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Research Article

Estimation of Health Risks in Borehole Water Supply, Case Study in Ogbia, Nigeria

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Abstract

Hazard of any form has been known to be undesirable condition all over the world. The natural radiation contaminants which exist in rock formation could mix with borehole water drilled for human consumption. Therefore, the aim of this study was to determine the health risks associated with borehole water supply in some communities in Ogbia local government area, Nigeria. The method used was computational on activity concentrations of radionucleides of radium, thorium and potassium found in the water samples. Dose coefficient of the isotopes and volume of water intake for certain age brackets involving infant, children and adult were applied in the computation. The results obtained showed that the annual effective dose (AED) for the infants drinking the water ranged from 4.2x10-5 to 0.03018 < 0.26 µSvy-1. The AED for teens ranged from 1.5x10-5 to 0.01838 µSvy-1< 0.20 while it ranged from 1.5 x10-5 to 0.00308 < 0.1µSvy-1 for adult human beings. Fatality Cancer Risk to adult ranged from 9.2x10-7 < 2.59x10-5 to 0.00019 ≥2.59x10-5. Lifetime Fatality Cancer Risk ranged from 0.00022 to 0.01321 < 18.18. The severity hereditary effect in adult ranged from 3.34924x10-8 <9.44x10-7 to 6.8606 x10-6 ≥ 9.44x10-7 whereas the estimated lifetime hereditary effect ranged from 2.3x10-6 to 4.8 x10-6 < 6.61x10-5. In conclusion, the implication of these results is that the borehole water samples from the twenty communities are radiologically safe for human consumption.

Keywords: *Cancer Risk; Borehole Water; Effective Dose; Health Indices; Hereditary Effect; Community.*

Introduction

Water is found everywhere but most times none good enough to drink. Its major sources are the underground and surface water naturally available. Water is constantly being polluted regardless of location and it is indispensable in human existence. The World Health Organization in its effort to ensuring availability of good drinking water for the general public provided permissible limits for radionuclide contents in drinking-water. When radionuclide is inhaled or ingested through eating and drinking, the emissions can come into direct contact with sensitive tissues or organs in the body [1, 12]. These limits in form of guidelines specify acceptable levels of concentration for nuclides in drinking water. Life depends on water; therefore, the knowledge of contaminants in drinking water is of utmost importance to human healthy living [2]. Borehole water is underground source in touch with radioactive materials of the earth's crust and as such suffers radiation pollution. Human cells contain 70% of water and when they are irradiated chemical reactions take place through the biological medium causing excitation and ionization. These excitation and ionization produce free radicals, OH^{o} and H^{o} and the release of aqueous electrons. These free radicals being reactive may form stable ions and molecules or they may attack the Deoxyribonucleic acid (DNA) and Ribonucleic acid (RNA) being biologically most important molecules. The concentration of the reactive species via ingestion and inhalation at a sight determines which of the above two competing mechanisms will occur [3].

The nucleides found in underground water are mostly radium ^{226}Ra and ^{228}Ra isotopes. ^{226}Ra is good alpha emitter having half-life of 1600 year whereas ^{228}Ra are beta emitters with half-life of 5.8 years [15]. Of utmost importance is that human beings are exposed to ionizing radiation from contaminated water when these radionuclides are emitted. The radionucleids of Uranium in water emit weak gamma radiation and, in this case, the human skin may not be negatively affected. Ionizing radiation is unarguably a major pollutant that perturbs the natural ecosystem when brought to the surface of the earth.

Radioisotopes are absorbed into the blood, about 66% of uranium is rapidly eliminated through urine and the rest stored in the kidney while 10-15 % in the bone [6] recorded that once radionuclides are incorporated, distribution and irradiation in the body take place by alpha, beta particle and gamma photons emissions.

The committed effective dose from consumption of water in a year should not exceed 100 µSv World Health Organization, WHO [21]. The possible sicknesses that associate high level irradiation are cancer of the bladder, lings, testis and leukemia Isinkaye and Emelue [8]. The dose of radiation depends on concentration of nucleides of Radium, Thorium and potassium. Radioactivity in water depends on the geology of the rock or soil bearing the nuleides [20, 22]. The processes of erosion and dissolution bring radioactive elements from the rocks into the ground water [9]. Other sources of these radionuleides into underground water is through leaching from rocks and soils, and deposition from the atmosphere. In environmental studies, water is considered very important because of its daily domestic use, human consumption and its ability to transport contaminants [4]. It is very important to maintain the environment and its content for rural and urban populations where environmental sustainability is fundamental to human development and wellbeing [13].

In time past the world major health threat from water contamination has been bacterial and viral infections. In recent time, environmental physicists have shown much interest in anthropogenic conditions that lead to serious poor drinking water quality that has potential to pose radiological problems [14].

The most well-known ionizing radiation emanates from the naturally occurring radioactive materials (NORMs) and technologically enhanced naturally occurring radioactive materials (TENORMs). These materials emit alpha, beta and gamma radiations. Radionuclides such as ^{226}Ra, ^{232}Th, ^{40}K which emit these radiations in drinking water may pose health challenge or health hazard if ingested into the human body hence the need to determine **radiological Hazards and level of health risks** associated with borehole water in the area investigated. Studies relating to health risk in drinking water in Nigeria have been carried out [16] but effective dose, fatality cancer risk, lifetime cancer risk, hereditary effect and lifetime hereditary effect have not been estimated in the drinking water in these communities. Therefore, the aim of this study was to estimate levels of water hazards in these communities. So, in this regard this research provided information on level of risks associated with continuous intake of the sampled water source. It also revealed information on possibility of cancer, impaired organ, gastrointestinal syndrome that may result from prolonged consumption of the water from these boreholes and ultimately provides recommendations towards risks reduction.

Methodology

Study Area

This study was carried out in twenty autonomous communities in Ogbia local government area of Bayelsa within latitude 4.63°, 4.80° N and longitude 6.22°, 6.42° E. These communities are Abobiri,Akipelai, Amorekeni, Anyama, Elebele, Emekalaka, Emeyal2, Imiringi, Kolo3, Ogbia town, Okiki, Okodi, Oloibiri, Onuebum, Opume, Oruma, Otuabula1, and Ewoi. Ogbia is one of the eight LGAs in Bayelsa State of Nigeria and as such all these communities are located in the lower Delta plain formed during the Holocene period by accumulation of sedimentary deposits of alluvium. The Ogbia communities lie within the Niger Delta which has the same geomorphology as the region of Bight of Biafra. The area is characterized of network of creeks, varying volumes/velocities of streams and rivers as Otuoke, Onuebum rivers etc. The entire area is made of abandoned beach ridges with many tributaries of River Niger. The coastal barrier islands support fresh water forests and fauna associated with them. The fresh water zone is usually under the influence of seasonal flooding.

Some of the islands are less than one meter above sea level. As lowland, the area is characterized by flood plains, beach ridge barriers, tidal flats and coastal beaches with cliffs features. The soil types found in the area are young shallow, poorly drained and sulphate soils. These soils are of the high-lying levees e.g. sandy loam, loamy sandy, and silt loamy soils as well as sands. The sandy unit constitutes the hydrocarbon reservoir in the Niger Delta oil fields while the shales form the seal [10]. Where the main formation is sand, and the gamma radiation emanating from NORMs in the upper layer becomes higher than in the underlying marine clays as the grain size increases upwards.

The socio-political life is that the natives of these communities are traditionally farmers, fishermen and petty traders. Scrambling for oil wealth has made many abandon their traditional agricultural practices and many farm lands have been lost due the activities of oil companies in the area. Usage of borehole water has replaced the use of stream/river water for drinking and domestic use, since surface water has been abysmally polluted. The industrial and economic activities of the area include but not limited to crude oil activities, host to university and sand mining, *et cetera*. Fig. 1 Map showing the study area.

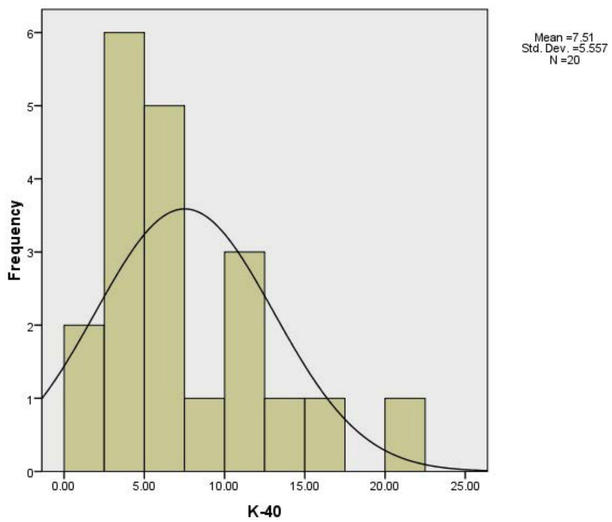

Figure 1: Frequency distributions of 40K in the drinking water sources

Computation of Radiological Health Risks

The parameters used to calculate risks include activity concentration of 226Ra, 232Th and 40K found in the drinking water, dose coefficient of each of the radionuclide and volume of water intake for 3 age brackets, infants, children and adults in accordance with uncear [19, 7]. 0.5 L/d and 1.0 L/d for infants (0-1 years) and children (10 years), and 2 L/d for adults (≥ 17 years) were used in computing the indices.

The annual effective dose due to intake of drinking water sources sampled was also calculated using the equation 1 [11, 19].

$$H_{ing}\ (mSvy^{-1}) = \sum_{i=1}^{i=3} DCF_{ing}\ (i) \text{x Ai x 1} \quad (1)$$

were DCFing(i) is the dose coefficient of a particular radionuclide in Sv/Bq for a particular age category (Table 1). *Ai* is the specific activity concentration of radionuclide in water sample which is measured in Beacural per litre. The radionuclide intake in liters per year is as shown in Table 2.

Table 1: Effective dose coefficients for ingestion of radionuclides for members of the public to 70 years of age (ICRP, 2012; pub 119)

S/N	Radioisotopes	Infant ≤ 1 year	Children 10 years	Adult ≥ 17 years
1	22Ra	5.7 E -06	8.0 E -07	2.8 E-07
2	232Th	1.6 E -06	2.9 E -07	2.3 E-07
3	40K	5.2 E -05	1.3 E -08	6.2 E -09
Water intake		0.5L/day	1.0L/day	2.0L/day

Table 2: Activity concentrations of radionuclides in the water samples (Anekwe and Ibe, 2021)

S/N	Location	Latitude (degree)	Longitude (degree)	Elevation (m)	^{40}K (Bql^{-1})	^{226}Ra (Bql^{-1})	^{232}Th (Bql^{-1})
1	Abobiri	4.690594	6.346430	_6.70-	11.59±0.84	4.85±0.88	2.33±0.21
2	Akipelai	4.631006	6.338827	22.40-	0.47±0.04	0.26±0.05	1.08±0.09
3	Amorekeni	4.770262	6.402325	3.50-	16.20±1.13	6.57±1.20	4.45±0.35
4	Anyama	4.759551	6.229732	11.90-	3.70±0.28	BDL	BDL
5	Elebele	4.856307	6.344791	7.50-	4.50±0.35	2.76±0.49	1.60±0.14
6	Emekalaka	4.650440	6.349701	0.40-	7.02±0.53	2.61±0.54	BDL
7	Emeyal 2	4.839074	6.350002	6.90	11.59±0.88	BDL	3.30±0.28
8	Imiringi	4.891768	6.372003	17.70	7.36±0.51	6.94±1.33	1.29±0.11
9	Kolo 3	4.810038	6.376089	6.20	2.79±0.22	3.29±0.71	1.92±0.16
10	Ogbia Town	4.689922	6.316899	9.40-	8.87±0.67	8.55±1.63	0.590.05
11	Okiki	4.720291	6.258814	5.60-	14.90±1.14	1.67±0.37	0.90±0.08
12	Okodi	4.676393	6.221625	3.90-	6.05±0.50	4.38±0.90	2.17±0.18
13	Oloibiri	4.670915	6.312865	2.20	6.08±0.44	1.25±0.24	1.08±0.11
14	Onuebum	4.805502	6.259044	1.20-	21.51±1.58	2.09±0.40	0.52±0.05
15	Opume	4.679380	6.399171	4.80-	0.91±0.08	7.67±1.37	3.34±0.28
16	Oruma	4.915971	6.418283	1.40	5.21±0.37	0.16±O.03	BDL
17	Otuabula 1	4.730946	6.299751	0.41-	3.36±0.27	BDL	2.69±0.23
18	Ewoi	4.790184	6.313882	5.10-	2.86±0.21	1.10±0.23	2.96±0.25
19	FUO	4.792694	6.322980	2.70	3.26±0.26	0.57±0.12	1.18±0.10
20	Otuasega	4.918310	6.399650	10.80	11.96±0.93	1.67±0.37	2.46±0.20
	Mean				7.51±0.56	2.99±0.57	1.78±0.14

Fatality Cancer Risk = Annual Effective Dose (Sv) × Cancer risk factor (5.5×10^{-2}) (2)

The stochastic effects of radiation in adult citizen that takes water from the various drinking water sources was estimated using the international Commission on effects of protection (ICRP) cancer risk methodology as recorded by Umunakwe and Aharanwa [18].

Lifetime fatality cancer risk to adult = Annual effective dose ×70 yrs × 5.5×10^{-2} (3)

The health risks to members of the public due to exposure to low dose radiation which is regarded as chronic risk of somatic or hereditary effects were also determined.

Severe Hereditary Effects = Annual Effective Dose (Sv) × Hereditary effect factor (0.2×10^{-2}) (4)

Cancer risk coefficient of 5.5× 10-2 Sv-1 and hereditary effect coefficient of and 0.2× 10-2 [5]. reports were used, together with the assumed 70 years lifetime of continuous exposure of human beings to low level radiation was adopted [17].

Estimated Lifetime hereditary effect in adult = Total annual Effective Dose (Sv) × 70 yrs. × 0.2×10^{-2} (5)

Results and Discussion

Results

The results of the study are presented in Tables 3 and 4. Table 3 represents Annual Effective Dose for Radionuclides of ^{40}K, ^{226}Ra and ^{232}Th to Infant, Child, Teen, and Adult while Table 4 shows results of level of Risks.

Table 3: Annual Effective Dose for Radionuclides of ^{40}K, ^{226}Ra and ^{232}Th to Infant, Child, Teen, and Adult

Annual Effective Dose for Radionuclides of ^{40}K, ^{226}Ra and ^{232}Th to Infant, Child, Teen, and Adult											
E_K Infant	E_{Ra} Infant	E_{Th} Infant	EK Child	Ra Child	E_{Th} Child	E_K Teen	E_{Ra} Teen	E_{Th} Teen	E_K Adult	E_{Ra} Adult	E_{Th} Adult
0.00013114	0.00416	0.0127568	8.88374E-05	0.001097555	0.002892	4.8226E-05	0.003983	0.006761	5.24563E-05	0.000991	0.001055
5.3181E-06	0.000223	0.005913	3.60255E-06	0.000058838	0.00134	1.95567E-06	0.000214	0.003134	2.12722E-06	5.31E-05	0.000489
0.0001833	0.005635	0.0243638	0.000124173	0.001486791	0.005522	6.74082E-05	0.005396	0.012913	7.33212E-05	0.001343	0.002014
4.1866E-05	0	0	2.83605E-05	0	0	1.53957E-05	0	0	1.67462E-05	0	0
5.0918E-05	0.002367	0.00876	3.44925E-05	0.000624588	0.001986	1.87245E-05	0.002267	0.004643	0.000020367	0.000564	0.000724
7.9431E-05	0.002239	0	5.38083E-05	0.000590643	0	2.92102E-05	0.002143	0	3.17725E-05	0.000533	0
0.00013114	0	0.0180675	8.88374E-05	0	0.004095	4.8226E-05	0	0.009576	5.24563E-05	0	0.001494
8.3278E-05	0.005953	0.0070628	5.64144E-05	0.001570522	0.001601	3.0625E-05	0.005699	0.003743	3.33114E-05	0.001419	0.000584
3.1569E-05	0.002822	0.010512	2.13854E-05	0.000744527	0.002383	1.16092E-05	0.002702	0.005571	1.26275E-05	0.000672	0.000869
0.00010036	0.007334	0.0032303	6.79886E-05	0.001934865	0.000732	3.69081E-05	0.007022	0.001712	4.01456E-05	0.001748	0.000267
0.00016859	0.001432	0.0049275	0.000114209	0.000377921	0.001117	6.19989E-05	0.001371	0.002612	6.74374E-05	0.000341	0.000407
6.8456E-05	0.003757	0.0118808	4.63733E-05	0.000991194	0.002693	2.51741E-05	0.003597	0.006297	2.73823E-05	0.000895	0.000982
6.8795E-05	0.001072	0.005913	4.66032E-05	0.000282875	0.00134	2.52989E-05	0.001027	0.003134	2.75181E-05	0.000256	0.000489
0.00024339	0.001793	0.002847	0.000164874	0.000472967	0.000645	8.95031E-05	0.001716	0.001509	9.73543E-05	0.000427	0.000235
1.0297E-05	0.006579	0.0182865	6.97515E-06	0.001735721	0.004145	3.78651E-06	0.006299	0.009692	4.11866E-06	0.001568	0.001512
5.8951E-05	0.000137	0	3.99347E-05	0.000036208	0	2.16788E-05	0.000131	0	2.35805E-05	3.27E-05	0
3.8018E-05	0	0.0147278	2.57544E-05	0	0.003338	1.3981E-05	0	0.007806	1.52074E-05	0	0.001217
3.2361E-05	0.000944	0.016206	2.19219E-05	0.00024893	0.003673	1.19005E-05	0.000903	0.008589	1.29444E-05	0.000225	0.00134
3.6887E-05	0.000489	0.0064605	2.49879E-05	0.000128991	0.001464	1.35649E-05	0.000468	0.003424	1.47548E-05	0.000117	0.000534
0.00013533	0.001432	0.0134685	9.16734E-05	0.000377921	0.003053	4.97656E-05	0.001371	0.007138	5.4131E-05	0.000341	0.001113

Table 4: Levels of Health Risk

S/N	Location	Total Annual Effective Dose (µSv/yr)				Fatality Cancer Risk to Adult per year	Lifetime Fatality Cancer Risk	Severity Hereditary Effect in Adult per year	Estimated Lifetime Hereditary Effect
		Infant	Child	Teen	Adult	X10-6	X10-5	X10-8	X10-6
1	Abobiri	0.01705	0.00408	0.01079	0.0021	0.00012	0.00808	0.00000419671	0.00029
2	Akipelai	0.00614	0.0014	0.00335	0.00054	0.00003	0.00209	0.00000108816	0.000076
3	Amorekeni	0.03018	0.00713	0.01838	0.00343	0.00019	0.01321	0.0000068606	0.00048
4	Anyama	4.2E-05	2.8E-05	1.5E-05	1.7E-05	0.0000092	0.000064	0.0000000334924	0.0000023
5	Elebele	0.01118	0.00264	0.00693	0.00131	0.000072	0.00504	0.00000261734	0.00018
6	Emekalaka	0.00232	0.00064	0.00217	0.00057	0.000031	0.00218	0.00000113051	0.000079
7	Emeyal 2	0.0182	0.00418	0.00962	0.00155	0.000085	0.00595	0.00000309207	0.00022
8	Imiringi	0.0131	0.00323	0.00947	0.00204	0.00011	0.00784	0.0000040714	0.00028
9	Kolo 3	0.01337	0.00315	0.00828	0.00155	0.000085	0.00598	0.00000310819	0.00022
10	Ogbia Town	0.01066	0.00274	0.00877	0.00205	0.00011	0.00791	0.0000041096	0.00029
11	Okiki	0.00653	0.00161	0.00405	0.00082	0.000045	0.00314	0.00000163225	0.00011
12	Okodi	0.01571	0.00373	0.00992	0.0019	0.0001	0.00733	0.00000380959	0.00027
13	Oloibiri	0.00705	0.00167	0.00419	0.00077	0.000042	0.00297	0.00000154365	0.00011
14	Onuebum	0.00488	0.00128	0.00331	0.00076	0.000042	0.00293	0.0000015198	0.00011
15	Opume	0.02488	0.00589	0.01599	0.00308	0.00017	0.01187	0.0000061671	0.00043
16	Oruma	0.0002	7.6E-05	0.00015	5.6E-05	0.0000031	0.00022	0.000000112569	0.0000079
17	Otuabula 1	0.01477	0.00336	0.00782	0.00123	0.000068	0.00475	0.0000024654	0.00017
18	Ewoi	0.01718	0.00394	0.0095	0.00158	0.000087	0.00607	0.00000315496	0.00022
19	FUO	0.00699	0.00162	0.00391	0.00067	0.000037	0.00256	0.00000133066	0.000093
20	Otuasega	0.01504	0.00352	0.00856	0.00151	0.000083	0.00581	0.00000301775	0.00021
WHO, 2004; IAEA, 2000		13.0076 0.26	7.610E-05 0.20	7.610E-05 0.20	472.30 0.10	2.59E-05	18.185E-04	9.447E-07	6.613E-05

Table 5: Statistical description of Nuclides and AEDE

		K40	Ra226	Th232	E_{Infant}	E_{Child}	E_{Teen}	E_{Adult}	FCR	LFCR	SHE	ELHE
N	Valid	20	20	20	20	20	20	20	20	20	20	20
	Missing	1	1	1	1	1	1	1	1	1	1	1
Mean		7.5095	2.8195	1.6930	.0165	.0034	.0146	.0019	4.8365	4.1769	2.2490	1.4502
Std. Error of Mean		1.24254	.61850	.27992	.00209	.00039	.00719	.00026	1.24772	1.25025	.47412	1.44999
Median		6.0650	1.8800	1.4450	.0150	.0030	.0080	.0020	3.1500	1.0959	1.5880	.0002
Mode		11.59	.00	.00	.01	.00	.00[a]	.00	.85[a]	.00[a]	.00[a]	.00[a]
Std. Deviation		5.55682	2.76601	1.25183	.00933	.00176	.03217	.00117	5.57998	5.59127	2.12035	6.48456
Variance		30.878	7.651	1.567	.000	.000	.001	.000	31.136	31.262	4.496	42.049
Skewness		1.002	.859	.440	.808	.764	4.331	2.430	1.503	1.627	.684	4.472
Std. Error of Skewness		.512	.512	.512	.512	.512	.512	.512	.512	.512	.512	.512
Kurtosis		.577	-.494	-.459	.866	.316	19.109	7.852	1.516	3.007	-.364	20.000
Std. Error of Kurtosis		.992	.992	.992	.992	.992	.992	.992	.992	.992	.992	.992
Range		21.04	8.55	4.45	.04	.01	.15	.00	18.88	20.90	6.86	29.00
Minimum		.47	.00	.00	.00	.00	.00	.00	.12	.00	.00	.00
Maximum		21.51	8.55	4.45	.04	.01	.15	.01	19.00	20.90	6.86	29.00
Sum		150.19	56.39	33.86	.33	.07	.29	.04	96.73	83.54	44.98	29.00

a. Multiple modes exist. The smallest value is shown

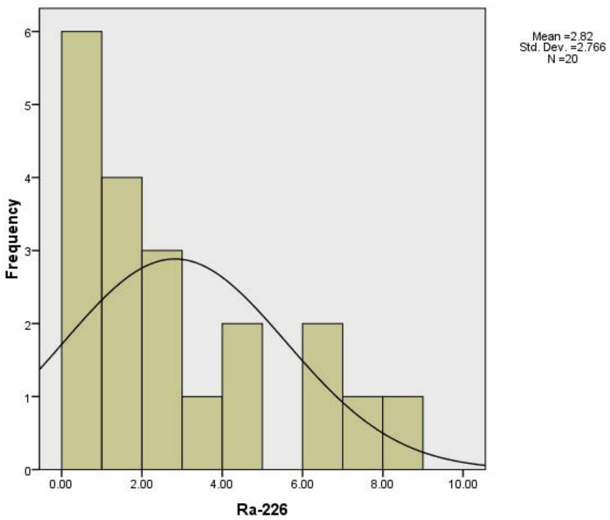

Figure 2: Frequency distributions of 226Ra in drinking water sources

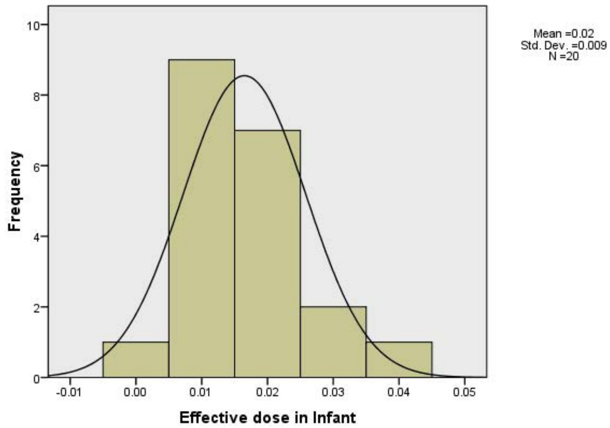

Figure 4: Frequency distributions of Infant $E_{ff}D$ in drinking water sources

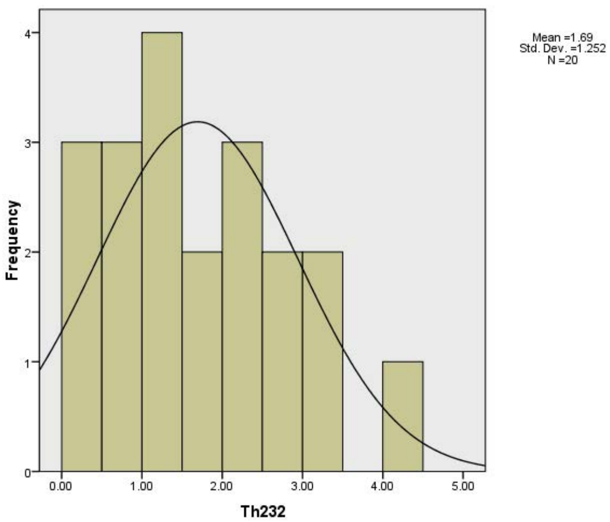

Figure 3: Frequency distributions of 232Th in drinking water sources

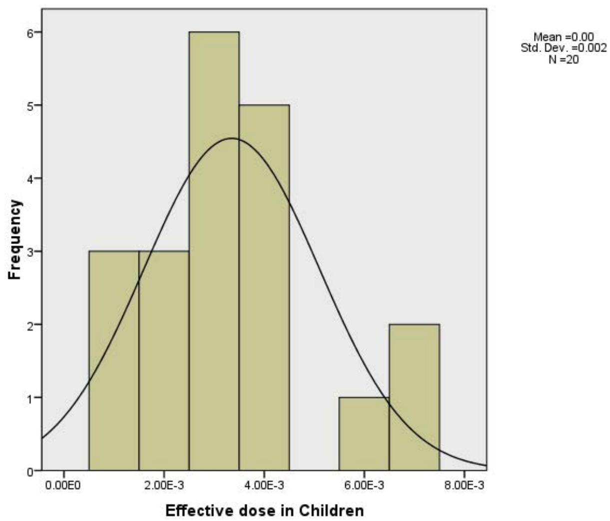

Figure 5: Frequency distributions of Children $E_{ff}D$ in drinking water sources

Table 6: Risk analysis using Pearson's Correlations

		K40	Ra226	Th232	Infant	Child	Teen	Adult	FCR	LFCR	SHE	ELHE
K40	Pearson Correlation	1										
	Sig. (2-tailed)											
	N	20										
Ra226	Pearson Correlation	.147	1									
	Sig. (2-tailed)	.537										
	N	20	20									
Th232	Pearson Correlation	.068	.261	1								
	Sig. (2-tailed)	.776	.266									
	N	20	20	20								
Infant	Pearson Correlation	-.031	.128	.427	1							
	Sig. (2-tailed)	.896	.591	.060								
	N	20	20	20	20							
Child	Pearson Correlation	-.013	.312	.547*	.271	1						
	Sig. (2-tailed)	.957	.181	.013	.247							
	N	20	20	20	20	20						
**. Correlation is significant at the 0.01 level (2-tailed).												
*. Correlation is significant at the 0.05 level (2-tailed).												
Correlation												
Teen	Pearson Correlation	-.150	-.150	-.201	.676**	.035	1					
	Sig. (2-tailed)	.527	.528	.397	.001	.884						
	N	20	20	20	20	20	20					
Adult	Pearson Correlation	-.066	.152	.077	-.034	.841**	.040	1				
	Sig. (2-tailed)	.782	.522	.748	.887	.000	.868					
	N	20	20	20	20	20	20	20				
FCR	Pearson Correlation	.129	.363	.700**	.464*	.600**	-.069	.279	1			
	Sig. (2-tailed)	.588	.116	.001	.040	.005	.772	.233				
	N	20	20	20	20	20	20	20	20			
LFCR	Pearson Correlation	-.058	.195	.096	.076	-.046	.121	-.053	.084	1		
	Sig. (2-tailed)	.807	.410	.686	.749	.849	.610	.824	.726			
	N	20	20	20	20	20	20	20	20	20		
SHE	Pearson Correlation	.216	.848**	.519*	.243	.433	-.137	.170	.456*	.341	1	
	Sig. (2-tailed)	.361	.000	.019	.301	.056	.566	.473	.043	.141		
	N	20	20	20	20	20	20	20	20	20	20	
ELHE	Pearson Correlation	.173	.173	.120	.088	.087	-.027	.020	.302	.164	.216	1
	Sig. (2-tailed)	.466	.466	.615	.711	.715	.911	.933	.195	.489	.360	
	N	20	20	20	20	20	20	20	20	20	20	20
**. Correlation is significant at the 0.01 level (2-tailed).												
*. Correlation is significant at the 0.05 level (2-tailed).												

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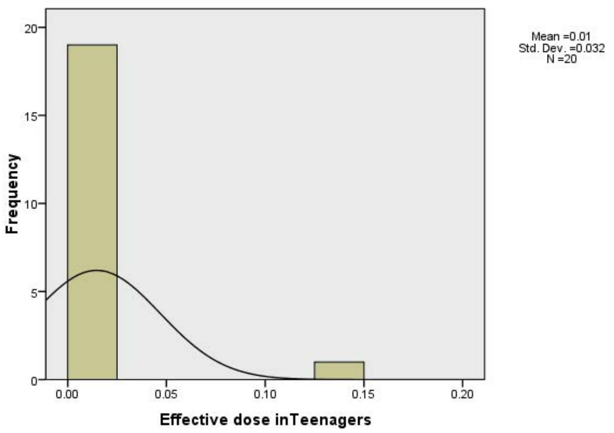

Figure 6: Frequency distributions of Teenager $E_{ff}D$ in drinking water sources

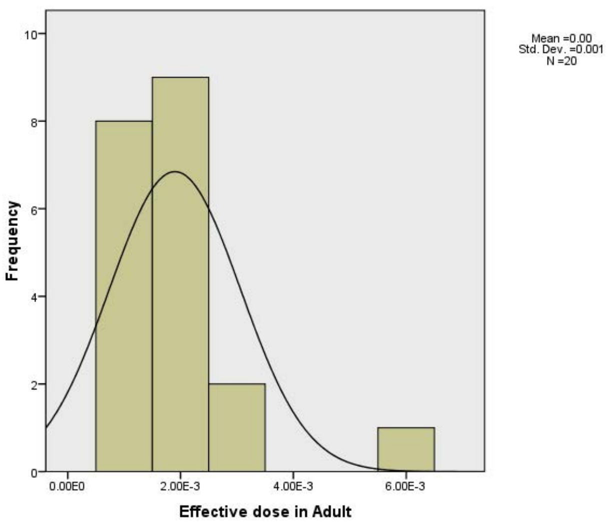

Figure 7: Frequency distributions of Adult $E_{ff}D$ in drinking water sources

Discussion

Statistical Analysis

In order to analyze the relationship between the mean and standard deviations of the radionuclides, software SPSS 16.0 was used. The statistical analysis of the measured activity was presented in Table 5 with the corresponding histogram shown in Figures 2, 3, and 4. A situation where the standard deviation was higher than the mean value is regarded as low degree of uniformity. Conversely when the standard deviation is lower than the mean the situation is regarded as good or high degree of uniformity. This analysis showed high degree of uniformity, the mean values being greater than the standard deviations. Table 5 also showed the skewness of the frequency distribution. The Skewness of the nuclides showed positive values meaning that their distributions were asymmetric. Kurtosis of the radioisotopes were also shown in Table 5. Effective doses of 40K in infants, children, teenagers and adults Potassium indicated positive Kurtosis whereas 226Ra and 232Th showed negative Kurtosis. The frequency distribution of effective doses in infants, children, teenagers and adults are shown in Figs 5, 6 and 7 respectively. The positive Kurtosis indicated that there are lesser returns above or below the mean and that the frequency of occurrence increases around the mean, hence the distribution showed low Kurtosis known as leptokurtic with high peak. On the other hand, ^{226}Ra and ^{232}Th AEDE adult showed negative Kurtosis which indicated less peaked curve than normal, a condition known as platykurtic. Correlation between the nucleides using SPSS 16.0 software were as presented in table 6 with low positive correlation between 40K and 232Th, 40K and 226Ra. The implication was that the presence of 232Th and 226Ra may not have relation with the high concentration of 40K. Similarly, 232Th and 226Ra may not necessarily be from the same source since their correlation coefficients were quite low.

Radiological Health Risks

The results Obtained showed that the annual effective dose (AED) for the infants drinking the water ranged from $4.2x10^{-5}$ (Anyama) to 0.03018 μSvy^{-1} (Amorekeni). The AED for teens ranged from $1.5x10^{-5}$ to 0.01838 μSvy^{-1} while For Adult it ranged from 1.5 $x10^{-5}$ to 0.00308 μSvy^{-1} for adult human beings. The reference levels of the effective dose for infants, children and adult due to one-year continuous ingestion of various drinking water were 0.00026, 0.00020 and 0.00010 μSvy^{-1} respectively. World Health Organization recommended reference dose level (RDL) of committed effective dose of 100 µSv from one-year consumption of drinking water. Gamma rays can enter the skin and interact with tissues or organs. Uranium and radium found in water and do not emit strong gamma radiation, so showering with that water will not pose any significant risk. When these radionuclide emissions come into direct contact with sensitive tissues or organs in the body the effect would be significant [1, 12]. Fatality cancer risk and severe hereditary effects of ingestion of the sampled drinking water sources were determined. The result showed that Fatality Cancer Risk to adult ranged from $9.2x10^{-7}$(Anyama) to 0.00019 (Amorekeni). Lifetime Fatality Cancer Risk ranged from 0.00022 (Oruma) to 0.01321 (Amorokeni). The severity hereditary effect in adult ranged from $3.34924x10^{-8}$ (Anyama) to 6.8606 $x10^{-6}$ (Amorekeni) whereas the estimated lifetime hereditary effect ranged from $2.3x10^{-6}$ (Anyama) to 0.00048 Amorekeni). The results of limetime cancer risks is in consonant with the results recoded by Ndontchueng *et al* [11]. The United States Environmental protection Agency (USEPA) recommended acceptable cancer fatality risk limit of $1.0x10^{-6}$ to $1.0x10^{-4}$. The implication is that very few water samples showed elevation above the permissible level whereas many out of the 20 samples were quite below the recommended value. The amount to which the values exceeded the standard cannot be said to be radiologically unsafe for human consumption in consideration of the $9.2x10^{-7}$ to 1.9 $x10^{-4}$ (Study) and $1.0x10^{-6}$ to $1.0x10^{-4}$ USEPA).

Conclusion

Virtually all the parameters used in this investigation yielded empirical values which fell within the internationally accepted limits though with infinitesimal occurrences of elevation. Annual effective doses for infants, children and adult were all within permissible levels. Also, the estimated lifetime hereditary health effect was found to be normal. In General, the water from these twenty communities were found to be radiologically safe for human consumption especially in consideration of the cancer fatality risk of $9.2x10^{-7}$ to $1.9 x10^{-4}$ (Study) and $1.0x10^{-6}$ to $1.0x10^{-4}$ (US-EPA). However, as a recommendation, it should be a must that water quality regarding ionizing radiation content must be checked before supplying to the general public.

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