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Assessment of Ingested Radionuclide Dose from Groundwater Sources in Rumuekpe, Rivers State, Nigeria

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Abstract
A study to evaluate the annual effective dose (AED) of radionuclides due to consumption of well water samples from some randomly selected communities in Rumuekpe, Emohua Local Government Area, Rivers State, Niger Delta, Nigeria, was carried out. The aim of the study is to determine the annual effective dose in infants, children and adult population of the study area who consume the well water. Twenty-eight well water samples were collected and acidified to allow for homogeneity as well as to minimize the effect of microbial/bacterial activities. Activity concentration (AC) of radionuclides was determined with the aid of NaI gamma-ray spectrometer. Mean AC of ^{40}K, ^{232}Th and ^{238}U are 79.51, 2.73 and 9.67 Bql^{-1} respectively. Mean TAED of all radionuclides in infants (0-1 and 1-2)yr, children (2-7 and 7-12)yr and adults (12-17 and >17)yr are (3.703 and 1.085), (1.169 and 0.861), and (1.368 and 1.093) $mSvy^{-1}$ respectively. Mean activity concentration of ^{40}K and ^{232}Th are above recommended safe limit of 10.0 and 0.10 Bql^{-1} respectively while that of ^{238}U was lower than the 10.0 Bql^{-1} recommended safe limit. Mean TAED in infants, children and adults are higher than the recommended safe limit of 0.26, 0.20 and 0.10 $mSvy^{-1}$ respectively. This indicates that the well water supplies are harmful for human consumption. Proper water treatment or provision of good water supplies is highly recommended for the inhabitants of the study area.

Keywords: Consumption, Recommended, Inhabitants, Homogeneity, Concentration

Introduction
The annual effective dose (AED) refers to the measure of the potential radiation dose absorbed by a person over the period of a year, and is often expressed in Sieverts (Sv). This is one of radiation indices used to evaluate the risk of exposure to radiation resulting from radiologically contaminated environmental media (air water and sediments) as well as from medical facilities. The AED is particularly important when considering the potential health risks from radionuclide contamination in water sources. Rumuekpe, a community located in the Niger Delta region of Nigeria, make use of well water supplies for domestic purposes. Generally, underground water sources have been reported to potentially contain radionuclides due to natural and/or anthropogenic contamination (Ajayi, 2008). The presence of naturally occurring radioactive materials in drinking water is of great concern, and vary very significantly as they depend on the nature of aquifer (Tchokossa et al., 2011). The presence of radionuclides in water can contribute to the internal exposure of individuals to ionizing radiation, which may result to various health risks such as cancer and other diseases as a result of long-term exposure (Ononugbo & Tutumeni, 2016). The AED received by individuals, particularly infants, children, and adults, depends on various factors such as the radionuclide concentration in the water, the amount of water consumed, the age of the individual (Ononugbo and Anyalebechi, 2017), and the specific dose coefficients or conversion factor for each radionuclide (1gbudu & Brigs-Kamara, 2023). Infants and children are more vulnerable to radiation exposure due to their smaller body sizes, higher and ongoing developmental processes. Research studies have revealed that the concentrations of radionuclides in drinking water also varies significantly with the geographical location and the geology of the study area. In Rumuekpe communities, the presence of radionuclides in well water may be as a result of natural geological formations of thorium and uranium bearing rocks and minerals in the soil. These radionuclides, when ingested through water, pose a potential health risk as they emit alpha, beta, and gamma radiation, which can damage internal tissues and increase the likelihood of cancer. The aim of the study is to determine the annual effective dose of radionuclides in infants, children and adults population of the study area due to ingestion of well water samples from some selected communities in Rumuekpe, Emohua Local Government Area, Rivers State, Nigeria.

The presence of radionuclides in underground water can pose significant health risks to humans, particularly within regions with high levels of naturally occurring radionuclides in groundwater sources. The entire population of the study area rely heavily on well water as their primary source of drinking water. Hence, there is growing concern on possibility of contamination of well water with radionuclides due to the presence of naturally occurring radionuclides in ground water as well as anthropogenic activities that influence the level of radionuclide concentration in the water. Studies revealed that there are limited available data or literature on the annual effective dose (AED) of radionuclides due to consumption of well water in Rumuekpe. This factor had resulted to limited access to true extent of the health risk posed by the water in the community. This limitation has implications for public health interventions and regulatory standards. This study however, aims to address this gap in knowledge by measuring the radionuclide concentrations in well water sources as well as to determine annual effective doses in infants, children, and adult population of the study area. The findings could form local public health policies, water safety guidelines, and recommendations for mitigating radiation exposure in the region. There are no available literatures on annual effective dose in well water samples in Rumuekpe communities. This is because of the volatile nature of the area caused by agitations due to lack of economic, social and infrastructural development by government at all levels, non-governmental organizations (NGO) and multinational companies, despite being host to companies such as SPDC, Elf, Mobil and Agip. However, there are several research studies on annual effective dose in infants, children and adults populations due to consumption of underground water within and outside Niger Delta. Ononugbo and Ndodo (2019) reported that the annual effective dose and lifetime fatality risk in adult population in some of the communities in Tai Local Government Area, Rivers State, as a result of intake of radionuclides such as ^{226}Ra, ^{228}Ra (^{232}Th) and ^{40}K in well water samples are above recommended safe limit values. Igbudu et al. (2023) reported that the annual effective dose of radionuclides in children aged (2-7 and 7-12)yr due to ingestion of surface water sample from the New Calabar river was higher than the recommended safe limit. Similarly, another study by Igbudu and Briggs-Kamara (2023), highlighted that the annual effective dose in infants population due to intake of surface water from some river banks along the New Calabar river exceeded the recommended limit set by the International Commission on Radiological Protection (ICRP, 2012) and United Nations Scientific Committee on Effect of Atomic Radiation (UNSCEAR, 2010). Tchokossa et al. (2011) conducted a study to assessment concentration of radionuclide and absorbed dose as a result of ingestion of some water supplies from oil and gas producing areas in Delta State, Niger Delta, Nigeria. Their study reported that the annual effective dose of radionuclides in infants, children and adults due to ingestion of some water supplies including well water from the study area exceeded the recommended permissible limit. Ononugbo and Tutumeni (2016), in their study to assess the natural radioactivity and radiation dose estimation in various water samples in Abua/Odua Local Government Area, Rivers State, reported that the activity concentration of radionuclides, as well as the annual effective dose in infants, children and adults as a result of intake of well and borehole waters recorded values above the internationally recommendation safe limits. The study further highlighted that all sources of water supply in the study area, as well as the borehole and hand-dug well waters contained radiological substances capable of damaging human cells and tissue hence, are unsafe for human consumption.

A study conducted by Dankawu et al. (2021), to estimate excess lifetime cancer risk and annual effective dose for underground water in Dutse, Jigawa State, Nigeria, reported that excess lifetime cancer risks as well as annual effective dose of radionuclides in infants, children and adults due to intake of hand-dug well and borehole water samples recorded values above recommended safe limits in some bore hole and well waters. Their findings further highlighted that only 36.36 percent of borehole water and 18.18 percent of hand-dug well water were below recommended safe limit. A study conducted by Anekwe et al. (2023) to determine the health implications associated with intake of borehole water supply from some communities in Ogbia Local Government Area, Bayelsa State, Nigeria, reported that all radiological parameters under consideration as well as annual effective dose of radionuclides in infants, children and adults were within recommended permissible limits. Generally, the above findings reported values of annual effective dose of radionuclides in infants, children and adults due to consumption of underground (bore hole and well) water supplies higher than internationally recommended safe limits set by International Commission on Radiological Protection (ICRP, 2012). The studies further reported that the underground water supplies from some of the above research areas are radiologically polluted, contaminated, and harmful to human health when consumed. However, there is an exception to the above findings. The studies by Anekwe et al. (2023), reported values of annual effective dose of radionuclides due to intake of borehole water within recommended safe limit, with the water supplies being safe and free from radiological risks to human health.

Materials and Methods

Rumuekpe comprises two major communities, namely Nvakohia and Oduoha. Nvakohia is composed of three villages: Ovelle, Imogu and Ekwutche while Oduoha is made up of five villages: Omegwa, Ovelle-Oduoha, Mgbodo, Mgbuhie and Omoviri. Rumuekpe is located in Emohua Local Government Area, Rivers State, Nigeria.

It is bounded by Rundele in the East, Ahoada in the West and South, and Elele-Alimini in the North. Rumuekpe is surrounded by mangrove forests and observe heavy rainfall annually, hence their main occupation is farming, fishing and petty trading. Rumuekpe plays host to the biggest manifold of Shell Petroleum Development Company (SPDC) Eastern Division, with a flow station processing between 10,000 and 15,000 barrels of oil per day (Chigbo, 2011). It also plays host to other multinational companies such as Total, Elf, and NPDR (Niger Delta Petroleum Resources), as well as criss-crossing oil and gas pipelines through which 10,000 barrels of oil flow every day (Chigbo, 2011). This amounts to 10% of Shell's daily production in the country. Rumuekpe serves as the centre point for oil and gas pipelines as well as other facilities and installations that cut across the Niger Delta Region (Smith, 2012). Despite the presence of these multinational companies, Rumuekpe lacked economic, social and infrastructural development as well as basic amenities such as good drinking water.They relied on river and well water for their domestic uses. Unfortunately, these sources of water supply to the community have been severely polluted as a result of frequent gas flares and oil spillages that date back to the 1990s.

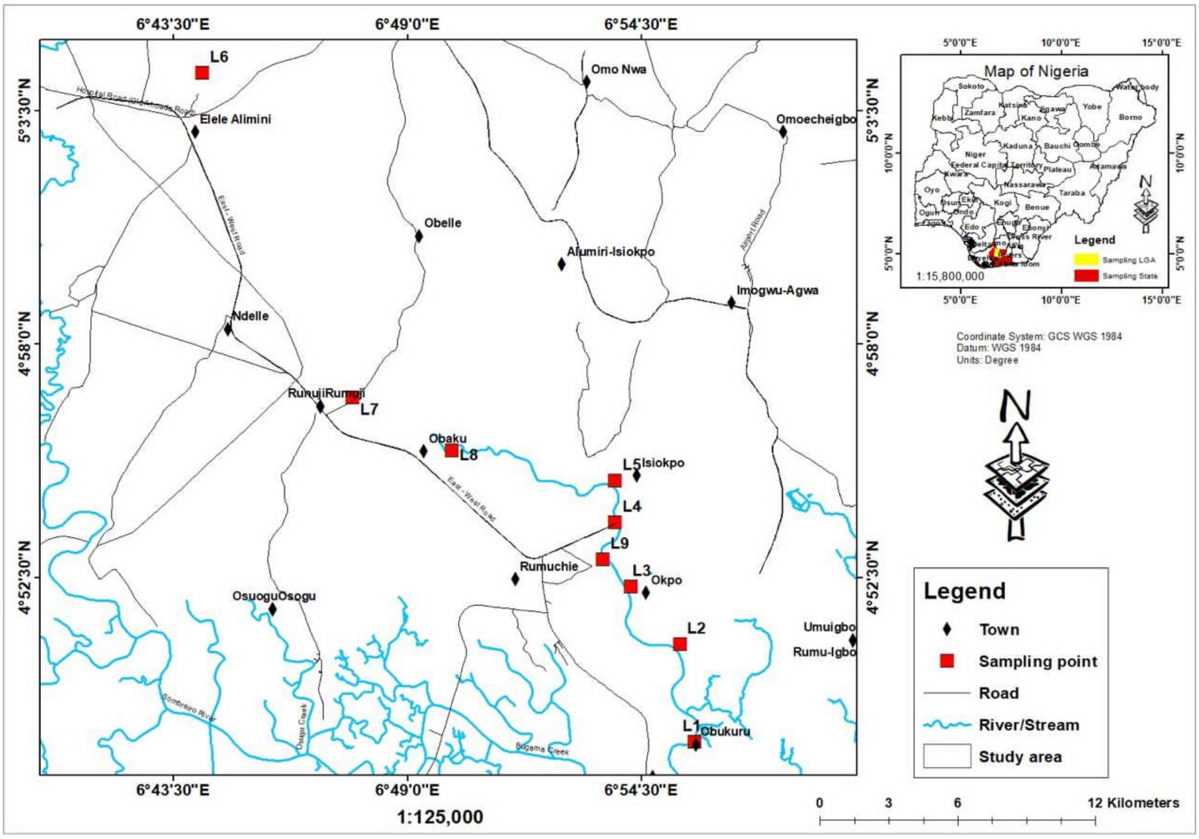

Fig 1: Map of Emohua showing Rumuekpe communities

The following materials were used in this study: sterilized plastic (50 cl) sample container for sample collection, bleach or alcohol used as sterilizing agents. These sterilizing agents helped to keep the sample containers from contaminants. Other materials include global positioning system GPS), used to measure the coordinates of sample locations; nitric (HNO_3) or HCl acid solution for reduction of pH of well water sample; Sodium Iodide (NaI) spectrometer for detection of radionuclides in the well water samples; Cesium-137 or Cobalt-60 for calibration of radiation detecting instrument; laboratory coats, safety googles, and hand gloves were used for protection against hazardous substances; and record book and pen for recording of sample location and other details. Twenty-eight hand dug wells from four out of eight communities that make up Rumuekpe, were sampled. Twenty-eight plastic (50 cl) sample containers were thoroughly washes with detergents and rinsed with distilled water. Well water samples were collected into the sample containers, and were treated by injecting about 16 ml of HNO_3 solution with the aid of injection syringe. The addition of acid solution to the water samples helped to avoid change in the state of the ions present in the water samples, as well as to allow for secular equilibrium before the gamma-ray analysis. The sample containers were properly labelled, tightly cocked and stored in the refrigerator or ice cooled between 1ºC and 4ºC for a minimum of 24 hours. Samples were transported to the laboratory, and allowed for 28 days before analysis was carried out with the aid of Sodium-Iodide (NaI) gamma-ray spectrometer. The spectrometry system, connected to ORTEC 456 Amplifier, as well as a computer programme (SAMPO 90 window), helped to match energies to a library of possible isotopes (Ononugbo & Anyalebechi, 2017). The activity

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concentration of radionuclides present in the well water samples were obtained with the aid of computer monitor with software connected to the gamma-ray spectrometer. The values of activity concentration were estimated after subtracting decay corrections.

Estimation of Hazard Indices
Annual Effective Dose (AED)

This refers to the amount of radiation a person receives annually, and is a measure of the type of radiation as well as the sensitivity of the different organs and tissues in the body. The AED which helps to assess the potential health risks from radiation exposure over time, also accounts for both primordial (or terrestrial) sources of radiation such as from the sun, soil and radon, as well as from artificial sources of radiation such as from medical imaging, occupational exposure, and nuclear sources (industrial activities). The AED can be estimated using eq. (1): (Ononugbo et al., 2013; Igbudu & Briggs-Kamara, 2023):

AED (mSvy^{-1}) = $(I_D A_C C_f) \times 365$ (1)

Where I_D is the daily water intake (Ld^{-1}), A_C is activity concentration (Bql^{-1}) of radionuclides in well water sample; C_f is the dose conversion factor (mSvBq^{-1}), 365 is the period of one year. Note that the conversion factor varies with the type of radionuclides in water sample as well as the age of human population. The table below indicates the values of dose conversion factor of each of the radionuclides in well water samples, daily and annual water consumption for the six different categories of human (infants, children and adults).

Table 1: Dose Conversion Factor for Ingested Radionuclides: ^{40}K, ^{232}Th and ^{238}U for the Six Categories of Human Population (Infants, Children and Adults) (Source: Extracted from STUK, 2014).

S/No	Age of population	Radionuclides ^{40}K	^{232}Th	^{238}U	Water Intake Daily (Ld^{-1})	Annually (Ly^{-1})
	Infants					
1	(0-1)yr	6.2 E-8	4.6 E-6	3.4 E-7	0.5	182.5
2	(1-2)yr	4.2 E-8	4.5 E-7	1.2 E-7	1.0	365.0
	Children					
3	(2-7)yr	2.1 E-8	3.5 E-7	8.0 E-8	1.0	365.0
4	(7-12)yr	1.3 E-8	2.9 E-7	6.8 E-8	1.0	365.0
	Adults					
5	(12-17)yr	7.6 E-9	2.5 E-7	6.7 E-8	1.5	547.5
6	(>17)yr	6.2 E-9	2.3 E-7	4.5 E-8	2.0	730.0

Total Annual Effective Dose (TAED)

This refers to the addition of annual effective dose contributions from each of the radionuclides in well water samples. It can be estimated using eq. (2): (Ononugbo & Anyalebechi, 2017; Igbudu et al., 2023):

TAED (mSvy^{-1}) = $\sum(I_D A_C C_f) \times 365)$ (2)

where all parameters are same with those in eq. (1) above.

Results

Tables 2 represents annual effective dose of ^{40}K in infants (0-1 and 1-2)y, children (2-7 and 7-12)y and adults (12-17 and >17) due to intake of well water samples while Tables 3 and 4 represent annual effective dose of ^{232}Th and ^{238}U in infants, children and adults due to intake of well water samples. Table 5 represents total annual effective dose of radionuclides in infants, children and adults due to intake of water samples. Fig 2 represents pie chart of mean values of the radionuclides in well water samples.

Table 2: Annual Effective Dose ($mSvy^{-1}$) Due to Ingestion of ^{40}K in Well Water from Rumuekpe Communities for the Six Age Groups.

Sample Code	Annual Effective Dose ($mSv\ y^{-1}$)					
	Infant		Children		Adult	
	(0-1)yr	(1-2)yr	(2-7) yr	(7-12) yr	(12-17) yr	> 17 yr
W1	0.222	0.301	0.151	0.093	0.109	0.089
W2	0.233	0.315	0.158	0.098	0.114	0.093
W3	0.295	0.400	0.200	0.124	0.145	0.118
W4	0.310	0.420	0.210	0.130	0.152	0.124
W5	0.367	0.498	0.252	0.154	0.180	0.147
W6	1.188	1.610	0.805	0.498	0.583	0.475
W7	0.669	0.907	0.453	0.281	0.328	0.268
W8	0.946	1.282	0.641	0.397	0.464	0.378
W9	0.132	0.179	0.090	0.055	0.065	0.053
W10	0.487	0.666	0.330	0.204	0.239	0.195
W11	1.357	1.839	0.919	0.569	0.665	0.543
W12	1.194	1.618	0.809	0.501	0.586	0.478
W13	0.371	0.503	0.252	0.156	0.182	0.148
W14	1.820	2.466	1.233	0.763	0.892	0.728
W15	1.517	2.055	1.028	0.636	0.744	0.607
W16	0.255	0.345	0.173	0.107	0.125	0.102
W17	1.832	2.482	1.241	0.768	0.898	0.733
W18	0.324	0.464	0.232	0.143	0.168	0.137
W19	1.461	1.979	0.989	0.612	0.716	0.584
W20	0.259	0.351	0.173	0.109	0.127	0.104
W21	1.507	2.041	1.021	0.632	0.739	0.603
W22	0.881	1.193	0.597	0.369	0.432	0.352
W23	0.808	1.095	0.548	0.339	0.396	0.323
W24	0.567	0.768	0.384	0.238	0.278	0.227
W25	0.614	0.833	0.416	0.258	0.301	0.246
W26	0.722	0.518	0.489	0.303	0.351	0.289
W27	1.425	1.931	0.965	0.598	0.699	0.570
W28	0.870	1.179	0.590	0.590	0.427	0.348
Min.	**0.132**	**0.301**	**0.151**	**0.055**	**0.065**	**0.053**
Max	**1.188**	**2.482**	**1.241**	**0.768**	**0.898**	**0.733**
Mean	**0.808**	**1.080**	**0.548**	**0.347**	**0.397**	**0.324**
SD	**0.530**	**0.725**	**0.359**	**0.227**	**0.260**	**0.212**
WAV	**0.12**		**0.12**		**0.12**	

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Table 3: Annual Effective Dose (mSv y^{-1}) Due to Ingestion of ^{232}Th in Well Water from Rumuekpe Communities for the Six Age Groups

Sample Code	Annual Effective Dose (mSv y^{-1})					
	Infant		Children		Adult	
	(0 –1) yr	(1-2)yr	(2 – 7) yr	(7 – 12) yr	(12 – 17) yr	> 17 yr
W1	3.165	0.619	0.482	0.399	0.688	0.633
W2	3.660	0.716	0.560	0.461	0.796	0.732
W3	2.594	0.507	0.395	0.327	0.564	0.519
W4	1.293	0.253	0.197	0.163	0.281	0.259
W5	0.537	0.105	0.082	0.068	0.117	0.107
W6	2.367	0.463	0.360	0.298	0.515	0.473
W7	0.109	0.021	0.017	0.014	0.024	0.022
W8	0.831	0.163	0.126	0.105	0.181	0.166
W9	2.309	0.452	0.351	0.291	0.502	0.462
W10	2.670	0.522	0.406	0.337	0.580	0.534
W11	0.142	0.028	0.022	0.018	0.031	0.028
W12	4.987	0.976	0.759	0.629	1.084	0.997
W13	2.493	0.488	0.379	0.314	0.542	0.499
W14	2.686	0.526	0.409	0.339	0.584	0.537
W15	1.170	0.228	0.178	0.147	0.254	0.233
W16	0.965	0.189	0.147	0.122	0.210	0.193
W17	1.721	0.337	0.262	0.217	0.374	0.344
W18	1.880	0.368	0.286	0.237	0.409	0.376
W19	3.207	0.627	0.488	0.404	0.697	0.641
W20	1.855	0.363	0.282	0.234	0.403	0.371
W21	3.182	0.622	0.484	0.401	0.692	0.636
W22	2.980	0.583	0.453	0.376	0.648	0.596
W23	2.157	0.422	0.328	0.272	0.469	0.431
W24	1.805	0.353	0.275	0.228	0.392	0.361
W25	BDL	BDL	BDL	BDL	BDL	BDL
W26	1.251	0.245	0.190	0.158	0.272	0.250
W27	8.445	1.652	1.285	1.065	1.836	1.689
W28	3.811	0.746	0.580	0.580	0.829	0.762
Min.	**0.109**	**0.021**	**0.017**	**0.014**	**0.024**	**0.022**
Max	**8.445**	**1.652**	**1.285**	**1.065**	**1.836**	**1.689**
Mean	**0.380**	**0.466**	**0.362**	**0.304**	**0.518**	**0.476**
SD	**1.676**	**0.328**	**0.255**	**0.215**	**0.364**	**0.355**
WAV	**0.17**		**0.17**		**0.17**	

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Table 4: Annual Effective Dose (mSv y^{-1}) Due to Ingestion of ^{232}U in Well Water from Rumuekpe Communities for the Six Age Groups

Sample Code	Annual Effective Dose (mSv y^{-1})					
	Infant		Children		Adult	
	(0 –1) yr	(1-2)yr	(2 – 7) yr	(7 – 12) yr	(12 – 17) yr	> 17 yr
W1	BDL	BDL	BDL	BDL	BDL	BDL
W2	0.434	0.307	0.204	0.174	0.342	0.230
W3	0.864	0.610	0.407	0.346	0.681	0.458
W4	0.012	0.009	0.006	0.005	0.010	0.007
W5	BDL	BDL	BDL	BDL	BDL	BDL
W6	0.900	0.635	0.423	0.360	0.709	0.476
W7	0.306	0.216	0.155	0.123	0.242	0.064
W8	0.090	0.063	0.042	0.036	0.071	0.048
W9	0.187	0.132	0.088	0.075	0.147	0.100
W10	0.450	0.318	0.212	0.180	0.355	0.238
W11	1.503	1.061	0.708	0.601	1.185	0.796
W12	1.283	0.906	0.604	0.513	1.011	0.679
W13	0.040	0.028	0.019	0.016	0.032	0.021
W14	0.066	0.047	0.031	0.027	0.052	0.035
W15	1.004	0.709	0.472	0.402	0.791	0.531
W16	0.237	0.167	0.111	0.095	0.187	0.125
W17	0.012	0.009	0.006	0.005	0.010	0.007
W18	0.071	0.050	0.033	0.028	0.056	0.037
W19	0.071	0.050	0.033	0.028	0.056	0.037
W20	0.752	0.531	0.354	0.301	0.593	0.398
W21	0.190	0.134	0.090	0.076	0.150	0.010
W22	0.545	0.385	0.257	0.218	0.430	0.289
W23	0.972	0.687	0.458	0.389	0.767	0.515
W24	1.980	1.398	0.932	0.792	1.561	1.048
W25	1.144	0.807	0.538	0.457	0.901	0.605
W26	0.237	0.167	0.111	0.095	0.187	0.125
W27	2.073	1.463	0.976	0.829	1.634	1.097
W28	1.368	0.966	0.644	0.547	1.078	0.724
Min.	**0.012**	**0.009**	**0.006**	**0.005**	**0.010**	**0.007**
Max	**2.073**	**1.463**	**0.976**	**0.829**	**1.634**	**0.724**
Mean	**0.646**	**0.456**	**0.304**	**0.258**	**0.509**	**0.335**
SD	**0.617**	**0.436**	**0.290**	**0.247**	**0.486**	**0.332**
WAV	**0.17**		**0.17**		**0.17**	

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Table 5: Total Annual Effective Dose (mSv y^{-1}) Due to Ingestion of ^{40}K, ^{232}Th and ^{232}U in Well Water Samples from Rumuekpe Communities for the Six Age Groups

Sample Code	Annual Effective Dose (mSv y^{-1})					
	Infant		Children		Adult	
	(0 –1) yr	(1-2)yr	(2 – 7) yr	(7 – 12) yr	(12 – 17) yr	> 17 yr
W1	3.387	0.920	0.633	0.492	0.797	0.722
W2	4.327	1.338	0.922	0.733	1.252	1.055
W3	3.753	1.517	1.002	0.797	1.390	1.095
W4	1.615	0.682	0.413	0.298	0.443	0.390
W5	0.904	0.603	0.334	0.222	0.297	0.254
W6	4.455	2.708	1.588	1.156	1.807	1.424
W7	1.084	1.144	0.625	0.418	0.594	0.354
W8	1.867	1.508	0.809	0.538	0.716	0.592
W9	2.628	0.763	0.529	0.421	0.714	0.615
W10	3.607	1.506	0.648	0.172	1.174	0.967
W11	3.002	2.928	1.649	1.188	1.881	1.367
W12	7.464	3.500	2.172	1.643	2.681	2.154
W13	2.904	1.019	0.650	0.486	0.756	0.668
W14	4.572	3.039	1.673	1.129	1.528	1.300
W15	3.691	2.992	1.678	1.185	1.789	1.371
W16	1.457	0.701	0.431	0.324	0.522	0.420
W17	3.565	2.828	1.509	0.990	1.282	1.084
W18	2.275	0.882	0.551	0.408	0.633	0.550
W19	4.739	2.656	1.505	1.044	1.469	1.262
W20	2.866	1.245	0.809	0.644	1.123	0.873
W21	4.879	2.797	1.595	1.109	1.581	1.249
W22	4.406	2.161	1.307	0.963	1.510	1.237
W23	3.937	2.204	1.334	1.000	1.632	1.269
W24	4.352	2.519	1.591	1.258	2.231	1.636
W25	1.758	1.640	0.954	0.715	1.202	0.851
W26	2.210	0.930	0.790	0.556	0.810	0.664
W27	11.94	5.046	3.226	2.492	4.169	3.356
W28	6.049	2.891	1.814	1.717	2.334	1.834
Min.	**0.904**	**0.603**	**0.334**	**0.222**	**0.297**	**0.254**
Max	**11.94**	**5.046**	**3.226**	**2.492**	**4.169**	**3.356**
Mean	**3.703**	**1.952**	**1.169**	**0.861**	**1.368**	**1.093**
SD	**2.205**	**1.085**	**0.652**	**0.521**	**0.815**	**0.641**
WAV	**0.26**		**0.20**		**0.10**	

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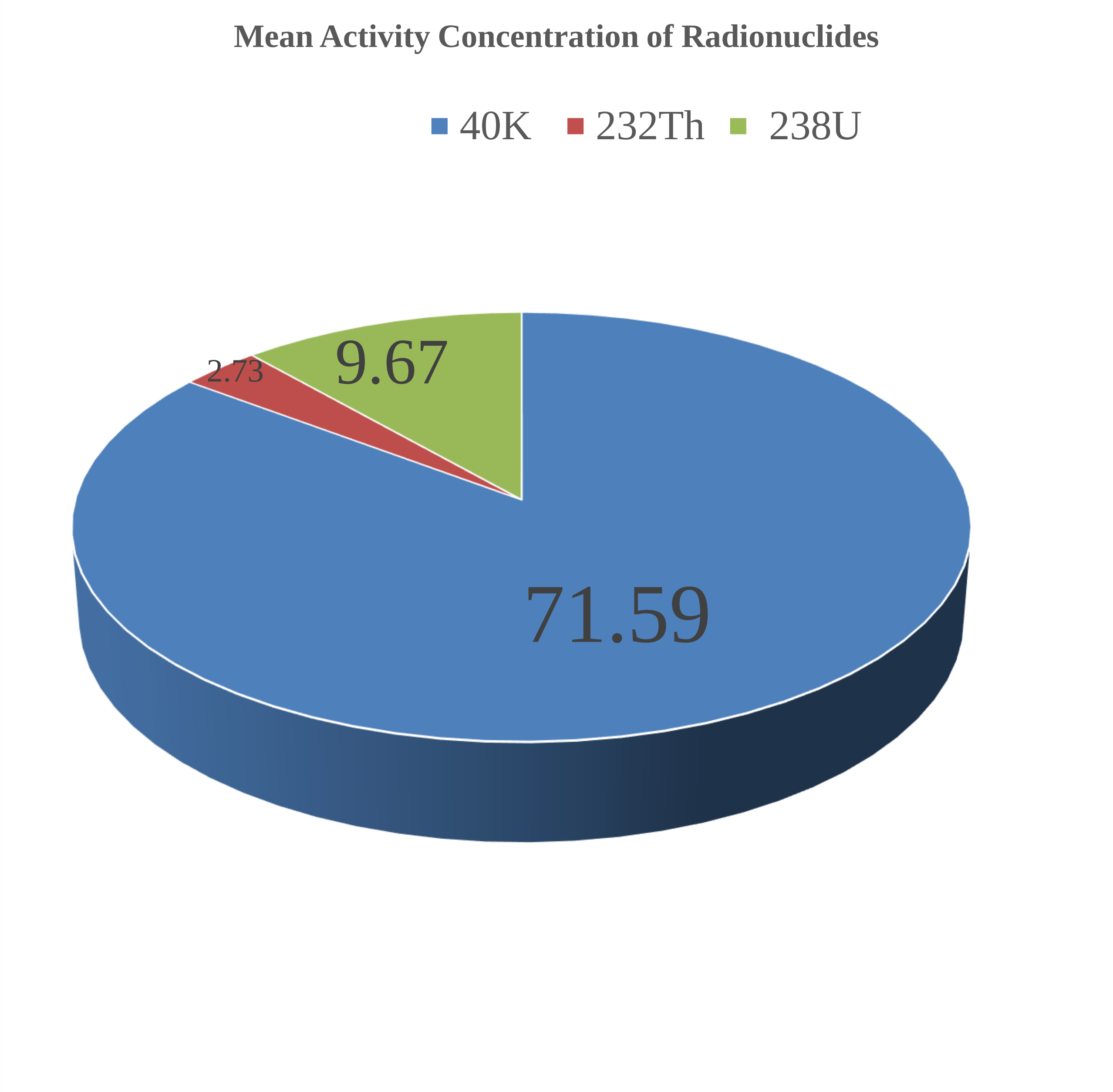

Fig 2. Mean activity concentration of radionuclides

Discussion

The results in Fig. 2 revealed that mean values of radionuclides ^{40}K, ^{232}Th and ^{238}U are 71.51, 2.73 and 9.67 Bql^{-1} respectively. The mean activity concentration of ^{40}K and ^{232}Th are higher than their recommended safe limits of 10.0 and 0.1 Bql^{-1} respectively while that of ^{238}U was about 3.3 percent lower than the internationally recommended safe limit of 10 Bql^{-1}. The abundance of ^{40}K in the well water samples is influenced by several factors. Ononugbo and Anyalebechi (2017) stated that that potassium is a naturally occurring radioactive material in the earth's crust, and when groundwater interacts with rocks and minerals beneath the earth, its isotope is leached into the groundwater. Again, potassium decays over time, emitting beta particles and gamma radiation, thereby contributing to the presence of ^{40}K in groundwater, as it is naturally found in all potassium sources. Other factors that can influence the concentration of potassium in underground water are geologic formation of rock and soil in the region surrounding the well, pH and mineral content of the ground water which affects the amount of potassium that leaches into the groundwater, the rate of ground water movement (Tchokossa et al., 2011) and length of time spent in contact with potassium-rich geological formation, as well as human activities such as use of fertilizers (Akinloye, 2008), activities oil and gas exploration, and the presence of potassium-rich industrial wastes sites (Ononugbo & Anyalebechi, 2017). Results in Tab 2 indicated that the annual effective dose of ^{40}K ranged from 0.132 to 1.188, and 0.301 to 2.482 $mSvy^{-1}$in infants (0-1 and 1-2)y, 0.151 to 1.241 and 0.055 to 0.768 $mSvy^{-1}$ in children (2-7 and 7-12)y, and 0.065 to 0.898 and 0.053 to 0.733 in adults (12-17 and >17)y. The mean AED of ^{40}K in infants (0-1 and 1-2)y, children (2-7 and 7-12)y are (0.808 and 1.080), (0.548 and 0.347), and (0.397 and 0,324) mSvy-1 respectively. Results in Table 3 showed that AED of ^{232}Th ranged from 0.109 to 8.445 and 0.021 to 1.652 $mSvy^{-1}$ in infants (0-1 and 1-2)y, 0.017 to 1.285 and 0.014 to 1.065 $mSvy^{-1}$ in children (2-7 and 7-12)y, and 0.024 to 1.836 and 0.022 to 1.689 $mSvy^{-1}$in adults (12-17 and >17)y. The mean AED of ^{232}Th in infants (0-1 and 1-2)y, children (2-7 and 7-12)y are (0.380 and 0.466 mSvy-1, 0.362 and 0.304 $mSvy^{-1}$ and 0.518 and 0.476 mSvy-1 respectively. Table 4 revealed that AED of ^{238}U ranged from 0.012 to 2.073 and 0.009 to 1.463 $mSvy^{-1}$ in infants (0-1 and 1-2)y, 0.006 to 0.976 and 0.005 to 0.829 $mSvy^{-1}$ in children (2-7 and 7-12)y, and 0.010 to 1.634 and 0.007 to 0.724 $mSvy^{-}$1in adults (12-17 and >17)y. The mean AED of ^{238}U in infants (0-1 and 1-2)y, children (2-7 and 7-12)y are 0.646 and 0.456 mSvy-1, 0.304 and 0.258 $mSvy^{-1}$ and 0.509 and 0.335 mSvy-1 respectively. Mean AED of ^{40}K in infants, children and adults are higher than the internationally recommended safe limits of 0.12 $mSvy^{-1}$. Similarly, mean AED of ^{232}Th and ^{238}U in well water samples are higher than the internationally recommended safe limits of 0.17$mSvy^{-1}$ across all categories of age groups considered. This implied that the well water samples are unsafe for human consumption. This is because the water samples contain some radiological substances that can cause serious health issues in humans when consumed. Results in Table 5 indicated that TAED of radionuclides in well water samples ranged from 0.904 to 11.940 and 0.603 and 5.046 $mSvy^{-1}$ in infants (0-1 and 1-2)y, 0.334 to 3.226 and 0.222 to 2.492 $mSvy^{-1}$ in children (2-7 and 7-12)yr, and 0.297 to 4.169 and 0.254 and 3.356 $mSvy^{-1}$ in adults (12-17 and >17)y. The mean TAED of radionuclides are 3.703 and 1.952mSvy-1, 1.169 and 0.861 $mSvy^{-1}$, and 1.368 and 1.093 $mSvy^{-1}$ in infants (0-1 and 1-2)y, children (2-7 and 7-12)y and adults (12-17 and >17)y respectively. Mean TAED of radionuclides in well water samples are higher than the world average value (WAV) of 0.26, 0.20 and 0.10 $mSvy^{-1}$ in infants, children and adults respectively, as recommended by UNSCEAR (2010) and WHO (2011). This is an indication that the well water samples are radiologically contaminated and unsafe for consumption by human across all categories of age group.

Conclusion

A study on determination of annual effective dose of radionuclides (^{40}K, ^{232}Th and ^{238}U) in infants, children and adults due to ingestion of well water samples from some randomly selected communities in Rumuekpe, Emohua Local Government Area, Rivers State, Nigeria, was carried out. The radioelements in the well water samples were detected with the aid of NaI gamma-rays spectrometry system. Mean activity concentration of ^{40}K and ^{232}Th exceeded the UNSCEAR (2010) and WHO (2011) recommended safe limits of 10.0 and 0.10 Bql^{-1} respectively while mean activity concentration of ^{238}U was slightly lower than recommended safe limit of 10.0 Bql^{-1}. Mean AED of ^{40}K in infants, children and adults are lower than recommended limit of 0.12 $mSvy^{-1}$ for the six different categories of age groups while those of ^{232}Th and ^{238}U are also lower than recommended safe limit of 0.17 $mSvy^{-1}$ for the six categories of age group considered. Mean TAED of radionuclides (^{40}K, ^{232}Th and ^{238}U) due to intake of well water samples are higher than UNSCEAR (2010) and WHO (2011) recommended safe limits of 0.26, 0.20 and 0.10 $mSvy^{-1}$ in infants, children and adults respectively. Results further revealed that AED and TAED in well water samples in the present study area are higher than internationally recommended safe limits. This indicates that the well water supplies contain some radiological hazards that can cause radiation-related health effects such as lung diseases, anaemia, leucopoenia (Jegede et al., 2017; Aliyu et al., 2015). Others are brain, pancreas, hepatic bone kidney and skin cancers, as well as cataract, leukemia and internal organ damage (Ononugbo et al., 2013; Avwiri et al., 2007).

Recommendations

1. Provision of clean, safe and alternative source of drinking water for the inhabitants of the study area by multinational companies operating within the area, as well as the state and federal governments is highly recommended.
2. Routine medical check-ups and treatments especially on the infants are also recommended.

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