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Research Article

Determination of Annual Effective Dose of Radionuclides in Groundwater Consumed By Selected Age Groups in Veritas University and Its Environs

Ashia. G. Bijimi[1], Margaret A. Briggs-kamara[2] and Patrick O. Akusu[3]

[1,3]Department of Physics, Faculty of Natural and Applied Science,
Veritas University Abuja, FCT Abuja Nigeria.
[2]Department of Physics, Faculty of Science, Rivers State University,
Nkpolu-Oroworukwo; P.M.B 5080, Port Harcourt, Rivers State, Nigeria.
*** Corresponding Authors:** bijimig@veritas.edu.ng; briggs-kamara.margaret@ust.edu.ng

ABSTRACT

This study was carried out to determine the annual effective dose of radionuclides; Potassium (^{40}K), Uranium (^{232}U) and Thorium (^{232}Th) from the ingestion of groundwater in Veritas and its environs. Thirty (30) water samples were collected and analyzed by adding 1ml of nitric acid (HNO_3) to prevent adsorption of radionuclides to the container walls and kept for 30 days to attain secular equilibrium after which NaI detector was used to measure the activity concentration. Results showed that the estimated mean activity concentrations were 88.50±7.84Bq.l^{-1}, 9.28±1.71Bq.l^{-1} and 6.87±0.60Bq.l^{-1} for ^{40}K, ^{238}U and ^{232}Th respectively. The mean annual effective dose to children of ages 7-12 months, 1-3 years and 4-8 years are: 1.602±0.142mSvBq^{-1}, 1.764±0.156mSvBq^{-1}, and 1.153±0.101mSvBq^{-1}, respectively for ^{40}K; 0.379±0.070mSvBq^{-1}, 0.528±0.098mSvBq^{-1}, and 0.461±0.085mSvBq^{-1} respectively for ^{238}U and 9.223±0.812mSvBq^{-1}, 1.466±0.129mSvBq^{-1}, and1.491±0.131 mSvBq^{-1} respectively for ^{232}Th. The total annual effective doses (AED) and mean total AED to children of age 7-12 months, 1-3 years and 4-8 years was estimated. The results showed that the mean activity concentration of ^{40}K, ^{238}U and ^{232}Th (Bq.l^{-1}) in all the water samples exceeded the WHO and UNSCEAR recommended safe limits of 10.0, 10.0 and 0.10 respectively. The mean total annual effective dose (mSvyr^{-1}) of ^{40}K, ^{232}Th and ^{238}U for children within the ages of 7 months to 8 years also exceeded the WHO and UNSCEAR recommended safe limits of 0.26-1mSvyr^{-1}. Thus, the groundwater supplies under investigation have been found to be radiologically contaminated and unsafe for human consumption. It is hereby recommended that, Government, Non-Governmental Organizations and private individuals should provide alternate safe sources of water supply for residents of the study area as to protect public health and prevent any public health challenges.

Keywords: Radionuclides, groundwater, activity concentration, effective dose, age groups, public health.

Introduction

The human surroundings contain radioactive elements, which mean that humans are regularly exposed to radiation from various sources. These sources include cosmic rays, natural radioactive substances present in water, air, soil, and plants. Additionally, there are artificial sources of radiation, such as fallout from nuclear testing and medical applications. Radionuclides, including those from the ^{238}U and ^{232}Th series, as well as non-series ^{40}K, enter the groundwater system through the leaching of naturally occurring radionuclides in water-bearing rocks (Seddique *et al.*, 2020). However, anthropogenic activities such as the disposal of radioactive waste have also been identified as sources of groundwater contamination (Singhal and Gupta, 2010).

The concentrations of natural radionuclides in groundwater vary depending on the characteristics of the underlying soil or rock (Zlatić *et al.*, 2021). Basement and sedimentary aquifers are known to exhibit varying levels of radionuclide concentrations.

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The concentrations of radionuclides are also influenced by their residence time in an aquifer, their decay rates, and the rate of their exchange between the dissolved and solid phases (Vengosh *et a*l., 2022).

The consumption of natural radionuclides found in groundwater has been linked to various health risks. Radiation is a well-established cause of cancer and its carcinogenic effects are known in considerable detail; previous epidemiological research has primarily focused on high doses of external radiation. Auvinen *et al*. (2002) conducted a study investigating the connection between ingesting radionuclides through groundwater and the development of Leukemia. Similarly, Canu *et al*. (2011) discovered instances of abnormal renal biomarkers and cancer incidence resulting from the consumption of radionuclide-contaminated groundwater, although they recommended further research to substantiate their findings. The presence of renal biomarker anomalies has been associated with the potential accumulation of radionuclides in the kidneys, leading to adverse effects such as electrolyte excretion in urine (Bangotra *et al*., 2021). Additionally, the chemical toxicity of radionuclides in bones has been reported (Kaur and Mehra, 2018).

The discovery of radiation has brought dramatic advances in industry, agriculture and research. There is a need to identify the benefits and risks of radiation-related practices, make informed decisions about their use, and minimize the risks. Nevertheless, they can be harmful to the human body, which needs to be protected from unnecessary or excessive exposure.

Groundwater is a major source of drinking water for millions of people worldwide. The presence of natural radionuclides in groundwater is a major public health concern. Ingestion of water containing these radionuclides may lead to radiation exposure and increase the risk of cancer. There is a strong link between the intake of Naturally Occurring Radioactive Materials (NORMs) contaminated water and the development of life-threatening illnesses such as hereditary disorders, cancer, renal failure, sterility, brain tumor and decreased blood cell counts (Taskin *et al*., 2009). Before making claims about pollution, it is important to gather scientific data. Therefore, it is crucial to collect baseline data by evaluating the levels of radioactivity concentrations of radionuclides such as ^{40}K, ^{238}U, and ^{232}Th in water obtained from groundwater (boreholes). Additionally, it is essential to assess the potential health risks associated with the ingestion of natural radioactivity in groundwater in the specified study area. The obtained results will then help in formulating appropriate solutions. The lack of data on groundwater quality in the study area, particularly concerning radiological aspects, has also motivated this study. This study aims to provide valuable insights for strategic planning aimed at safeguarding the public from the detrimental effects of radiation stemming from the consumption of radionuclide-contaminated groundwater.

Materials and Methods

Materials used for this study

The materials used for this study comprises thirty (30) one-liter plastic jars with lids, plastic funnels, masking tape, a GPS reader, dilute HNO_3 acid, a large sack and borehole water samples.

Description of study area

The Veritas university and its environs where this study was carried out is located in Bwari Area Council of Abuja, the Federal Capital Territory of Nigeria and lies between latitudes 9° 15'N and 9° 18'N and longitudes 7° 19'E and 7° 25'E. It has a surface area of approximately 40km². The general elevation varies from 535m to 597m above mean sea level. The climate is characterized by a dry season (November to February) and a rainy season (April to October). Mean annual rainfall ranges from 1500 mm to 2099 mm. The mean annual temperature ranges from 27ºC to 30°C. The inhabitants of the study area depend mainly on groundwater (Boreholes) for domestic and industrial purposes. For the purpose of this study, the study area was divided into ten (10) locations designated; A, B, C, D, E, F, G, H, I, and J; with three (3) sub-sections in each location, designated; 1, 2, and 3.

Collection of groundwater (Borehole) samples

Groundwater samples were directly collected from 30 randomly chosen boreholes using plastic funnels into plastic jars with a capacity of one liter each. Immediately after collection, a small amount of dilute nitric acid (HNO_3) was added to the samples to prevent adsorption of radionuclides to the container walls, and the jars were tightly sealed with their respective labels before being placed inside a large bag. In order to reduce turbulence and radon loss, the method used by Sasser and Watson (1978) was used.

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Each sample was acidified using the method by Avwiri *et al*. (2007). To further ensure that there was no loss of radon and to achieve secular equilibrium between the daughter and parent nuclides the containers were sealed for 30 days. The collection of all the groundwater samples took place within a single day.

Analysis of Radionuclides in groundwater samples

Gamma Spectrometry Analyses, one of the applications of nuclear technology, was employed in the analysis of the radionuclides; Potassium (^{40}K), Uranium (^{232}U) and Thorium (^{232}Th) in groundwater samples, while a Sodium Iodide (NaI) doped detector was used to detect the presence of the radionuclides. The estimated annual effective dose and total annual effective dose of the radionuclides due to the ingestion of the water was also calculated using the recommended models and equations stated as follows;

The Annual Effective Dose (AED)

The annual effective dose (AED) ($mSvyr^{-1}$) from the radionuclides due to intake of water samples was calculated from the mean Activity Concentration of each natural radionuclide, using the formula (Agbalagba *et al*., 2013):

$$AED = IAC \times 365 \text{ ---------------------- } (1)$$

where: I is the Daily water consumption (in Ld^{-1})
A is the Activity Concentration (BqL^{-1}) of the radionuclide in the water sample.
$C$is the Dose conversion factor ($mSvBq^{-1}$) which varies with age of individuals and the radionuclide present in the water sample. Its values were extracted from (ICRP, 2012; ICRP, 1997; IAEA, 2003; US EPA, 2000).

Total Annual Effective Dose (TAED)

The total annual effective dose, TAED (in $mSvy^{-1}$) to an individual due to ingestion of water samples was obtained by adding contributions of the three radionuclides (^{40}K, ^{238}U and ^{232}Th) present in the water samples using the formula by: (Ajayi and Adesida, 2009; Ononugbo and Anyalebechi, 2017)

$$TAED\ (mSvy^{-1}) = \sum \quad A_C I_A C_F \text{ ------------------- } (2)$$

where:
A_C is the Activity concentration ($BqL{-}1$) of the radionuclide in the water sample.
I_A is the Daily water consumption ($Ld{-}1$).
C_F is the Dose conversion factor ($mSvBq{-}1$)
The age groups were: children (7-12months, 1-3years and 4– 8years).

Results

The results of the activity concentrations in Bq.l^{-1} for ^{40}K, ^{238}U and ^{232}Th are presented in Table 1. The values of the dose conversion factors in mSvBq.l^{-1}, the ingestion rate for the age range under consideration were extracted from (ICRP publication 67, 1993; Saidou et al 2019). The annual effective dose in mSvBq.l^{-1}, are presented in Table 2 for ^{40}K, ^{238}U and ^{232}Th. The Total AEDs are presented in Table 3 for ^{40}K, ^{238}U and ^{232}Th. Figure 1 showed the Total AED received by children of ages 7-12 months, 1-3years and 4-8years from ^{40}K. Figure 2 showed the Total AED received by children of ages 7-12 months, 1-3years and 4-8years from ^{238}U. Figure 3 showed the Total AED received by children of ages 7-12 months, 1-3years and 4-8years from ^{232}Th.

The results presented in Table 1 shows that the activity concentration for K-40 ranged from 7.00 to 174.62Bq.l^{-1}, with mean activity concentration of 88.50±7.84Bq.l^{-1}. The highest activity concentration was recorded in water samples collected from E1 and least value from C1. The Activity of U-238 ranged from 0.89 to 31.61 Bq.l-1, with a mean value of 9.28±1.71Bq.l-1. The highest activity concentration was recorded in water samples collected from A2 and least value from B3. The Activity of Th-232 ranged from 0.24-15.22Bq.l-1, with a mean value of 6.87±0.60Bq.l-1. The highest activity concentration was recorded in water samples collected from F2 and least value from J1. Results in Table 2 indicated that the annual effective dose of ^{40}K ranged from 0-3.161 with mean value 1.602±0.142 in children 7-12months; 0-3.480 with mean value 1.764±0.156 in children 1-3years and 0-2.27 with mean value 1.153±0.101 in children 4-8years. The annual effective dose of ^{238}U ranged from 0-1.292 with mean value 0.379±0.070 in children 7-12months; 0-1.799 with mean value 0.528±0.098 in children 1-3years and 0-1.569 with mean value 0.461±0.085 in children 4-8years. The annual effective dose of ^{232}Th ranged from 0-20.444 with mean value 9.223±0.812 in children 7-12months; 0-13.249 with mean value 1.466±0.129 in children 1-3years and 0-3.305 with mean value 1.491±0.131 in children 4-8years.

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Table 1: Activity concentration of Radionuclide in groundwater samples in Veritas University and environs

Groundwater Sample Location	Activity concentration of Radionuclide (Bql^{-1})		
	Potassium (^{40}K)	Uranium (^{232}U)	Thorium (^{232}Th)
A1	47.28±4.52	18.66±3.01	8.25±0.71
A2	45.78±4.48	31.61±5.12	BDL±BDL
A3	151.60±12.61	3.31±0.88	6.60±0.61
B1	73.30±6.55	BDL±BDL	7.65±0.67
B2	82.30±7.58	13.48±2.82	6.04±0.57
B3	157.85±12.97	0.89±0.24	9.22±0.83
C1	7.00 ± 0.73	7.23±1.32	6.32±0.52
C2	74.55 ± 7.47	BDL±BDL	5.79±0.55
C3	102.07±9.15	17.23 ± 2.91	9.02±0.76
D1	157.35±11.88	5.81±1.15	10.51±0.95
D2	109.32±9.83	BDL±BDL	BDL±BDL
D3	BDL±BDL	BDL±BDL	10.75±0.89
E1	174.62±14.45	BDL±BDL	8.57±0.79
E2	75.55±6.63	6.43±1.15	8.73±0.77
E3	134.59±11.87	11.43±2.22	6.12±0.57
F1	90.56±8.84	22.95±3.83	3.75±0.36
F2	61.54±5.86	2.50±0.58	15.22±1.18
F3	93.56±8.09	2.86±0.82	4.55±0.42
G1	19.76±2.06	11.07±2.36	10.59±0.92
G2	104.32±9.57	11.07±2.95	5.47±0.54
G3	25.01±2.21	15.89±3.01	9.86±0.84
H1	41.52±4.04	BDL±BDL	4.51±0.43
H2	BDL±BDL	BDL±BDL	11.79±0.99
H3	75.55±7.17	31.35±4.98	10.71±0.98
I1	142.85±10.92	8.03±1.77	1.01±0.11
I2	149.01±13.77	BDL±BDL	12.68±1.07
I3	74.05±7.53	21.61±4.35	BDL±BDL
J1	71.55±6.85	4.19±0.85	0.24±0.02
J2	146.85±12.53	4.46±0.97	9.30±0.82
J3	165.61±14.41	26.34±4.20	2.74±0.27
Range	7.00-174.62	0.89-31.61	0.24-15.22
Mean	88.50±7.84	9.28±1.71	6.87±0.60

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Table 2: Estimated values of annual effective dose (*mSv Bq* $^{-1}$) for radionuclides (^{40}K, ^{232}U, and ^{232}Th) in groundwater samples for different age groups

Water sample location	Radionuclide and Age Groups								
	Potassium (^{40}K)			Uranium (^{232}U)			Thorium (^{232}Th)		
	7-12 Months	1-3 Years	4-8 Years	7-12 Months	1-3 Years	4-8 Years	7-12 Months	1-3 Years	4-8 Years
A1	0.856±0.082	0.942±0.090	0.616±0.059	0.763±0.123	1.063±0.171	0.926±0.149	11.081±0.954	1.762±0.152	1.792±0.154
A2	0.829±0.081	0.912±0.089	0.597±0.058	1.292±0.209	1.799±0.292	1.569±0.254	0±0	0±0	0±0
A3	2.745±0.228	3.021±0.251	1.975±0.164	0.135±0.036	0.189±0.050	0.164±0.044	8.865±0.819	1.409±0.130	1.433±0.133
B1	1.327±0.119	1.461±0.131	0.955±0.085	0±0	0±0	0±0	10.275±0.899	1.634±0.143	1.661±0.146
B2	1.489±0.137	1.640±0.151	1.072±0.099	0.551±0.115	0.768±0.161	0.669±0.139	8.113±0.766	1.289±0.122	1.312±0.124
B3	2.858±0.235	3.146±0.258	2.057±0.169	0.036±0.098	0.051±0.013	0.044±0.012	12.384±1.115	1.969±0.177	2.002±0.180
C1	0.127±0.013	0.139±0.015	0.091±0.009	0.296±0.054	0.412±0.075	0.359±0.066	8.489±0.699	1.349±0.111	1.373±0.113
C2	1.349±0.013	1.486±0.149	0.971±0.097	0±0	0±0	0±0	7.777±0.739	1.236±0.117	1.257±0.119
C3	1.848±0.166	2.034±0.182	1.330±0.119	0.704±0.119	0.981±0.166	0.855±0.145	12.116±1.021	1.926±0.162	1.959±0.165
D1	2.849±0.215	3.136±0.237	2.050±0.155	0.238±0.047	0.331±0.066	0.288±0.057	14.117±1.276	2.244±0.203	2.283±0.206
D2	1.979±0.178	2.179±0.196	1.425±0.128	0±0	0±0	0±0	0±0	0±0	0±0
D3	0±0	0±0	0±0	0±0	0±0	0±0	14.439±1.196	2.295±0.190	2.335±0.193
E1	3.161±0.262	3.480±0.288	2.275±0.188	0±0	0±0	0±0	11.511±1.061	1.829±0.169	1.861±0.172
E2	1.368±0.120	1.506±0.132	0.985±0.086	0.263±0.047	0.366±0.066	0.319±0.057	11.726±1.034	1.864±0.164	1.896±0.167
E3	2.437±0.215	2.682±0.237	1.754±0.155	0.467±0.091	0.651±0.126	0.567±0.110	8.220±0.766	1.307±0.122	1.329±0.124
F1	1.639±0.160	1.805±0.176	1.180±0.115	0.938±0.157	1.307±0.216	1.139±0.190	5.037±0.484	0.801±0.077	0.814±0.078
F2	1.114±0.106	1.226±0.117	0.802±0.076	0.102±0.024	0.142±0.033	0.124±0.029	20.444±1.585	3.249±0.252	3.305±0.256
F3	1.694±0.147	1.865±0.117	1.219±0.027	0.117±0.033	0.163±0.047	0.142±0.041	6.112±0.564	0.972±0.089	0.988±0.091
G1	0.358±0.037	0.394±0.041	0.258±0.027	0.453±0.097	0.630±0.134	0.549±0.117	14.225±1.236	2.261±0.196	2.299±0.199
G2	1.889±0.173	2.079±0.191	1.359±0.125	0.453±0.121	0.630±0.168	0.549±0.146	7.347±0.725	1.168±0.115	1.188±0.117
G3	0.453±0.040	0.498±0.044	0.326±0.029	0.649±0.123	0.905±0.171	0.789±0.146	13.244±1.128	2.105±0.179	2.141±0.182
H1	0.752±0.073	0.828±0.081	0.541±0.053	0±0	0±0	0±0	6.058±0.578	0.963±0.092	0.979±0.093
H2	0±0	0±0	0±0	0±0	0±0	0±0	15.836±1.329	2.518±0.211	2.561±0.215
H3	1.368±0.129	1.506±0.143	0.985±0.093	1.282±0.204	1.785±0.284	1.556±0.247	14.386±1.316	2.287±0.209	2.326±0.213
I1	2.586±0.198	2.847±0.218	1.861±0.142	0.328±0.072	0.457±0.101	0.399±0.088	1.357±0.148	0.216±0.023	0.219±0.024
I2	2.698±0.249	2.969±0.274	1.942±0.179	0±0	0±0	0±0	17.032±1.437	2.708±0.229	2.754±0.232
I3	1.341±0.136	1.476±0.150	0.965±0.098	0.883±0.178	1.231±0.248	1.073±0.216	0±0	0±0	0±0
J1	1.295±0.124	1.426±0.137	0.932±0.089	0.171±0.035	0.239±0.048	0.208±0.043	0.322±0.027	0.051±0.004	0.0521±0.004
J2	2.659±0.227	2.927±0.249	1.914±0.163	0.182±0.039	0.254±0.055	0.221±0.048	12.492±1.101	1.986±0.175	2.019±0.178
J3	2.998±0.261	3.300±0.287	2.158±0.188	1.077±0.172	1.499±0.239	1.308±0.208	3.680±0.363	0.585±0.058	0.595±0.059
mean	1.602±0.142	1.764±0.156	1.153±0.101	0.379±0.070	0.528±0.098	0.461±0.085	9.223±0.812	1.466±0.129	1.491±0.131

Table 3: Total Annual Effective Dose of Radionuclides (mSvyr^{-1}) (^{40}K, ^{232}U, and ^{232}Th) in groundwater samples received by the different age groups

Water sample location	Radionuclide and Age Groups								
	Potassium (^{40}K)			Uranium (^{232}U)			Thorium (^{232}Th)		
	7-12 Months	1-3 Years	4-8 Years	7-12 Months	1-3 Years	4-8 Years	7-12 Months	1-3 Years	4-8 Years
A	4.43±0.391	4.875± 0.43	3.188± 0.281	2.19±0.368	3.051±0.513	2.659±0.447	19.946±1.773	3.171± 0.282	3.225± 0.287
B	5.674± 0.491	6.247± 0.54	4.084± 0.353	0.587± 0.213	0.819± 0.174	0.713± 0.151	30.772±2.78	4.892± 0.442	4.975± 0.45
C	3.324± 0.192	3.659± 0.346	2.392± 0.225	1±0.173	1.393± 0.241	1.214± 0.211	28.382±2.459	4.511± 0.39	4.589± 0.397
D	4.828± 0.393	5.315± 0.433	3.475± 0.283	0.238± 0.047	0.331± 0.066	0.288± 0.057	28.556±2.472	4.539± 0.19	4.618± 0.399
E	6.966± 0.597	7.668± 0.657	5.014± 0.429	0.73±0.138	1.017± 0.192	0.886± 0.167	31.457±2.861	5±0.455	5.086± 0.463
F	4.447± 0.413	4.896± 0.41	3.201± 0.218	1.157± 0.214	1.612± 0.296	1.405± 0.26	31.593±2.633	5.022± 0.418	5.107± 0.425
G	2.7±0.25	2.971± 0.276	1.943± 0.181	1.555± 0.341	2.165± 0.473	1.887± 0.409	34.816±3.089	5.534± 0.49	5.628± 0.498
H	2.12±0.202	2.334± 0.224	1.526± 0.146	1.282± 0.204	1.785± 0.284	1.556± 0.247	36.28± 3.223	5.768± 0.512	5.866± 0.521
I	6.625± 0.583	7.292± 0.642	4.768±0.419	1.211± 0.25	1.688± 0.349	1.472± 0.304	18.389±1.585	2.924± 0.252	2.973± 0.256
J	6.952± 0.612	7.653± 0.673	5.004± 0.44	1.43± 0.246	1.992± 0.342	1.737± 0.299	16.494±1.491	2.622± 0.237	2.666± 0.241
Mean	4.807±0.412	5.291±0.463	3.459±0.298	1.065±0.219	1.585±0.293	1.382±0.255	27.659±2.437	4.398±0.367	4.473±0.394

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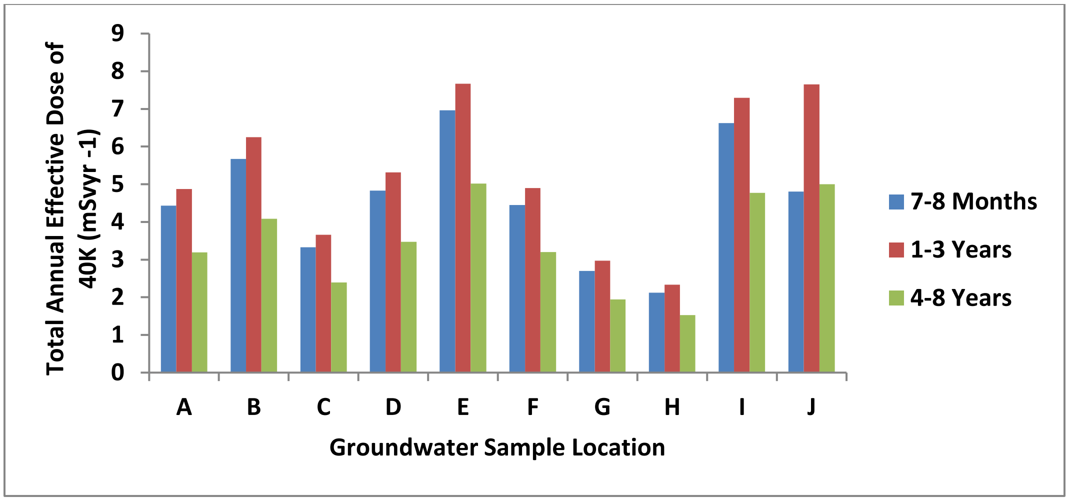

Fig 1: Total Annual Effective Dose of ^{40}K (mSvyr^{-1}) received by the different age groups

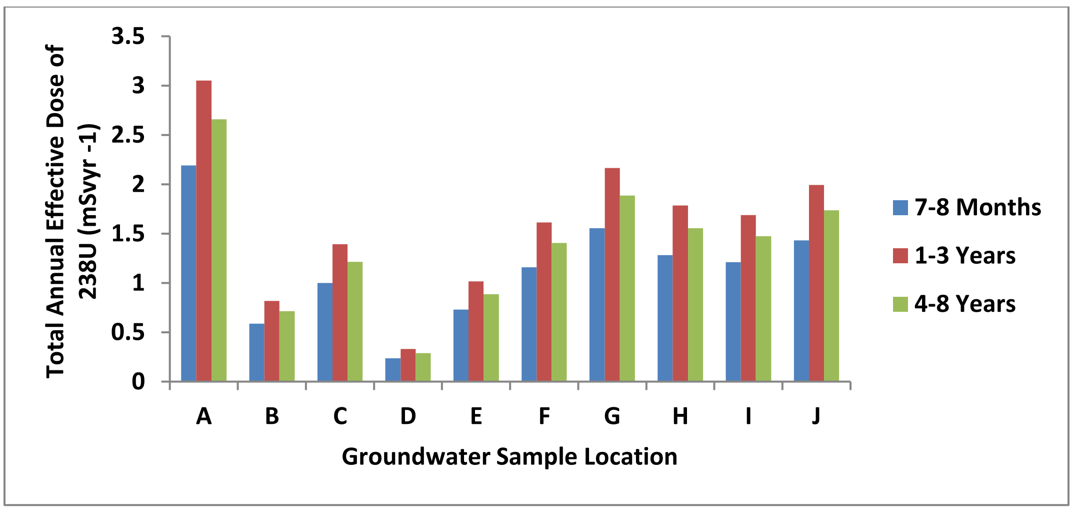

Fig 2: Total Annual Effective Dose of ^{238}U (mSvyr^{-1}) received by the different age groups

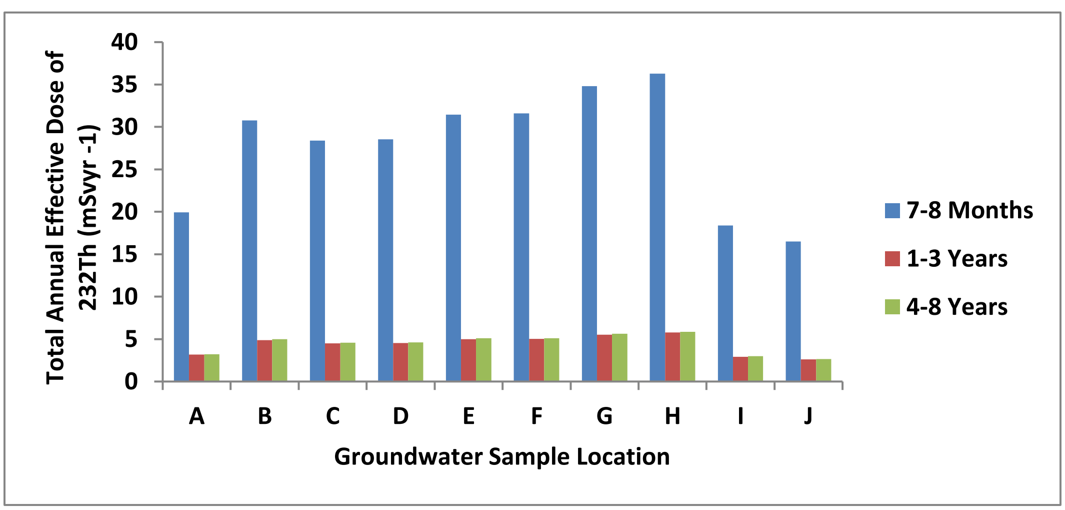

Fig 3: Total Annual Effective Dose of ^{232}Th (mSvyr^{-1}) received by the different age groups

Discussion

This present study has revealed the activity concentration and the total annual effective dose of radionuclides; Potassium (^{40}K), Uranium (^{232}U) and Thorium (^{232}Th) in groundwater in Veritas University and its environs. The results presented in Table 1 showed the activity concentration for ^{40}K ranged from 7.00 to 174.62Bq.l^{-1}, with mean activity concentration of 88.50±7.84Bq.l^{-1}. The highest activity concentration was recorded in water samples collected from E1 and least value from C1. This high activity concentration of ^{40}K in the study area in some of the water samples collected from the study area may have been from its predominance as the naturally occurring radionuclide largely present in the earth's crust (ICRP, 1984). This could also as be due to the use of N-P-K fertilizer in plant cultivation. The fast movement of surface water, which can carry potassium to different areas, could be the cause of the low activity concentration of ^{40}K in some of the locatios. The Activity of ^{238}U ranged from 0.89 to 31.61 Bq.l^{-1}, with a mean value of 9.28±1.71Bq.l^{-1}. The highest activity concentration was recorded in water samples collected from A2 and least value from B3. The Activity of ^{232}Th ranged from 0.24-15.22Bq.l^{-1}, with a mean value of 6.87±0.60Bq.l^{-1}. The highest activity concentration was recorded in water samples collected from F2 and least value from J1.These variations are attributable to the different activities and geology of the area. The mean activity concentration of ^{238}U was observed to be relatively higher than that of ^{232}Th. This might be due to the presence of Uranium source rocks leaching into groundwater in the study area and because ^{238}U is more mobile than ^{232}Th (Tchokossa et al., 2011). As revealed by the water sample analysis, ^{40}K had the highest activity concentration, followed by ^{238}U and then ^{232}Th contributing the least. The mean activity concentration for ^{40}K and ^{232}Th from the thirty sampled (30) locations exceeded the WHO and UNSCEAR recommended safe limit of 10.0 Bq.l^{-1} and 0.10 Bq.l^{-1} respectively while that of ^{238}U is below the recommended safe limit of 10.0 Bq.l^{-1} (WHO 2008).

The annual effective doses (mSvy^{-1}) of ^{40}K, ^{238}U and ^{232}Th in the water samples were calculated using eq. (1) with the activity concentration of the radionuclides presented in Table 1. The dose conversion factor for the children within the ages of 7-12months, 1-3years and 4-8years was obtained from: (ICRP publication 67, 1993; IAEA, 2003; US EPA, 2000; ICRP, 2012). Results in Table 2 indicated that the annual effective dose of ^{40}K ranged from 0-3.161 with mean value 1.602±0.142 in children 7-12months; 0-3.480 with mean value 1.764±0.156 in children 1-3years and 0-2.27 with mean value 1.153±0.101 in children 4-8years. The annual effective dose of ^{238}U ranged from 0-1.292 with mean value 0.379±0.070 in children 7-12months; 0-1.799 with mean value 0.528±0.098 in children 1-3years and 0-1.569 with mean value 0.461±0.085 in children 4-8years. The annual effective dose of ^{232}Th ranged from 0-20.444 with mean value 9.223±0.812 in children 7-12months; 0-13.249 with mean value 1.466±0.129 in children 1-3years and 0-3.305 with mean value 1.491±0.131 in children 4-8years. The high effective dose of ^{40}K, ^{238}U and ^{232}Th in the children population under consideration in the study area were recorded in samples of location E1, A2 and F3 respectively. The mean annual effective dose (mSvy^{-1}) of ^{40}K, ^{238}U and ^{232}Th are all above the WHO and UNSCEAR recommended safe limits of 0.12, 0.17 and 0.17 respectively.

The calculation of the total annual effective dose (TAED) of ^{40}K, ^{238}U and ^{232}Th was carried out using eq. (2). The annual effective doses of all the three radionuclides in the water samples were added. The total annual effective doses (mSvy^{-1}) of ^{40}K due to ingestion of the water samples ranged from 2.12±0.202 to 6.966±0.597, with mean value 4.807±0.412 for ages 7-12months; 2.334±0.224 to 7.668±0.657, with mean value 5.291±0.463 for ages 1.3years and 1.526±0.146 to 5.014±0.429, with mean value 3.459±0.298 for ages 4-8years. The total annual effective doses (mSvy^{-1}) of ^{238}U due to ingestion of the water samples ranged from 0.238±0.047 to 2.19±0.368, with mean value 1.065±0.219 for ages 7-12months; 0.331±0.066 to 3.051±0.513, with mean value 1.585±0.293 for ages 1.3years and 0.288±0.057 to 2.659±0.447, with mean value 1.382±0.255 for ages 4-8years. The total annual effective doses (mSvy^{-1}) of ^{232}Th due to ingestion of the water samples ranged from 16.491±1.491 to 36.28±3.223, with mean value 27.659±2.437 for ages 7-12months, 2.622±0.237 to 5.768±0.512, with mean value 4.398±0.367 for ages 1.3years and 2.666±0.241 to 5.866±0.521, with mean value 4.473±0.394 for ages 4-8years. Figures 1, 2 and 3 showed the obtained results. The highest total annual effective dose for ^{40}K, were recorded in children ages 1-3 years in location E, for ^{238}U, children ages 1-3 in location A and for ^{232}Th, children ages 7-12 months in location H while the lowest were recorded for ^{40}K in location H by children ages 7-12 months, for ^{238}U, location D, ages 7-12 months and for ^{232}Th, location J for ages 1-3 years.

Comparing the obtained result to the recommended safe limits by WHO (2008) and UNSCEAR (2000), it is revealed that the mean total annual effective dose of the radionuclides in children of the ages under consideration are above the WHO and UNSCEAR recommended safe limit of 0.26-1mSvyr^{-1} (WHO, 2017; WHO, 2008; WHO, 2005; UNSCEAR, 2008). By this finding, the water sample under investigation is radiologically polluted and unsafe for domestic uses.

In conclusion, the results obtained from this research showed that all the radiological parameters determined from the water samples in the area under investigation for children of ages 7months to 8 years are above the WHO and UNSCEAR recommended safe limits. The groundwater supplies in this area are found to be radiologically contaminated and harmful for human consumption, especially among the ages considered in this study.

Thus, it is hereby recommended that, Government, Non-Governmental Organizations and private individuals should provide alternate safe sources of water supply for residents of the study area as to protect public health and prevent any public health challenges.

Furthermore, research studies on the effective dose in teenage and adult populations of the study area should be carried out.

References

Aahraf Ali Seddique, Gui-Yao Xiong, Guang-Quan Chen, Xing-Yong Xu, Wen-Quan Liu, Teng-Fei Fu, Somkiat Khokiattiwong, Narumol Kornkanitnan, Xue-Fa Shi, Sheng-Fa Liu, Qiao Su, and Xiu-Li Xu, A. (2020). Comparative study on hydrochemical evolution and quality of groundwater in coastal areas of Thailand and Bangladesh. *Journal of Asian Earth Sciences. 195*: 104336.

Agbalagba, E.O; Avwiri, G.O. and Ononugbo, C.P. (2013). Activity Concentration and Radiological Impact Assessment of 226Ra, 232Th and 40K in Drinking Water from (OML) 30, 58 and 61 Oil Fields and Host Communities in Niger Delta Region of Nigeria". *Journal of Environmental Radioactivity. 116*: 197-200.

Ajayi, O. S and Adesida, G. (2009). Radioactivity in Some Sachet Drinking Water Samples Produced in Nigeria. *Iran. Journal of Radiation Research. 7(3):* 151-158.

Avwiri, G. O., Tchokossa, P., and Mokobia, C. E. (2007). Natural radionuclides in borehole water in Port Harcourt, rivers state, Nigeria. *Radiation Protection Dosimetry. 123(4)*: 509-514.

Bangotra, P., Sharma, M., Mehra, R., Jakhu, R., Singh, A., Gautam, A. S., and Gautam, S. (2021). A systematic study of uranium retention in human organs and quantification of radiological and chemical doses from uranium ingestion. *Environmental Technology and Innovation. 21*: 101360.

Canu, I. G., Laurent, O., Pires, N., Laurier, D., & Dublineau, I. (2011). Health effects of naturally radioactive water ingestion: the need for enhanced studies. *Environmental health perspectives. 119(12)*: 1676-1680.

International Atomic Energy Agency (IAEA). (2003). International Basic Safety Standards for Protection Against Ionizing Radiation and For the Safety of Radiation Sources. *Safety Series Number115*: *IAEA* Vienna.

International Commission on Radiological Protection, ICRP. (2012). *Compendium of Dose Coefficients Based on ICRP Publications. 119. 42*: 71-86.

International Commission on Radiological Protection, ICRP, 1993. Age-dependent Doses to members of the public from intake of Radionuclides-part 2 ingestion Dose Coefficients. *ICRP Publication 67. Ann. ICRP 23 (3-4).*

International Commission on Radiological Protection, (ICRP). (1997). Individual Monitoring For Internal Exposure of Workers. *78 : ICRP Publication.*

International Commission on Radiological Protection (ICRP). (1984). *Principles For Limiting Exposure of the Public to Natural Sources of Radiation. 14 (1)*:1-17.

Kaur, M., Kumar, A., Mehra, R., and Mishra, R. (2018). Human health risk assessment from exposure of heavy metals in soil samples of Jammu district of Jammu and Kashmir, India. Arabian Journal of Geosciences, 11, 1-15.

Citation: Bijimi *et al*. (2023). Determination of annual effective dose of radionuclides in groundwater consumed by selected age groups in Veritas University and its environs. *International Journal of Microbiology and Applied Sciences*. *2*: 47 - 56.

Kurttio, P., Auvinen, A., Salonen, L., Saha, H., Pekkanen, J., Mäkeläinen, I., and Komulainen, H. (2002). Renal effects of uranium in drinking water. *Environmental health perspectives*. *110(4)*: 337-342.

Ononugbo, C.P and Anyalebechi, C.D. (2017). Natural Radioactivity Levels and Radiological Risk Assessment of Surface Water from Coastal Communities of Ndokwa East, Delta State, Nigeria. *Physical Science International Journal*. *14(1):* 1-14.

Pandey, S., Kumar, P., Zlatic, M., Nautiyal, R., and Panwar, V. P. (2021). Recent advances in assessment of soil erosion vulnerability in a watershed. *International Soil and Water Conservation Research. 9(3)*: 305-318.

Saidou, shinji T., masahiro H. and Yvette F. T. S. (2019). Natural radioactivity measurements in drinking water and ingestion dose assessment: case of the uranium bearing region of Poli, Cameroon. *Journal of geochemical exploration DOI: 10.1016/j.gexplo.2019.106350*.

Sasser, M.K., and J. E Watson Jr, J. E. (1978). An evaluation of the radon concentration in North Carolina ground water supplies. *Health physics. 34. 6 (1988)*: 667-671.

Singhal, B. B. S., and Gupta, R. P. (2010). Applied hydrogeology of fractured rocks. *Springer Science and Business Media.*

Taskin, H; Karavus, M; Ay,P; Youzogh, A; Hindiroglu. S and Karaham, G. (2009). Radionuclides concentration in Soil and Lifetime Cancer Risk Due to Gamma Radioactivity in Kirkilareli Turkey. *Journal of Environmental Radioactivity*. *100*: 49-53.

Tchokossa, P; Olomo, J. B and Balogun, F. A. (2011). Assessment of Radionuclide Concentrations and Absorbed Dose from Consumption of Community Water Supplies in Oil and Gas Producing Areas in Delta State, Nigeria. *World Journal of Nuclear Science and Technology*. *1:*77-86.

United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR). (2008). Sources and Effect of Ionizing Radiation. Report Vol. 1 to the General Assembly with Scientific Annexes. *United Nations Sales Publications, United Nations*, New York.

United States Environmental Protection Agency (US, EPA). (2000). *Office of Water Setting Standards for Safe Drinking Water, Revised June 9 (2000)* (*US, EPA*, Washington DC).

Vengosh, A., Coyte, R. M., Podgorski, J., and Johnson, T. M. (2022). A critical review on the occurrence and distribution of the uranium-and thorium-decay nuclides and their effect on the quality of groundwater. *Science of the Total Environment. 808*: 151914.

World Health Organization (WHO). (2005). *Nutrients in Drinking Water: Water, Sanitation and Health. Protection and the Human Environment*. WHO. Geneva.

World Health Organization (WHO). (2008). *Guidelines for Drinking Water Quality Incorporating first Addendum, Vol. 1, Recommendations, third edition. Radiological Aspect Geneva.* World Health Organization, WHO. Geneva.

World Health Organization (WHO). (2017). Guidelines for drinking-water quality (4th ed. incorporating the first addendum), World Health Organization, Geneva.

Citation: Bijimi *et al*. (2023). Determination of annual effective dose of radionuclides in groundwater consumed by selected age groups in Veritas University and its environs. *International Journal of Microbiology and Applied Sciences*. *2*: 47 - 56.