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RESEARCH PAPER

Radiological Hazards Associated with ^{238}U, ^{232}Th, and ^{40}K in some selected Packaged Drinking Water in Ilorin and Ogbomoso, Nigeria

Ajibola Taiye Benjamine[1]., Orosun Muyiwa Michael[1*]., Ehinlafa Olusegun Emmanuel[1]., Sharafudeen Fatimah Anike[1]., Salawu Banji Naheem[2], Ige. Simon Olatunji[1]. and Akoshile Clement O[1].

1. Department of Physics, University of Ilorin, Ilorin, Nigeria.
2. BS Geophysical and Consultancy Limited, Nigeria.

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ABSTRACT
In order to ensure radiation monitoring and protection, investigation and assessment of radiological risks that may be associated with the consumption of packaged table waters commonly consumed in Ogbomoso and Ilorin metropolis, Nigeria, was carried out. The measurements were carried out using a '3 x 3' inch lead-shielded NaI (Tl) detector coupled through coaxial cable to a multichannel analyser. The measured activity concentrations of the natural radionuclides in the packaged drinking water sample are mostly within the recommended limits. The estimated mean Annual Effective Dose was found to be within the acceptable limits of 1 mSv/y for the general populace except for the infants which is slightly higher for some of the samples. The estimated Excess Lifetime Cancer Risk were found to be lower than the world average value of 0.2×10^{-3} in only two of the selected packaged drinking water. This implies the possibility of developing cancer over a lifetime considering seventy years as the average life span is considerably high.
Keywords: Radioactivity; Drinking water; Gamma-ray Spectrometry; Radiological Impact Assessment

INTRODUCTION

Radionuclides are atoms with unstable nuclei, which spontaneously transform by releasing energy in form of radiation from the nucleus or other parts of the atoms. These radiations are release in three forms: alpha particles, beta particle and gamma rays (photon) (RSSC, 2011). The term used to describe the rate of disintegration of these radionuclides is radioactivity. It is the spontaneous emission from this radioactive nuclide by the atomic nuclei causing the isotopic nucleus containing a specific number of protons and neutrons.

Radionuclides from the natural decay series are everywhere in the earth's crust and they penetrate natural water thereby entering the drinking water cycle. The contribution of drinking water from all sources to total exposure to radionuclides is crucial and is due largely to naturally occurring radionuclide in the uranium and thorium decay series. Common radionuclides found in groundwater include potassium-40, uranium isotopes, thorium isotopes, radium isotopes, lead-210 and polonium-210. Background radiation exposure varies widely across the earth, but the global average annual human exposure from natural sources is 2.4 mSv/y, and drinking water is one of the pathways to human exposure to radiation (Orosun

* Corresponding Author Email: muyiwaorosun@yahoo.com

et al., 2016b, 2018, 2020a, 2021a, 2021b). The activity concentration of natural radionuclide in ground water is connected to the activity concentration of uranium and thorium and their decay product in the ground and bedrock. This is due to the groundwater reacting with ground and bedrock material, which is releasing some quantities of dissolved components (Oluyide *et al*., 2019; Oluyide *et al*., 2018; Adagunodo, 2017a, 2017b; Vesterbacka, 2007).

Water is essential for the survival of all forms of life and the need for water is on the increase due to high rate of population growth and urbanization (Orosun *et al*., 2016a). Therefore, its quality is of great importance to human health but poor water quality prevents safe drinking water. Now the consumption of treated drinking water is wide due to its easy accessibility and low cost. Groundwater supply is an important source of drinking water but it may contains some natural radioactive nuclide such as uranium, thorium, potassium-40 and radium (Orosun *et al*., 2016b, 2017, 2018, 2019, 2020a&b; Oni and Adagunodo, 2019). The amount of naturally occurring radioactivity in drinking water may be high as it is often source from groundwater that is expose to bedrock and soil containing elements such as those in the uranium and thorium decay series (Ajibola *et al*., 2021; Oni and Adagunodo, 2019; Orosun *et al*., 2016b, 2018, 2021; WHO, 2006).

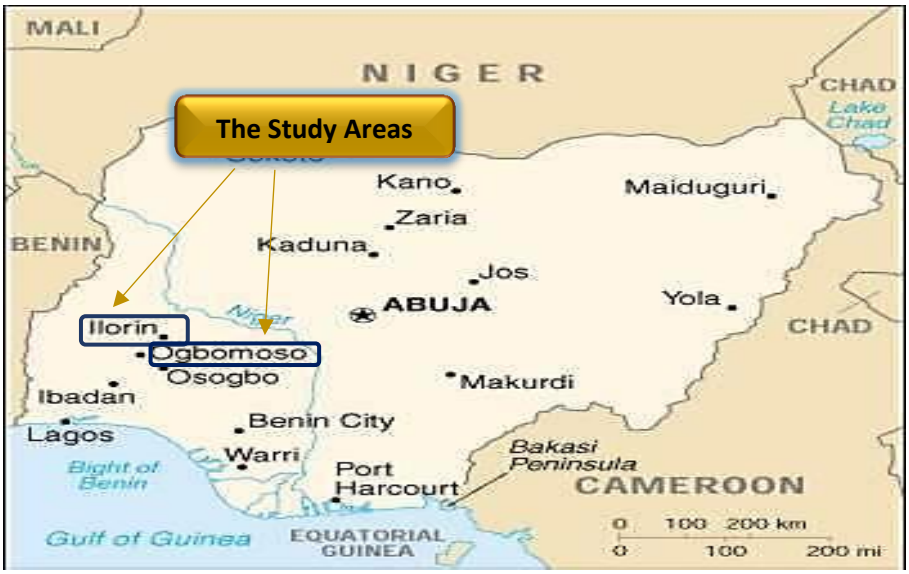
In recent years, many researches have been carried out in different parts of the country to determine the level of purity in drinking water. For instance, Awodugba and Tchokossa, in 2008, assessed the concentration of radionuclide in water supply from bore-holes in Ogbomoso land. Oni and Adagunodo in 2019, carried out an assessment of radon concentration in groundwater within Ogbomoso. Olafisoye *et al*., (2013), investigates groundwater contaminants at Aarada waste in Ogbomoso. Orosun *et al*., 2016 performed radiological impact assessment of soil and water in Tanke – Ilorin, Nigeria. Nwankwo, (2013) studied the radioactivity in groundwater from Tanke-Ilorin, Nigeria and Achuka *et al*., in 2017, carried out radiological risks assessment of Ogun state drinking water. Also, Radioactivity in some selected water samples produced in Nigeria was studied by Ajadi and Adesida in 2009. Researchers assess radionuclides in drinking water because ingestion pathway is major pathway through which a person can be exposed to radiation (WHO, 2011). Radionuclides in water and food can cause a greater health risk because the radiation is actually ingested which can damage internal tissue (Marianne, 2018). Data from University of Ilorin Teaching Hospital (UITH) shows that 74 different cancers of 2,246 (891 male and 1355 female) cancer patients within the age of 1-105 were recorded at the University of Ilorin Teaching Hospital (UITH) cancer registry between the period of 2007 and 2016 (Orosun *et al*., 2020c). Although record of cancer incidence in Ogbomoso was not available but the work of Abiodun *et al,* (2017) revealed the prevalence of cancer in Ogbomoso where the level of awareness and screening is low among patients attending the General Outpatient Clinic of Bowen University Teaching Hospital (BUTH), Ogbomoso. In view of this, the objective of this study is to use the activity concentration of radionuclides obtained from gamma spectrometry of the packaged drinking water to assess the radiological hazards in the water being sold in Ilorin and Ogbomoso. This was achieved by estimating the radiological impact parameters in order to know the level of radiological health imbalance due to the radioactive contaminant in the water.

MATERIALS AND METHODS

Ilorin: is the state capital of Kwara State in Nigeria and it is the 6th largest city by population. The city is located on the latitude of $8°30^{l}$ North and $4°33^{l}$ east of the equator and has an area of about $765Km^2$ landscape. One of the largest ethnic group in Nigeria (i.e. the Yoruba) found it and it has passed three stages of colonialism. Ilorin metropolis experience tropical wet-dry

climate, very hot during dry season from November to January while temperature ranges from 33℃ to 37℃ and the daily range of temperature during rainy season is 38℃. The soil characteristics in Ilorin depend largely on the nature of the parent material. The great variety of basement complex rocks gives rise to a large number of ferruginous group of soils (Orosun *et al*., 2020c). Thus, the main soil type in Ilorin is ferrallitic type usually deep red in color with high clay content. The availability, distribution and maintenance of various sources of water supply in Ilorin metropolis will further assist in decision-making process in packaged drinking water supply in Nigeria.

Ogbomosho: is a city in Oyo state, south- western Nigeria. It has a latitude of 8°08^{l} North and longitude of 4°16^{l} East on the Greenwich meridian. The major occupation of the people in the study area is farming and rearing of domestic animals like goats and sheep. The majority of the people are members of the Yoruba ethnic group. Notable agricultural products of the region are yam, cassava, maize and tobacco. The town lies in the transition zone forest of Ibadan (city capital of Oyo state) geographical region and the northern savannah region because of this; it is regarded as to be derived savannah vegetation. The area is seen as a low land forest with agricultural activities being the major activities carried on it. They experience two season (wet season and dry season) like most areas in the southern Nigeria i.e. wet seasons usually take place between the months of April and October, while dry seasons are experienced between the months of March and November. The rocks found in Ogbomosho are the pre Cambrian rocks that are typical for the basement complex of Nigeria. The rocks associated with the area form part of the Proterozoic schist belt of Nigeria, which are predominantly, develop in the western half of the country. The rock sequence composed of weathered quartzite and older granite.



Fige 1. Map of Nigeria showing the study areas

Forty samples were collected from ten brands (four from each brand) of packaged drinking water in Ilorin city of Kwara state and Ogbomosho south-west. The brand of water chosen in Ilorin were; UnilorinWA, panacheWA, dekuulWA, heritageWA and atinuolaWA water while those chosen in Ogbomosho are cornerstoneWA, mabsonWA, he-reignsWA, ireti-ogoWA and woodlandWA water. Four water sample per each brand was used for the analysis. The samples were prepared early in the morning so that certain properties of the sample such as the temperature cannot be alter by human activities (Ibironke *et al*., 2016). The temperature

was measured immediately using an infrared thermometer. The samples were then acidify with 11 M of HCl at rate of 10ml per liter and stored in a plastic container to avoid the adsorption of radionuclides on the walls of the container (Orosun *et al*., 2016b). These samples were then seal for 28 days before being analyze and stored in the environmental laboratory in the Pure and Applied Physics Department, LAUTECH, to ensure a state of secular equilibrium between uranium and thorium isotopes and their respective daughters before counted by gamma spectroscopy.

The simultaneous detection of several gamma emitter in the sample was carried out by using a lead shielded detector, which is used for the radioactivity measurement. The detector is a 5.1cm × 5.1 cm thalliated NaI detector coupled through coaxial cable to a multi-channel analyzer (MCA) of 4029 channels to determine gamma energies. The system has a resolution [Full Width at Half Maximum- FWHM] of 7.5% at 0.662Mev energy of ^{137}Cs, which is consider adequate to distinguish gamma energies of interest in the present study. Each sealed sample was placed on the lead shielded detector and counted for 36,000secs. Hence, the photons emitted by them would only be sufficiently discriminated if their emission probability and their energy were high enough, and the surrounding background continuum low enough. Therefore, the activity concentration of ^{214}Bi (determined from its 1.765MeV γ-ray peaks) were chosen to provide an estimate of ^{226}Ra (^{238}U) in the samples, while that of the daughter radionuclide ^{208}Tl (determined from its 2.615MeV γ-ray peak) was chosen as an indicator of ^{232}Th. ^{40}K was determined by measuring the 1.460 MeV γ-rays emitted during its decay. The net area under the corresponding peaks in the energy spectrum was computed by subtracting counts due to Compton scattering of higher peak and other background sources from the total area of the peaks.

The samples were placed symmetrically on top of scintillation detector, which scintillate by producing light (photon) when gamma ray from the sample falls on it. The photon produced corresponds to the energy of the gamma rays. The photon produced by the detector is low. Hence, it needs to be amplified. The amplifier connected to the photomultiplier tube (PMT) does the amplification. The amplified signal then goes to the multi-channel analyzer (MCA). The multi-channel analyzer is connected through RS232 to the computer for easy analysis.

The gamma spectrometry detector was calibrated before it was used for the analysis. This was done to ensure that the radiation parameters in the sample could be expressed in physical radiometric unit. This calibration was done in two stages. The stages are the energy calibration and efficiency calibration. The energy calibration converts channel numbers to gamma-ray energy in MeV. This was done by placing different gamma sources of known energy on the detector. These sources were used to perform the energy calibration. The mixed sources have energy spread between 0.3MeV and 4.092MeV, which was used to determine the energy-channel dependence of the system. After a certain preset counting time of about 100s, the channels of various photo-peaks corresponding to gamma energies were identified. Then the energy of each distinctive peak was entered into the computer software. The channel number associated with specific gamma energies is shown in Table 1.

The efficiency calibration of the system was to determine the gamma-ray counting efficiencies over the energy range 0.3Mev-4.092Mev. This was done by converting the count per seconds under the photo-peaks to the activity concentration (Bq/L) of the certified reference standard sample of same matrix as the water sample. The efficiency of the system was done for the energy peaks of interest [^{40}K-1.460Mev; ^{226}Ra (^{238}U)-1.765Mev; ^{208}Tl (^{232}Th)-2.615Mev] and with known activity concentration. The reference standard source was counted for 10hrs. The counting efficiency of each gamma energy was determine to have the values shown in the Table 2. After calibration, the analysis is done for 10hrs for each water

sample. The background count activity was measured by counting the same type of plastic container, which has no sample in it; this was counted for the same time as that of the water sample. The activity concentration for each of the radionuclides in the sample was calculated after subtracting decay correction by using the following expression (Avwiri, Ononugbo, and Nwokeoji, 2014):

$$A = \frac{N}{\epsilon_\gamma \rho_\gamma t_s V} \quad (1)$$

A = Activity concentration of a particular radionuclide in Bq/L, N= Net count in the corresponding photo-peaks i.e. [sample – background], ϵ_γ= Efficiency of the detector for a gamma energy of interest, ρ_γ= Gamma line abundance in radionuclide or gamma yield, t_s= Total counting time in seconds and V= Volume of water sample in (litre).

Table 1. Energy calibration for the system

Energy (MeV)	Radionuclide	Channel number
0.662	^{137}Cs	149
1.274	^{22}Na	382
1.460	^{40}K	465
1.765	^{214}Bi	563
2.615	^{208}Tl	817

Table 2. Efficiency calibration of the system

Energy (MeV)	Radionuclide	ρ_γ Gamma yield in %	$(N_{p)E}$ Count/second	ε_γ Detector efficiency
1.460	^{40}K	11	0.2317	0.440
1.765	^{214}Bi	16	0.2441	0.271
2.615	^{208}Tl	36	0.0101	0.141

Radiological impact parameters are parameters used to determine the level of radiation hazards or radiation risk that could be acquired from the exposure to the samples. The absorbed dose is the energy liberated by radiation within a sample and is measured in units known as Grays or Rad. A Gray is an energy liberation of 1 J/Kg of the sample. The absorbed dose rate D (nGyh^{-1}), due to activity concentration of ^{238}U, ^{232}Th and ^{40}K was calculated using:

$$D = (cuCU + cThCTh + ckCK)\ nGyh - 1 \quad (2)$$

where CU, CTh, CK are the radioactivity concentration in Bq/L and c_U, c_{Th}, and c_K are dose conversion factors which are 0.462, 0.604 and 0.0417 for ^{238}U, ^{232}Th and ^{40}K respectively The mean Absorbed Dose Rate for water is 57nGy/h (Orosun *et al*., 2020c, 2021a, 2021b; Avwiri *et al*, 2014; UNSCEAR, 2008).

The equivalent dose is when different form of ionizing radiation present in the same absorbed dose results into different biological effect. The effective dose equivalent is intended to reflect the total biological effect of a given exposure on a human. It is a weighted average if the individual doses to a number of important tissue (Orosun *et al*., 2018a; Robert, 2006). The annual effective dose rate for all the ingested radionuclides from water was calculated using:

$$AEDE_{Ingested} = \sum_i l_i \times 365 \times D_i \quad (3)$$

Where l_i is the daily intake of radionuclide (Bq/d) = (concentration of radionuclide in water in Bq/L) × (consumption rate of water or food in L/day) and the ingestion dose coefficient (dose

conversion factor) $D_{i\ for}$ all the members of the public for all ages is shown in Table 3 (UNSCEAR, 2000; ICRP, 2012). The annual effective dose resulting from the ingestion of water was estimated based on the assumption that a daily intake of water per person is 2 L/d for adults, 1 L/d for lower ages and 0.5 L/d for infants (WHO, 2011).

The dose conversion factor for ingested radionuclides of ^{40}K, ^{232}Th and ^{238}U respectively, corresponding with different age factors is given in the table below.

Table 3. Dose Conversion Factors {DCF} for ingestion of radionuclides for members of the public for different age's factors.

Radio Nuclides	$T_{1/2}$ (years)	DCF (Sv/Bq) for various age groups					
		Infants	1year	5years	10years	15years	Adults
^{40}K	$1.2x10^{9}$	5.2×10^{-8}	$4.2x10^{-8}$	$2.2x10^{-8}$	$1.3x10^{-8}$	$7.6x10^{-9}$	$6.2x10^{-9}$
^{232}Th	$1.405x10^{1}$	1.6×10^{-6}	$4.5x10^{-7}$	$3.5x10^{-7}$	$2.9x10^{-7}$	$2.5x10^{-7}$	$2.3x10^{-7}$
^{238}U	$4.468x10^{9}$	1.4×10^{-7}	$1.2x10^{-7}$	$8.0x10^{-8}$	$6.8x10^{-8}$	$6.7x10^{-8}$	$4.5x10^{-8}$

To estimate potential risk from long-term ingested natural radionuclides in water the lifetime excess cancer risk (ELCR) is used as an indicator of potential cancers occurring in a population. The excess lifetime cancer risk was calculated using (Orosun *et al*., 2018a; Avwiri, *et al.,* 2014):

$$ELCR = AEDE \times RF \times DL \quad (4)$$

Where, AEDE is the Annual Effective Dose Equivalent, DL is the average duration of life (estimated to be 70 years), and RF is the Risk Factor (Sv^{-1}), i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for public (Orosun *et al*., 2018a; Avwiri, *et al.,* 2014). Average value of ELCR is given as $0.2x10^{-3}$ (UNSCEAR 2000).

RESULTS AND DISCUSSIONS

The results of gamma ray spectrometry measurement of ^{238}U, ^{232}Th and ^{40}K in the selected packaged drinking water sample is presented in Table 4 and illustrated in Figure 2. The activity concentration of the non-series ^{40}K is found to be dominant over the activity concentration of ^{238}U and ^{232}Th as expected (Lorraine, 2013). The mean activity concentration of ^{238}U, ^{232}Th and ^{40}K in the selected packaged drinking water sample ranges from 0.07 Bq/L to 0.63 Bq/L, 0.06 Bq/L to 3.57 Bq/L and 2.17 Bq/L to 8.55 Bq/L-respectively. All the mean activity concentration of the ^{40}K and ^{238}U detected in the water sample were within the world safe limit, but the mean activity concentration of ^{232}Th detected in the water were found to be slightly above the corresponding world average in the sample W1, W4, W5,W6, W7 and W10.

The world average value for ^{40}K, ^{238}U and ^{232}Th are 10 Bq/L, 10 Bq/L and 1 Bq/L respectively (UNSCEAR, 2000). The temperature value ranged from 28.20^{0}C to 30.50^{0}C. All samples are within the range WHO standard of 39.7 ^{o}C. Knowledge about the distribution of these radionuclides present in natural materials helps one to assess any possible radiological health imbalance to human by the use of such materials. That is, the knowledge of radionuclide distribution levels in the environment is important in assessing the effects of radiation exposure due to natural and human-made sources.

The absorbed dose rate (D) for the selected packaged drinking water samples was calculated using equation 2 is presented in Table 5. The mean values ranged from 0.19 in water sample W3 to 2.71 nGy/h in sample W6 for the water samples. The mean Absorbed Dose Rate was found to be within the world average value of 57nGy/h in the selected packaged drinking water sample, and from the result, W3 has the lowest level of the mean absorbed dose rate (Avwiri *et al.,* 2012; UNSCEAR, 2000).

Table 4. Table showing the mean radionuclides concentration for each water sample and physico – chemical parameter

Water Samples	^{40}K	^{238}U	^{332}Th	Temp ^{0}C
W1 (UNILORINWA)	2.17	0.43	3.11	30.40±0.83
W2 (PANACHEWA)	3.40	0.58	0.09	29.80±0.95
W3 (DEKUULWA)	2.97	0.07	0.06	31.10±0.90
W4 (HERITAGEWA)	7.41	0.08	3.32	30.50±0.80
W5 (ATINUOLAWA)	5.36	0.53	2.43	30.10±0.85
W6 (CORNERSTONEWA)	7.92	0.61	3.48	29.50±0.95
W7 (MABSONWA)	6.89	0.06	3.57	29.30±0.95
W8 (HE REIGNSWA)	7.93	0.53	0.27	29.30±0.95
W9 (IRETI OGOWA)	8.55	0.63	0.06	28.20±0.90
W10 (WOODLANDWA)	6.93	0.08	1.94	27.50±0.92

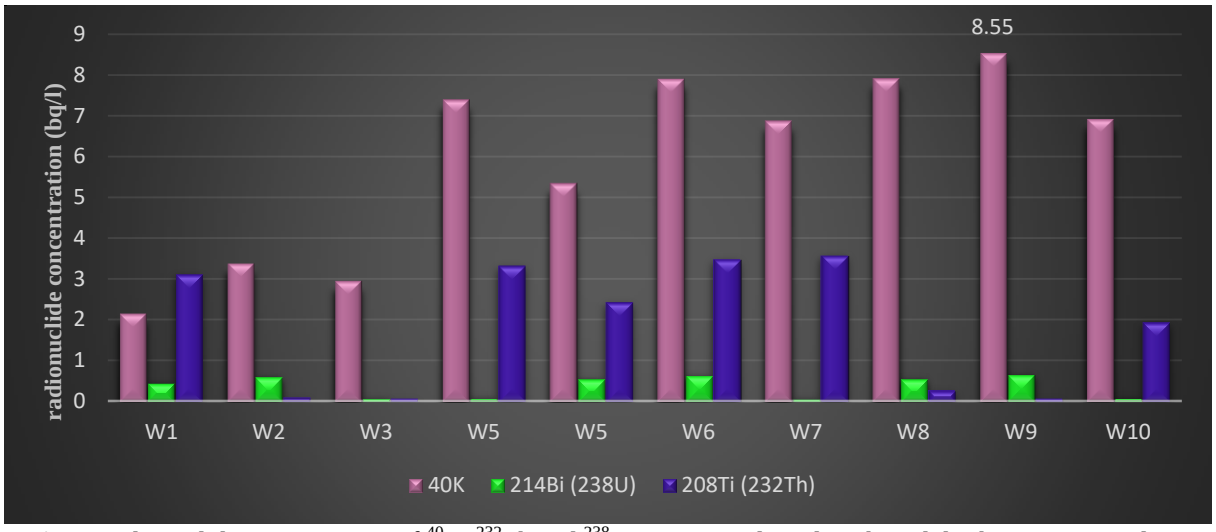


Fig 2. Radionuclide concentration of ^{40}K, ^{232}Th and ^{238}U in Some Selected Packaged drinking Water in Ilorin and Ogbomoso

Also, the mean annual effective dose equivalent {AEDE} of radionuclide ingested due to the consumption of the selected packaged drinking water in the study area was calculated using equation 3 and the results is presented in Table 6 and illustrated in Figure 3 – 15. W3 have the lowest effective dose of 0.048mSv/y, 0.059 mSv/y, 0.030mSv/y, 0.022mSv/y, 0.015mSv/y and 0.026mSv/y for infants, 1 year, 5 years, 10 years, 15 years and adult respectively while W6 has the highest effective dose of 1.107 mSv/y, 0.720 mSv/y, 0.530 mSv/y, 0.420 mSv/y, 0.350 mSv/y and 0.64 mSv/y. However, the average value of AEDE for the ingested radionuclide in the selected drinking water from the study area for different age groups of the general populace is found to be below the acceptable limits of 1 mSv/y except for the infant which is slightly above the world average of 1 mSv/y in W4, W6 and W7. Which implies that infants are more prone to been exposed to ionizing radiation hazard then the 1 year, the adults, the 5 years, the 10 years and the 15 years while consuming those water. Since all these estimated values were below the world average then, serious radiological effect may not result from consuming that drinking water (UNSCEAR, 2008).

Lastly, the excess lifetime cancer risk (ELCR) in (10^{-3}) due to ingestion of the radionuclide due to consumption of the water in the area was calculated using equation 4. The estimated mean value ranged from 0.09 (10^{-3}) in sample W3 to 2.24 (10^{-3}) in W6. This implies that the mean value for W2 and W3 are within the world average for the ELCR while W6, W7, W4, W1, W5, W10, W8 and W9 were above the average value of 0.2×10^{-3} as shown in Table 7 and Figure 13. W6 has the highest value and W3 has the lowest value. This indicates that the values will slightly lead

to respiratory diseases such as asthma and cancer and external diseases such as skin cancer and cataracts. ELCR for eight samples is slightly above the world average of 0.2×10^{-3} (UNSCEAR, 2000). This implies that the chances of having cancer over a lifetime considering seventy years as the average life span by the populace in general are significant.

Table 5. Mean values of D (nGy/h) and AEDE (mSv/y) for the water samples

Packaged Drinking Water Samples	D (nGy/h)	AEDE (mSv/y)
W1	2.17	0.550
W2	0.46	0.050
W3	0.19	0.026
W4	2.35	0.590
W5	1.94	0.450
W6	2.71	0.640
W7	2.47	0.630
W8	0.74	0.099
W9	0.68	0.070
W10	1.50	0.360

Table 6. Mean result for AEDE (mSv/y) for different age group

Water Samples	(AEDE mSv/y) for different age group					
	1nfant	**1 Year**	**5years**	**10years**	**15years**	**Adult**
W1	0.940	0.560	0.430	0.350	0.300	0.550
W2	0.073	0.092	0.020	0.040	0.032	0.050
W3	0.048	0.059	0.030	0.022	0.015	0.026
W4	1.040	0.660	0.490	0.390	0.330	0.590
W5	0.770	0.510	0.370	0.300	0.250	0.450
W6	1.107	0.720	0.530	0.420	0.350	0.640
W7	1.109	0.695	0.510	0.410	0.350	0.630
W8	0.168	0.190	0.110	0.079	0.060	0.099
W9	0.115	0.169	0.095	0.063	0.046	0.070
W10	0.630	0.430	0.310	0.240	0.198	0.360

Table 7. Mean result for Excess lifetime cancer risk

ELCR for the adults (since it is estimated to 70 years) ($\times10^{-3}$)	Packaged Drinking Water Samples									
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
	1.98	0.18	0.09	2.07	1.58	2.24	2.21	0.35	0.25	1.26

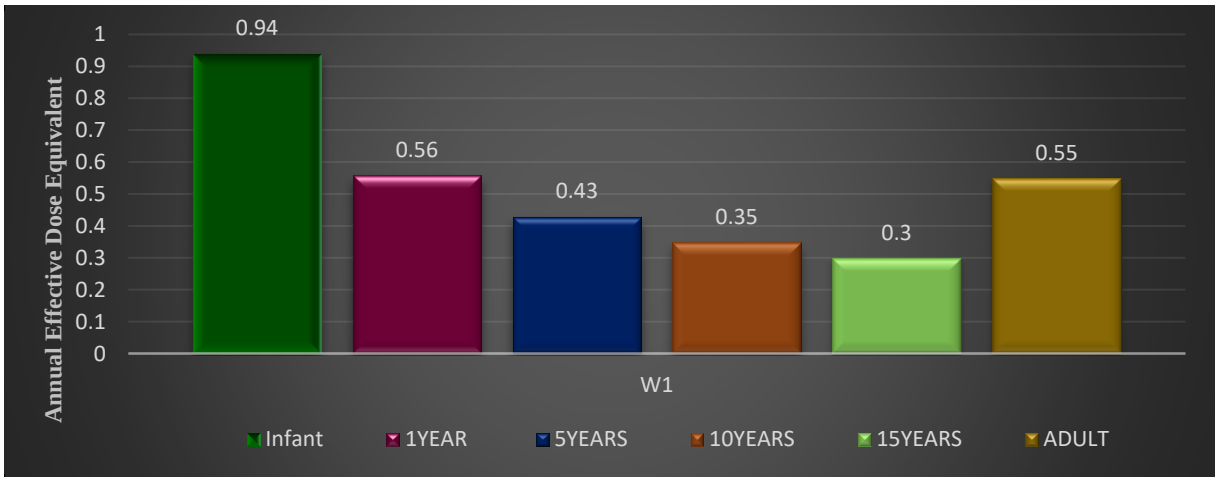


Fig 3. Mean AEDE (mSv/y) for different age group for the general populace in the study area in W1

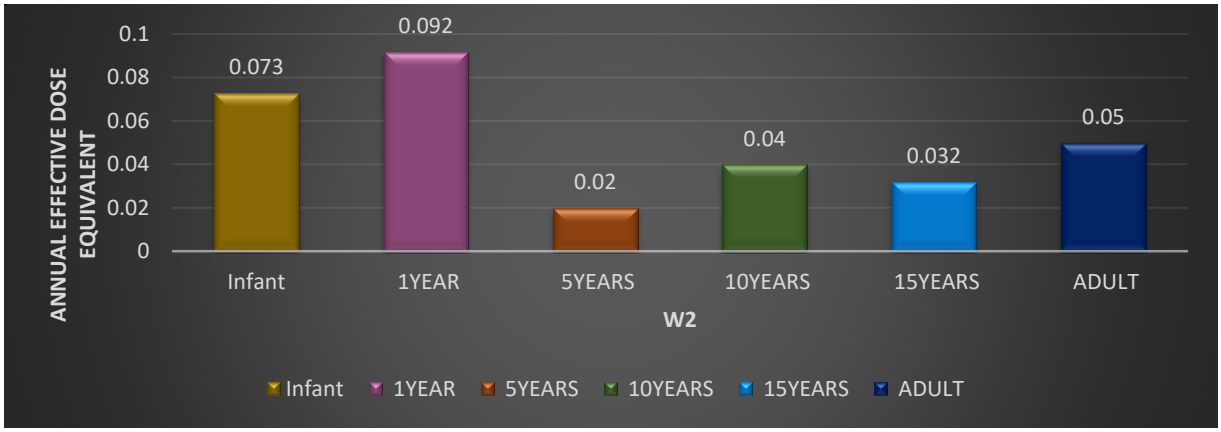


Fig 4. Mean AEDE (mSv/y) for different age group for the general populace in the study area in W2

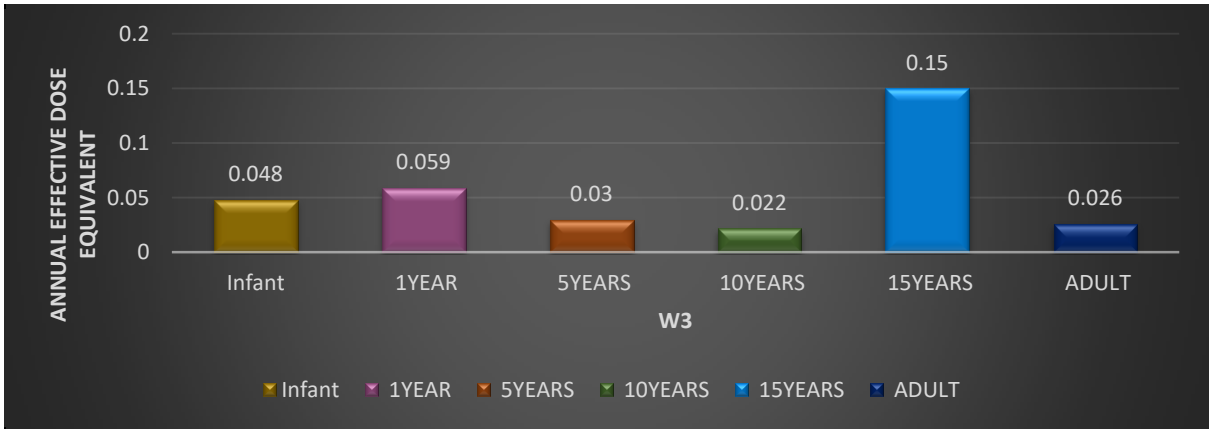


Fig 5. Mean AEDE (mSv/y) for different age group for the general populace in the study area in W3

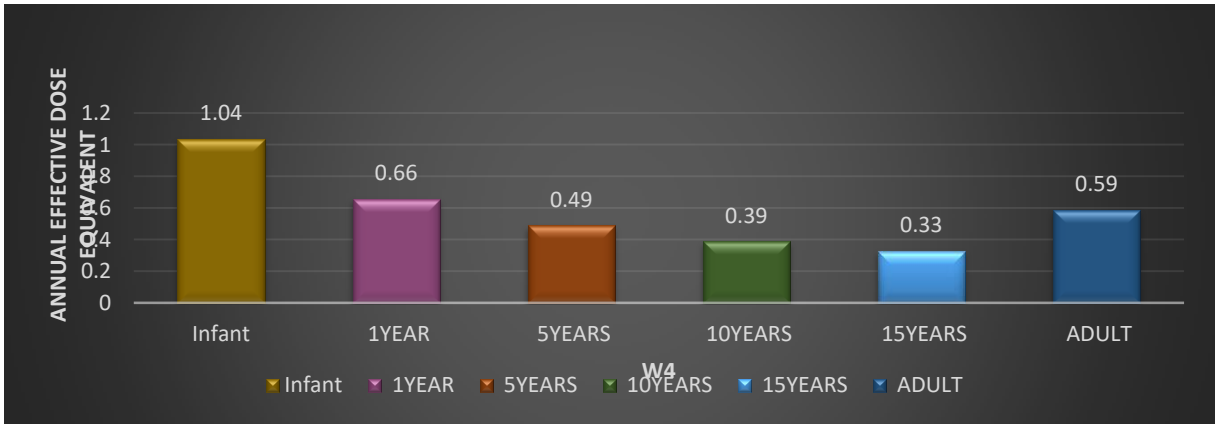


Fig 6. Mean AEDE (mSv/y) for different age group for the general populace in the study area in W4

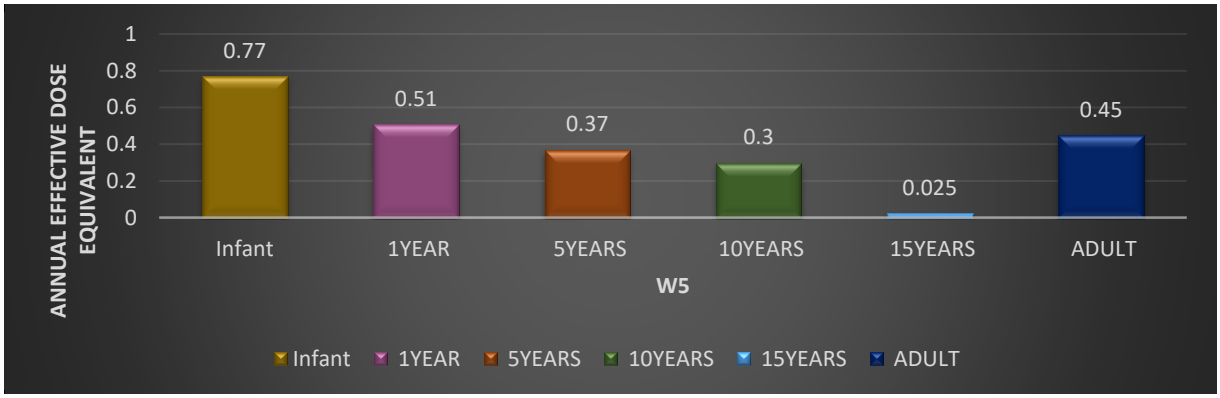


Fig 7. Mean AEDE (mSv/y) for different age group for the general populace in the study area in W5

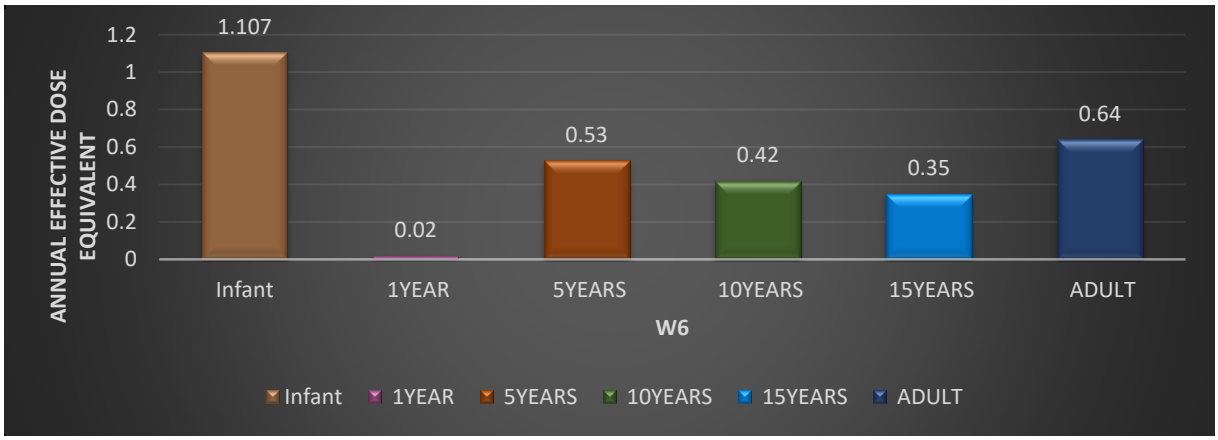


Fig 8. Mean AEDE (mSv/y) for different age group for the general populace in the study area in W6

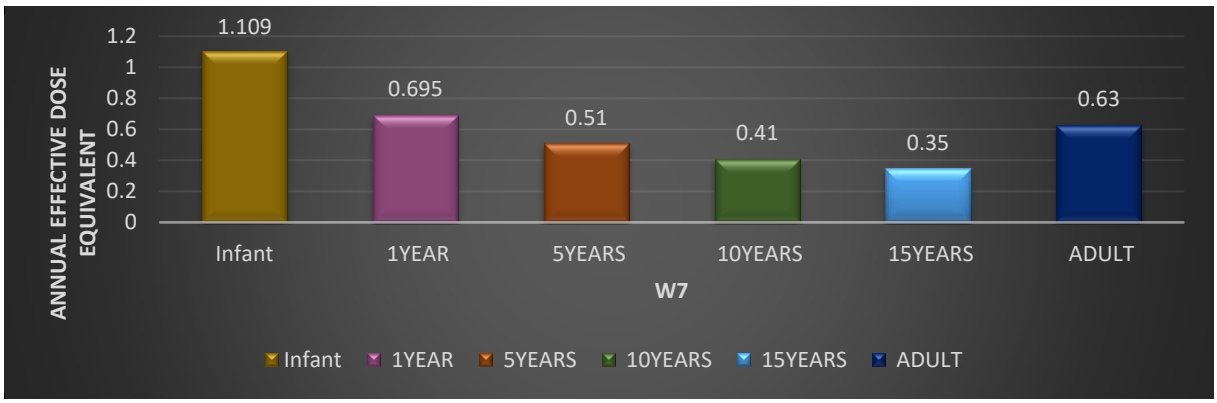


Fig 9. Mean AEDE (mSv/y) for different age group for the general populace in the study area in W7

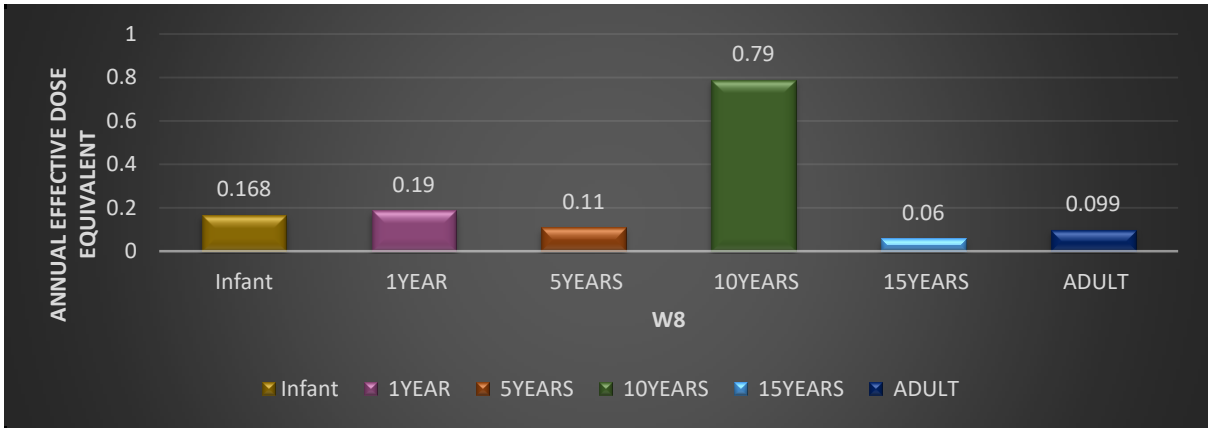


Fig 10. Mean AEDE (mSv/y) for different age group for the general populace in the study area in W8

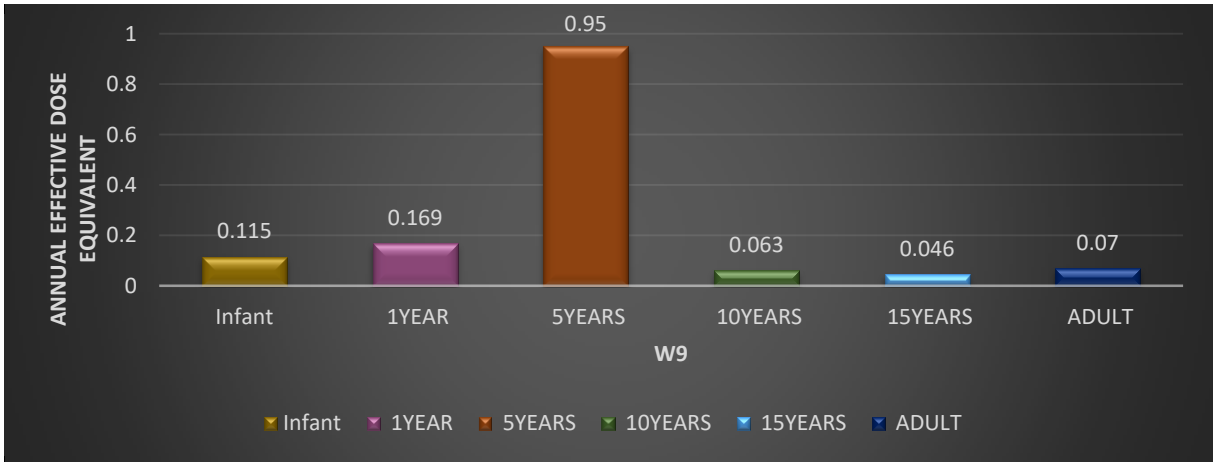


Fig 11. Mean AEDE (mSv/y) for different age group for the general populace in the study area in W9

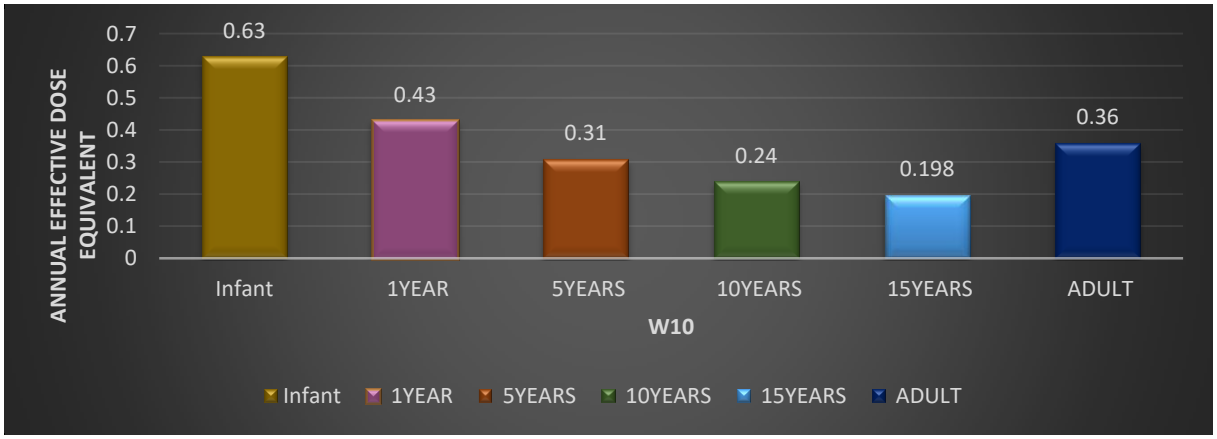


Fig 12. Mean AEDE (mSv/y) for different age group for the general populace in the study area in W10

Fig 13. Mean ELCR for adult in the selected packaged drinking water for the general populace in the study area

CONCLUSION

The radioactivity concentrations of the radionuclides ^{232}Th, ^{238}U, and, ^{40}K in some selected packaged drinking water samples from Ilorin city and Ogbomoso southwest were analyzed using Gamma-ray spectrometry. All the mean activity concentration of the ^{40}K and ^{238}U detected in the water sample were within the world safe limit, but the mean activity concentration of ^{232}Th detected in the water were found to be slightly above the corresponding world average in the sample W1, W4, W5, W6, W7 and W10 which can be due to the hydrogeological conditions of various groundwater region. The estimated radiological impact parameters has been conducted and the results show trends that are generally low for most of the radiological impact parameters estimated except for few indices whose values are above the world known standards.

Therefore, there may be no serious immediate radiological effects to the general populace in the study areas. It should be noted that for all the radiological health parameters estimated, W3 has the least value of the estimated parameters followed by W2, W9, W8, W10, W5, W1, W4, W6 and then W7 with highest value of the estimated parameters. It can therefore be deduced that the mean values for selected packaged drinking water consumed in Ogbomoso is higher than that of Ilorin city these can be due to hydrogeological conditions of various groundwater region or the kind of method adopted by each water manufacturing company because most companies in Nigeria are using filtration methods for treating raw water. So for this reason, it is safer to consume W3 in Ilorin and W9 in Ogbomoso since they has the least probability of causing any radiological health effect.

This work therefore, can be used as a baseline for future investigations that can be used for quality assurance/control of the analysis of natural radionuclides in drinking water samples, and for monitoring possible radioactivity pollution in the future.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent,

misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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