It is important that the issue of pollutants in these provisions be investigated. Mokobia (2022) indicated the availability of literature that confirms the presence of naturally occurring materials (NORM). He hinted that this acceptance has prompted a number of appropriate investigations both locally and international (Usikalu et al., 2015). The aim of this study is to access the activity concentration of natural radionuclides in drinking water available in some public and private secondary schools in the southern region of Delta State with the view to evaluating the radiological consequences. The resulting data from this study would provide baseline data of activity concentration of radionuclides in water from public and private schools in Nigeria.

Materials and Methods

Samples collection and Preparation

Water samples from selected public and private secondary schools located in southern part of Delta State were collected. A total of thirty samples were collected, five each from Warri South, Warri North, Patani, Bomadi, Isoko South and Isoko North local government areas(LGAs) (Figure 1). The sampling locations were chosen based on student population density and other considerations.

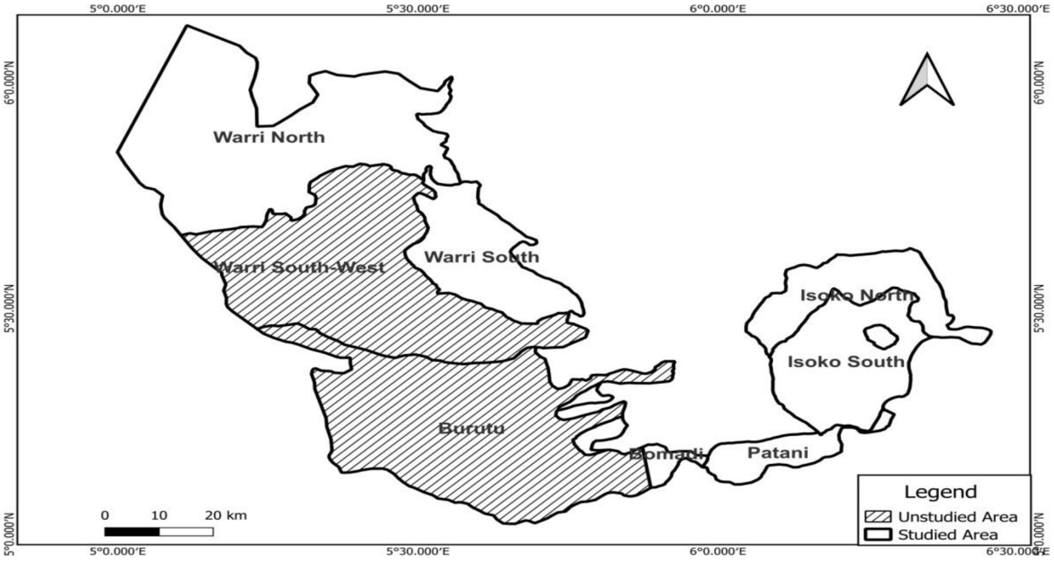

Figure 1: Map of study location

Samples were collected into 2-liter capacity plastic containers and labelled accordingly to avoid mix up. Prior to sampling, the plastic containers were thoroughly washed with detergent solution and rinsed several times with distilled water to remove any inorganic material that may have stuck to the container walls. At the point of sample collection, the containers were rinsed again severally with the water under study (Ajayi and Owolabi, 2008). The water samples were collected from borehole available in the school premises. For schools where no borehole is available, bottle and/or sachet water sold within the school premises were used. Following standard procedure, the water taps were initially turned on at maximum capacity for a few minutes to flush the plumbing system of any water that may have been there for some time (Avwiri et al., 2007). The taps were thereafter turned down to a low level to reduce turbulence, which in turn reduces radon leakage. Soon after collection, the water samples in the containers were acidified with HCl in order to avert adsorption of radionuclides onto the container walls and to prevent ionic changes and growth of organic materials pending analysis (Avwiri et al., 2007; Ajayi and Owolabi, 2008; Ahmad et al., 2015). The screw heads of the containers were taped shut and covered with thick vinyl tape and left for a period of four weeks. This is to ensure that ^{238}U and ^{232}Th and their progenies achieve secular equilibrium.

Measurement of activity concentration (AC)

Samples were analyzed using a low-level 76 mm x 76 mm NaI(TI) gamma detector at the department of Physics and Engineering Physics environmental radioactivity laboratory, Obafemi Awolowo University, Ile-Ife, Nigeria. A cylindrical 10 cm thick Canberra Pb shield was used to enclose the detector to reduce the background radiation.The gamma detector has a resolution of 8% efficiency at energy of 0.662 MeV (^{137}Cs) capable of differentiating the gamma-ray energies of the radionuclides of interest in this study. The output of the detector was connected to Canberra series 10 plus Multichannel Analyser (MCA) (Model No. 1104) through a preamplifier base and a computer with Canberra software analyzer for spectral acquisition and analysis that matches the acquired gamma energies to a library of possible isotopes. International Atomic Energy Agency (IAEA) reference water sample was used for efficiency calibration for the various energy peaks. After equilibrium, each sample was placed on top of the detector and counted for 60,000 seconds. As was carried out by previous investigator that had used this detector (Mokobia et. al. 2003 Balogun et., al., 2003 and Mokobia 2011) a tightly sealed empty container of same material and geometry with that of the samples was used as background and counted for same duration of time. The background counts and other counts due to Compton scattering of higher peaks were subtracted from the total counts toget the net area under the corresponding photopeaks. The analysis and activity of the parent radionuclides depends on thoseof the daughter energy peaks of the decay products in equilibrium with their parent radionuclides (Ajayi and Owolabi, 2008; Awodugba and Tchokossa, 2008). Therefore, the gamma-ray peak of 911.1 keV and 583.1 keV of ^{228}Ac and ^{208}Tl, respectively were used for the identification of ^{232}Th activity; that of ^{238}U was gotten from 1120.3 and 609.3 keV gamma peak of ^{214}Bi and 351.9 keVpeak of ^{214}Pb, while the single gamma peak of 1460.8 keV was used for ^{40}K.Using the net counts under the selected photopeaks, efficiency, gamma intensity, volume of the samples and counting time, the AC(in Bql^{-1}) of ^{40}K, ^{232}Th and^{238}U in the samples in were then estimated (Oyebanjo and Magbagbeola, 2015).

Calculation of committed annual effective dose

The committed annual effective dose (D$_{\mathrm{eff}}$) due to ^{40}K,^{238}U and^{232}Th in drinking water was calculated in order to evaluate the radiological risk to secondary school students under the age group of 12–17 years and teachers with age group17 years in southern region of Delta State. The D$_{\mathrm{eff}}$ in mSvy^{-1}due to each radionuclide was estimated using the relation (Ibikunle et al., 2017).

$$D_{eff} = AC.I.D \qquad (1)$$

Where AC is the activity concentration of respective radionuclide in water samples, I is the annual consumption rate of water which is 600 liter per year for age 12 – 17 years and 730 liter per yearfor age 17 year above (WHO, 2011).D is the dose conversion factors for radionuclides, which according to the International Commission on Radiological Protection (ICRP,1996) is 1.5×10^{-6}, 2.5×10^{-7} and 7.6×10^{-9} SvBq^{-1}for age group 12 – 17 years and 2.8×10^{-7}, 2.3×10^{-7} and 6.2×10^{-9}SvBq^{-1}for age group >17 years for ^{238}U, ^{232}Th and ^{40}K, respectively.The total D$_{\mathrm{eff}}$to an individual is therefore the sum of each radionuclide D$_{\mathrm{eff}}$. That is;

$$D_{eff} = \sum(AC.I.D) \qquad (2)$$

Results and Discussion

The measured ACs of radionuclides, ^{40}K^{238}U and^{232}Th, in the investigated water samples of public and private secondary schools in each LGA of southern region of Delta State are presented in Figures 2 to 7 for Warri South, Warri North, Patani, Bomadi, Isoko South and Isoko North, respectively. Table 1 shows the descriptive statistical summary of the AC across all the locations. In all, the AC of the radionuclides in the water samples ranged from 129.89 ± 11.37 to 256.60 ± 9.60 Bql^{-1}, 5.39 ± 1.04 to 9.01 ± 1.87 Bql^{-1} and 1.60 ± 0.02 to 7.35 ± 1.87 Bql^{-1} for ^{40}K, ^{238}U and ^{232}Th, respectively. These values show that samples S1 (Patani LGA), V2 (Isoko North LGA) and S3 (Patani LGA) have the lowest AC for ^{40}K, ^{238}U and ^{232}Th, respectively, where as samples U5 (Isoko South LGA), Q3 (Warri North LGA) and S1 (Patani North LGA) have the highest values for ^{40}K, ^{238}U and ^{232}Th, respectively. The slight differences between the AC of thorium and uranium may probably be due to similar aquifer characteristics of the study area (Ahmad et al., 2019). Also, the geological features of the aquifer environment of the Delta region may be responsible for the less variation of the radionuclide concentration noticed within and between the samples as evident from the % coefficient of variance values.

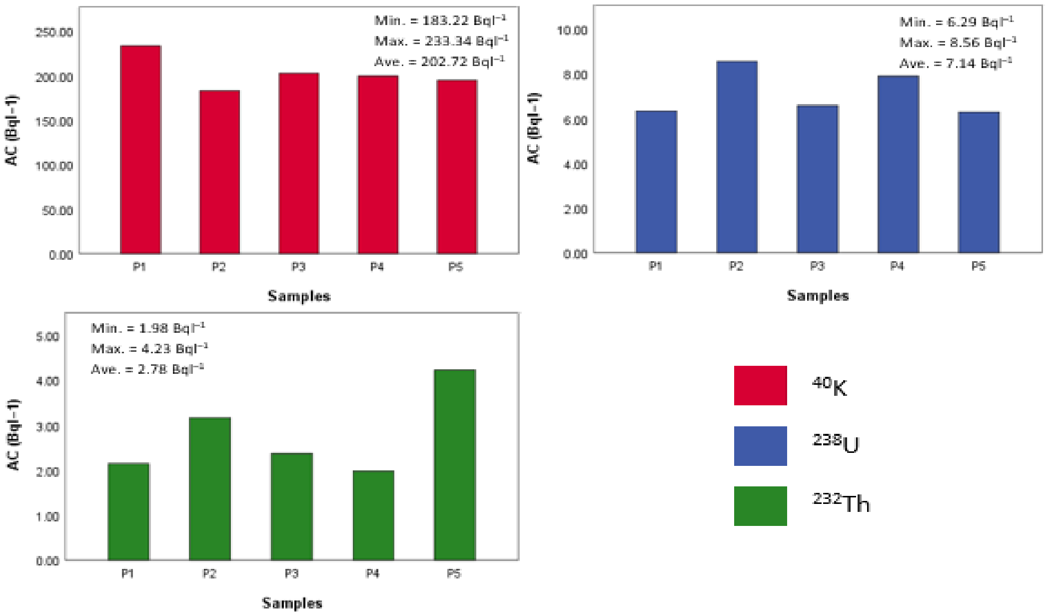

Figure 2: Measured activity concentrations of 40K, 238U and 232Th in water samples of Schools in Warri South

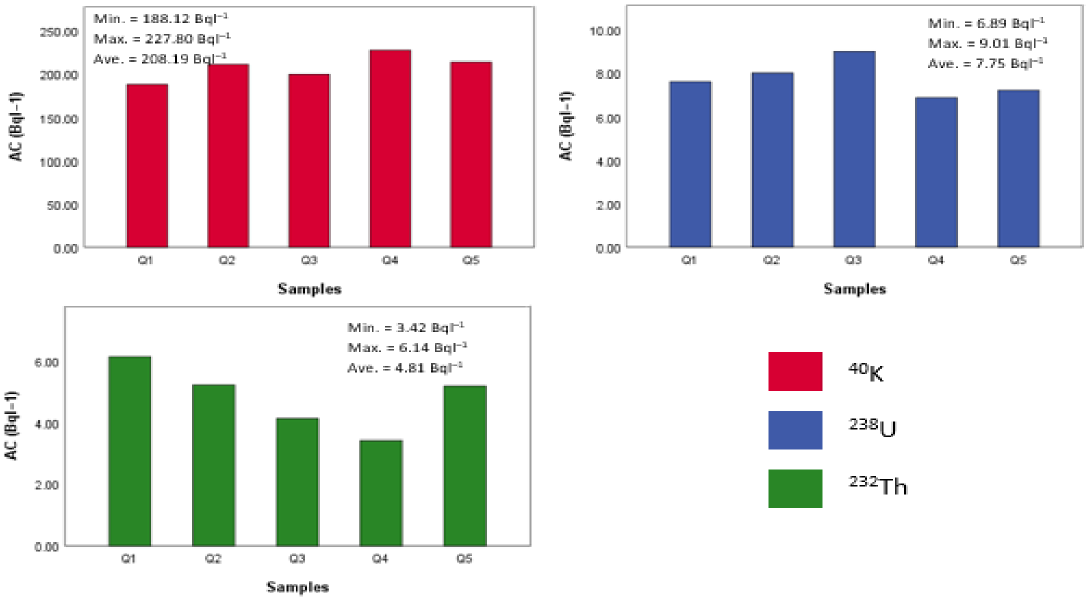

Figure 3: Measured activity concentrations of 40K, 238U and 232Th in water samples of Schools in Warri North

The result shows that the three natural radionuclides were detected in all samples with ^{40}K having higher values in all samples followed by ^{238}U in this order, ^{40}K >^{238}U >^{232}Th.The slightly higher AC of ^{238}U than ^{232}Th can be ascribed to their solubility difference with uranium being more soluble and mobile, thus can be leached from host rocks and minerals into groundwater sources (Ibikunle et al., 2017). The higher AC of ^{40}K was predictable since it is a natural radionuclide with wide abundant in the environment (Portuphy et al., 2018; Akpolile and Ugbede, 2019). The contribution of the radionuclides to the total radioactivity of the water across all the locations is depicted in Figure 8. As noted, the ACs of ^{232}Th and ^{238}U show no significant difference whereas significant difference exists between those of ^{40}K and ^{232}Th and ^{40}K and ^{238}U. The current AC results for drinking water in secondary schools of southern part of Delta State have been compared with the guidance level of WHO (2011) and was found that the measured ACs were all above the WHO values of 10.0, 1.0 and 0.1 Bql^{-1} for ^{40}K, ^{238}U and ^{232}Th, respectively. This shows that water from these study locations is out of the WHO radiological safety range of drinking water, an important water quality parameter of concern. In effect, the intake of the study water can accumulate the radionuclides in various organs of the body which may lead to irradiation of the organs due to emitted gamma photons thereby causing radiation damage (Akhter et al., 2007; Nahar et al., 2018).The extend of damage to any organisim linear correlation to the AC of the radionuclides in the respective organs (Jibiri et al., 2007; Ugbede et al., 2022). Kidney and lungs are perfect target for uranium to accumulate and can be absorbed in blood and growing bone and other soft tissues, thorium is also absorbed in bones, liver and the lungs (Akhter et al., 2007; Nahar et al., 2018; Ahmad et al., 2019). Potassium, being an essential intracellular cation with low risk, is distributed in the various body part (Hassan et al., 2021). Due to its low risk, specific guidance levels are not normally given for ^{40}K, however, children and other critical individuals suffering from hypertension, diabetes, renal failure, etc. may be susceptible to its presence (Portuphy et al., 2018).The measured average activity concentrations of examined radionuclides in the study water were greater than those reported for bottled water in Acrra (Portuphy et al., 2018); borehole water in Port Harcourt (Avwiri et al., 2007), Bomaa and Techire, Ghana (Darko et al., 2015); well and tap water in Kulim (Ahmad et al., 2019); surface water in Kuala Lumpur (Khandaker et al., 2019), Nkalagu (Ugbede et al., 2020), Osun (Ibikunle et al., 2016, 2017); groundwater in Akure (Ajayi and Owolabi, 2008), Ogun (Ajayi and Achuka, 2009), Makkah, Saudi Arabia (Alseroury et al., 2018). On the contrary, the present average values are much lower than values of 447.058, 68.678 and 75.675Bql$^{-1 40}$K, ^{232}Th and ^{226}Ra, respectively measured in drinking tap water of Chamchamal town in Iraq (Salih, 2022). The present values are comparably in range with values reported by UNSCEAR (2000) for some locations across the world, especially for ^{40}K in some regions where current value is slightly higher.

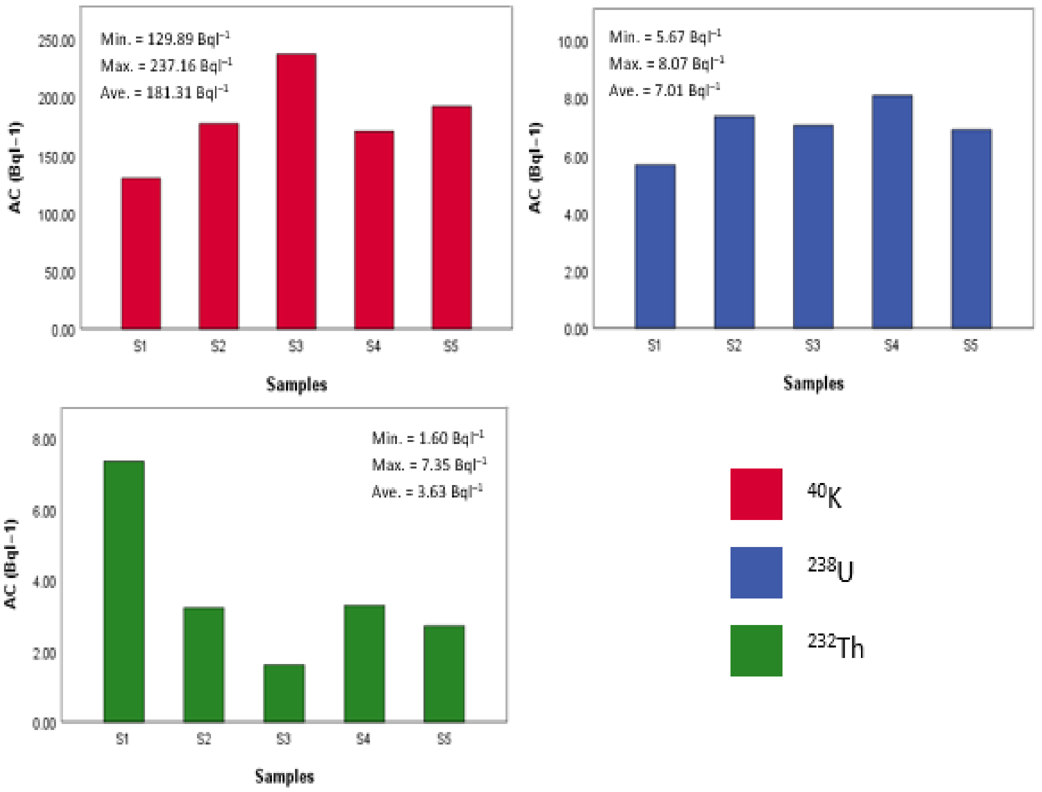

Figure 4: Measured activity concentrations of 40K, 238U and 232Th in water samples of Schools in Patani

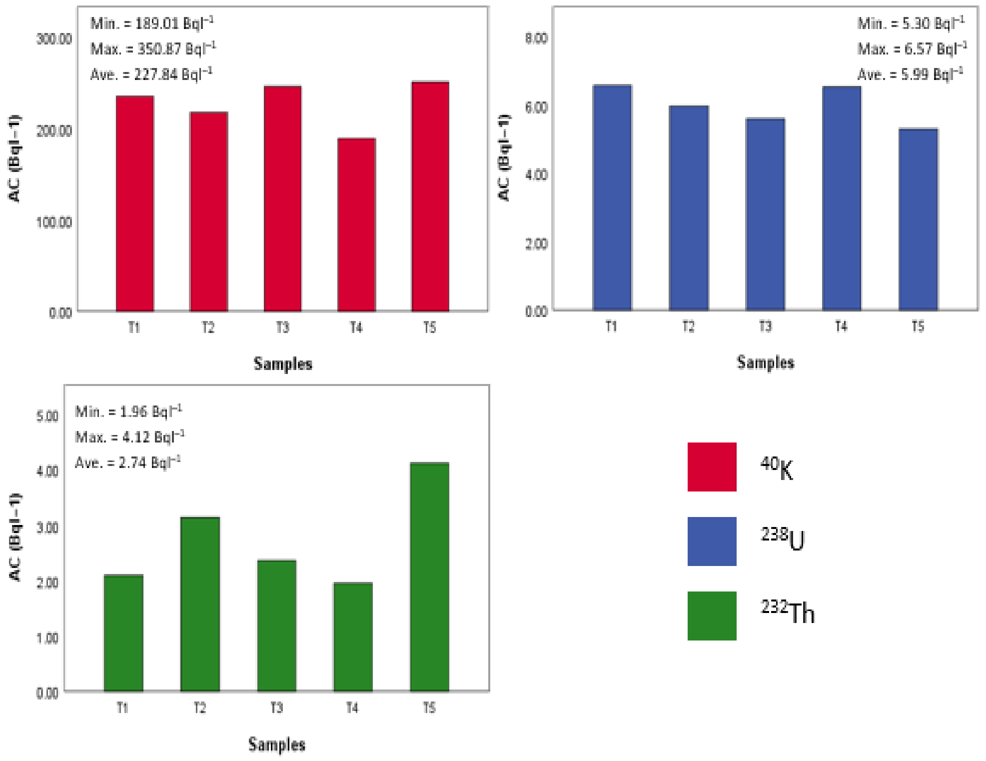

Figure 5: Measured activity concentrations of 40K, 238U and 232Th in water samples of Schools in Bomadi

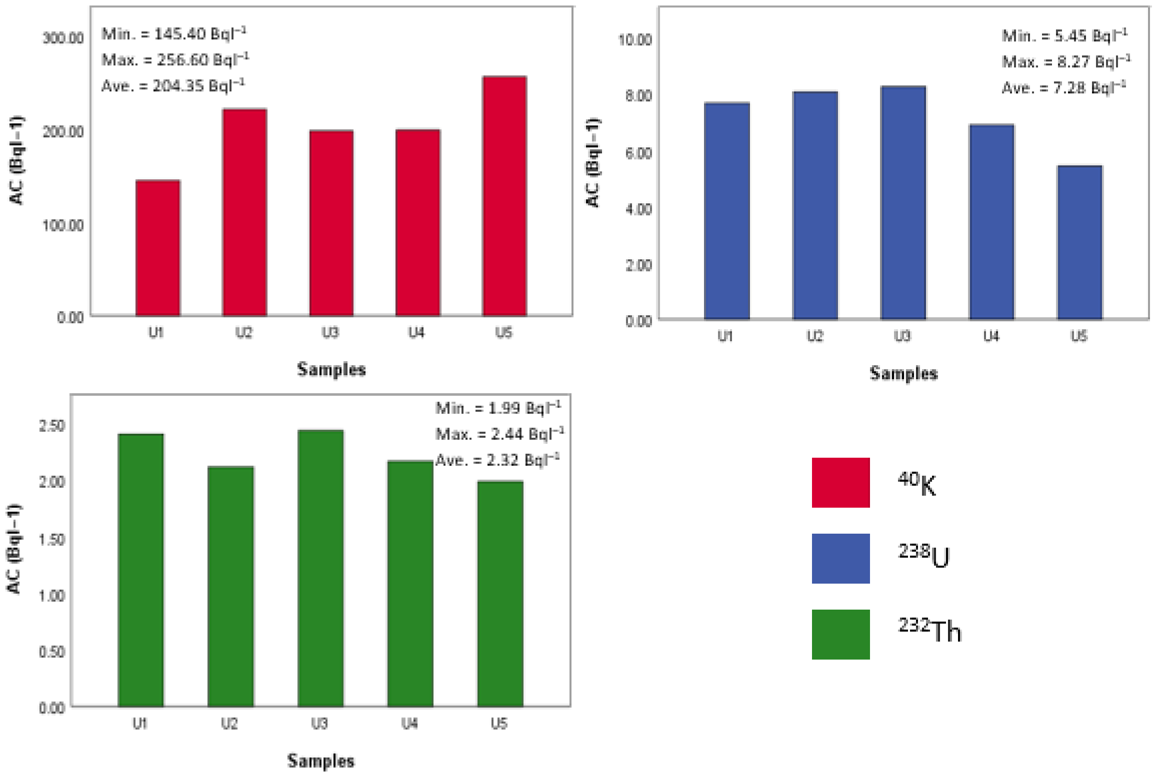

Figure 6: Measured activity concentrations of 40K, 238U and 232Th in water samples of Schools in Isoko South

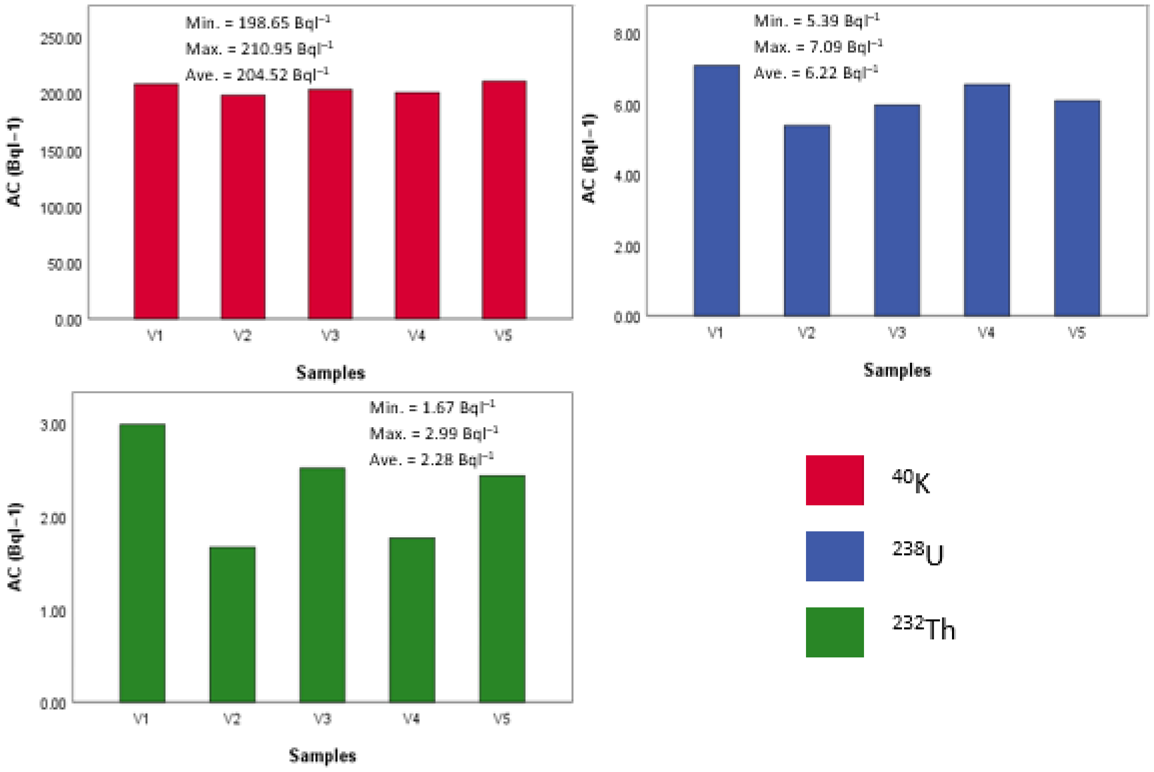

Figure 7: Measured activity concentrations of 40K, 238U and 232Th in water samples of Schools in Isoko North

Table 1: Descriptive statistical summary of activity concentration (Bql^{-1}) natural radionuclides in water samples of Secondary Schools

	Min.	Max.	Mean	Std. Deviation	Std. Error	% Coefficient of Variance	95% Confidence Interval for mean	
							Lower bound	Upper Bound
^{40}K	129.89	256.60	204.82	28.16	5.14	2.51	194.31	215.34
^{238}U	5.30	9.01	6.90	1.01	0.18	2.66	6.52	7.27
^{232}Th	1.60	7.35	3.08	1.39	0.25	8.25	2.56	3.60

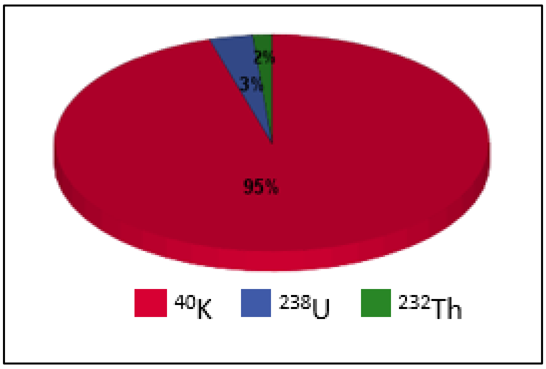

Figure 8: Percentage contribution of radionuclides to total radioactivity of water samples of Secondary Schools

Table 2 shows the summary of the calculated annual effective dose (D_{eff}) under the age group of 12 – 17 years and >17 years for students and teachers, respectively. The overall average $D_{eff}$for^{40}K, ^{238}U and ^{232}Th was estimated as 0.93, 6.21, 0.46mSvy^{-1}, respectively for group age 12 – 17 years (students) and 0.93, 1.41 and 0.52 mSvy^{-1}, respectively for group age > 17 years (teachers).The average D_{eff} due to ^{238}U was observed to be higher than that of ^{40}K and ^{232}Th in all the samples and locations in this order, ^{238}U >^{40}K >^{232}Th as against that of the AC. This shows the radiotoxic nature of uranium than potassium and thorium as well as its solubility and mobility characteristics in water (Ahmad et al., 2019; Khandaker et al., 2019). Also, it was noted that the D_{eff} of the radionuclides in age group 12 – 17 years were higher than those of >17 years group, indicating that students and other individual under this age group may be most susceptible and at higher risk to radiological hazard resulting from the intake of the investigated water. Furthermore, the total average annual effective dose due to combination of ^{40}K, ^{238}U and ^{232}Thacross the study locations was estimated at 7.60 mSvy^{-1}and 2.85 mSvy^{-1}for age group 12 – 17 years and >17 years, respectively. As presented in Figure 9, Warri North has the highest D_{eff} value of 8.65mSvy^{-1} and 3.33 mSvy^{-1}, respectively, accounting for 19% of the total effective radiation dose from natural radionuclides in drinking water from all secondary schools. This values clearly show that the annual effective dose resulting from ^{40}K, ^{238}U and ^{232}Thin water from the secondary schools of Delta south region is above the reference limits of 0.1 mSvy^{-1} by the World Health Organization (WHO, 2011)for drinking water and 1.0 mSvy^{-1} by the ICRP (ICRP,1991, 1996)and IAEA (IAEA, 2014) for ingestion of radionuclides from water and foods. More so, the values exceeded the 0.29 mSv world average annual effective dose estimated by UNSCEAR (2000) from different counties. These observations further designate the unsafe radiological nature of drinking water in secondary schools of southern part of Delta State.

Table 2: Summary of estimated annual effective dose (D_{eff}) of natural radionuclides in water samples

Location		**D_{eff} for 12 – 17 years ($mSvy^{-1}$)**				**D_{eff} for >17 years ($mSvy^{-1}$)**			
		^{40}K	**^{238}U**	**^{232}Th**	**Total**	**^{40}K**	**^{238}U**	**^{232}Th**	**Total**
Warri South	Min	0.84	5.66	0.30	7.09	0.83	1.29	0.33	2.66
	Max	1.06	7.70	0.63	9.01	1.06	1.75	0.71	3.11
	Ave	0.92	6.42	0.42	7.76	0.92	1.46	0.47	2.84
Warri North	Min	0.86	6.20	0.51	7.75	0.85	1.41	0.57	3.01
	Max	1.04	8.11	0.92	9.64	1.03	1.84	1.03	3.47
	Ave	0.95	6.98	0.72	8.65	0.94	1.58	0.81	3.33
Patani	Min	0.59	5.10	0.24	6.80	0.59	1.16	0.27	2.73
	Max	1.08	7.26	1.10	8.53	1.07	1.65	1.23	2.98
	Ave	0.83	6.31	0.55	7.68	0.82	1.43	0.61	2.86
Bomadi	Min	0.86	4.77	0.29	6.51	0.86	1.08	0.33	2.52
	Max	1.14	5.91	0.62	7.30	1.14	1.34	0.69	2.91
	Ave	1.04	5.39	0.41	6.84	1.03	1.22	0.46	2.72
Isoko South	Min	0.66	4.91	0.30	6.37	0.66	1.11	0.33	2.61
	Max	1.17	7.44	0.37	8.71	1.16	1.69	0.41	3.01
	Ave	0.93	6.55	0.33	7.82	0.92	1.49	0.37	2.79
Isoko North	Min	0.91	4.85	0.25	6.01	0.90	1.10	0.28	2.28
	Max	0.96	6.38	0.45	7.78	0.95	1.45	0.50	2.89
	Ave	0.93	5.60	0.34	6.87	0.93	1.27	0.38	2.58
Overall	Min	0.59	4.77	0.24	6.01	0.59	1.08	0.27	2.28
	Max	1.17	8.11	1.1	9.64	1.16	1.84	1.23	3.47
	Ave	0.93	6.21	0.46	7.60	0.93	1.41	0.52	2.85

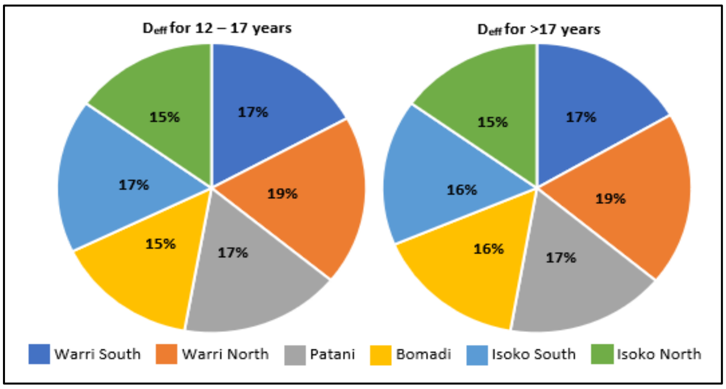

Figure 9:Fraction of annual effective dose in each location

Conclusion

So far, this study has presented the radiological state of drinking water available in some secondary schools from southern part of Delta State. The activity concentration of ^{40}K, ^{238}U and ^{232}Th in the obtained water samples exceeded guideline levels of 10.0, 1.0 and 0.1 Bql^{-1} for ^{40}K, ^{238}U and ^{232}Th, respectively by WHO. The overall annual effective dose to the targeted population of 12 – 17 years (students) and >17 years (teachers) as a result of the ingestion of the natural radionuclides in the water samples was estimated at 7.60 $mSvy^{-1}$ and 2.85 $mSvy^{-1}$, respectively which are higher than both WHO, ICRP and IAEA recommendations. In view of the fact presented by this study, it can be concluded that access to clean and safe drinking water is still far from the reach of the schools. It is recommended that prompt measures be taken by government and private school owners to provide safe drinking water to schools in order to reduce exposure of the public to radionuclides through water intake.

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