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Annual Effective Dose and Lifetime Cancer Risks Due to Natural Radioactivity in Hand –Dug Well Water of Tai Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author CPO designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the literature searches. Author NNN managed the analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

The presence of radionuclide in water poses a number of health hazards, especially when the radionuclide is deposited in the human body through drinking water. The aim of this study was to evaluate natural radioactivity and its associated health risk in hand dug well water of Tai Local Government Area of Rivers State, Nigeria by means of gamma spectroscopy techniques and radiation models. The well water was collected from five selected coastal communities of Tai and chemically treated by adding nitric acid and then pre-concentrated further by evaporating to certain levels and kept in marineli beaker properly sealed for 28 days, after which was counted with NaI(Ti) detector. The mean values of specific activity concentration of ^{40}K, ^{226}Ra and $^{228}Ra(^{232}Th)$ were 25.90, 19.21 and 18.50 Bql^{-1} respectively. The annual effective doses for different age categories were estimated taking into consideration the ingested dose conversion factors as well as their yearly average water consumption. The average annual effective dose estimated for infants, children, teenagers and adult population were 0.115, 0.027, 0.071 and 0.013 Svy^{-1} respectively. The annual effective dose due to ingestion of the sampled water were above the recommended

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values by WHO, IAEA and UNSCEAR for the age brackets. The paper presents the overview of the techniques used and the summary of the findings. The result of this study gives the radiological baseline data for effective monitoring of the study area.

Keywords: Annual dose; ground water; lifetime cancer risk; radionuclide; spectroscopy.

1. INTRODUCTION

There are numerous liquids found in nature, water being one of them has a vast usage to animals, plants, humans and humans' activities, operations, productions and other services. According to Stabans and Kinsars [1] water is a global solvent on our planet, whose main sources include rivers, springs, wells, boreholes, seas and other fresh water bodies. Environmental radiation is either natural or artificial, however results to production of radionuclide, energies, particles and waves. Saghatchi [2] reported that radioactive materials exist everywhere in human environment and the largest portion of human exposure comes from natural sources. Stabans and Kinsars [1] noted that, many radioactive compounds or radionuclides are released into the environment and hence into drinking water supply due to human activities. He added that radionuclide can also enter the food chain if the contaminated water is used for drinking or irrigation purpose.

Ajayi and Awolabi [3], reported that the presence of radionuclide in water poses a number of health hazards, especially when the radionuclide is deposited in the human body through drinking water. Ononugbo, Avwiri and Egbeya [4] stated that, many people are increasingly concerned about a variety of contaminants in drinking water, especially those which affect human health. Ononugbo et al. [4] stated that the presence of radionuclide in drinking water can be attributed to a variety of sources, including the improper disposal of household waste products, ground storage tanks, and discharge from oil and gas industry.

Radionuclide in drinking water causes human internal exposure, caused by the decay of radionuclide taken into the body by ingestion and inhalation indirectly when they are incorporated as part of the human food chain [4,5]. Several naturally occurring alpha and beta emitting radionuclide such as ^{238}U, ^{226}Ra, ^{216}pb, ^{228}Th and others are frequently dissolved in ground water supplies (well water inclusive) and their concentrations vary over an extremely wide range, mainly depending upon the amount of radioelement in bedrock and soil with which the water comes in contact [6].

Many part of the world get their water from ground water or deep wells and the quality of water we consume at every in time determines our state of health. Most materials and all environments are exposed to ionizing radiation and few of the materials exposed to this ionizing radiation are used as building materials for our accommodations which during processing add up to the amounts of radioactive elements in the environment [7]. Completely removing radionuclides from drinking water especially well water before consumption will probably reduce the cases of terminal diseases such as cancers, benign tumors and even cataracts by few percentage but mostly radon enters the air in a home through exposure to soil and rocks, uranium are eliminated via urine and radium is stored in the bone while others are stored in the blood [8].

In Tai Local Government Area, oil exploration, drilling and local refining of crude oil has resulted to oil leakage on river waters, farm lands and seas. Moreover, oil drilling companies including shell, Elf and Chevron do flare gases into the open air, thereby increasing soot concentration in the atmosphere, acid rain and more production of radionuclide like uranium, radon gas, thorium, and potassium. In most industrial areas and host communities in Rivers State (Tai Inclusive), availability of clean and safe drinking water has been a critical issue to tackle, due to oil reservoirs, crude oil co-exist with underground water called formation water [4]. Produced water contains some level of naturally occurring radionuclide [9]. The aim of this study is to evaluate activity concentration of radionuclide in hand dug well water from some selected communities in Tai Local Government Area in order to quantify the health implication of ingesting such water.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in five selected coastal Communities Tai Local Government Area of Rivers State, Nigeria these communities are Nonwa community, Borobara community, Kira community, Korokoro community and Kpite

community. It covers an area of 159 km^2 and lies between latitude 4^{0}430$^{''}$N and longitude 7^{0}18$^{'}$0$^{''}$E. the major communities within this region (seat of the monarch of Tail) include: Nonwa, Sime, Kira, Borobara, Kpite, Korokoro, Koroma, Bunu, Banogoi, Horo, Ueken. Generally, Tail Local Government Area has two broad sections. The Tua-Tua Kingdom and the Nonwa kingdom and is situated in the South East Area of River State. It is bounded by Eleme L.G.A, Gokana L.G.A, Khana L.G.A and Oyigbo L.G.A.

2.2 Sample Collection and Preparation

Sampling was conducted from Nonwa, Borobara, Kira, Kpite and Korokoro community respectively. A total of 22 water samples were collected, and four each from each community and 2 sample was collected from outside the communities which serve as control. Plastic bottles of 1 liter each were used to collect water samples. The containers were raised twice with the water sample in order to minimize contamination from the original content of the container [10]. The water sample were then acidified with 2 drops of diluted HCL in each of the water samples to minimize the precipitation of the radionuclide present in the water sample and also prevent the absorption of the radionuclide on the walls of the containers. The water samples were tightly covered and it was stored for four weeks to reach secular equilibrium.

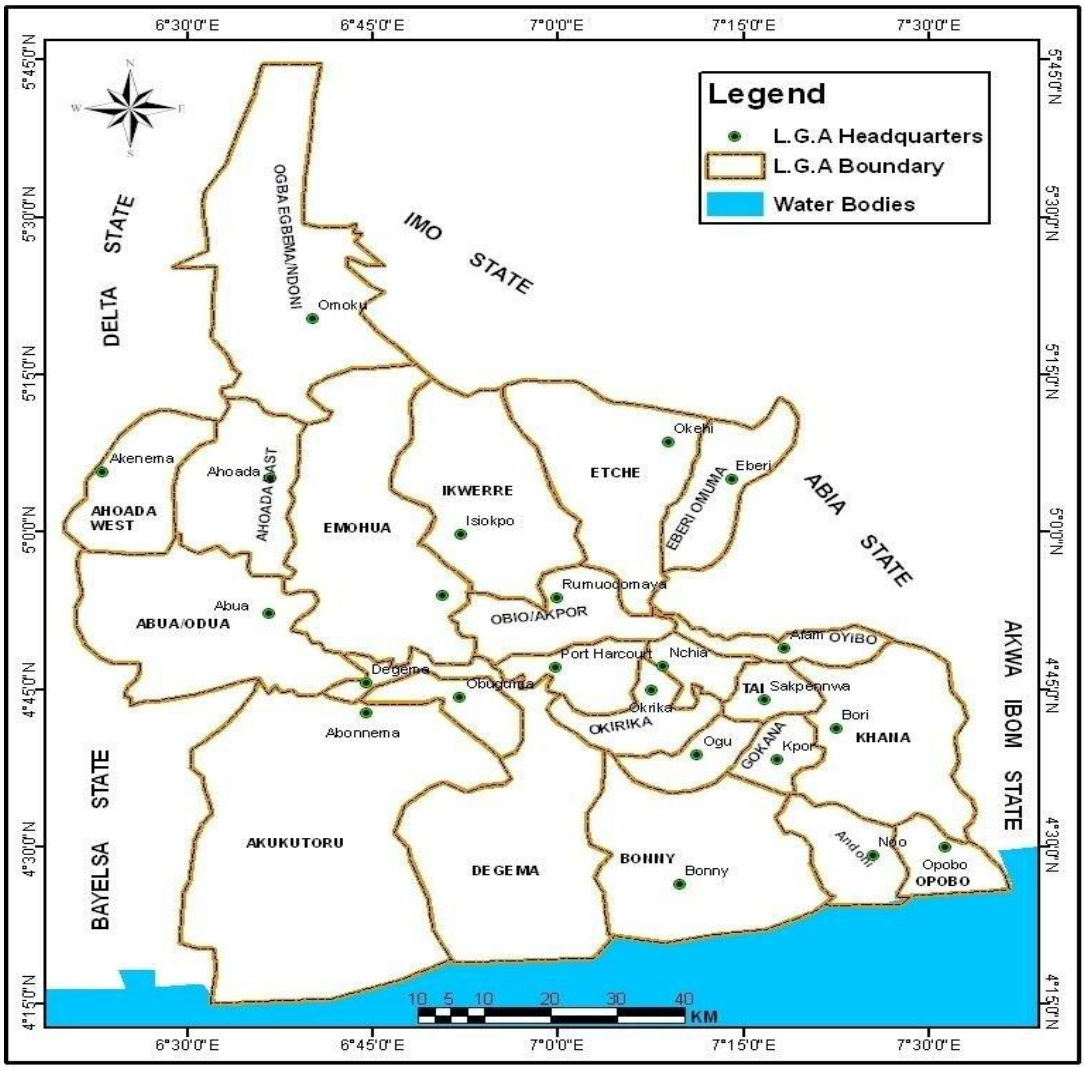

Fig. 1. Map of Rivers State showing Local Government Areas (including Tai study area)
(Source: Rivers state ministry of lands and housing)

2.3 Gamma-ray Activity Measurement

Activity measurements of radionuclides in surface water were performed at the University of Agriculture, Abeokuta with a gamma-ray spectrometry system with a thallium activated 3" x 3" sodium iodide on a Na(TI) detector connected to ORTEC 456 amplifier. The detector in a 100mm thick lead shield, was connected to a computer program called SAMPO 90 window that matched gamma energies to a library of possible isotopes. Since the accuracy of the quantitative measurement is dependent on the calibration of the spectrometry system and adequate energy; background measurement and efficient calibration of the system was made using Cs-137 and Co-60 standard sources from IAEA, Vienna [11].

The analysis was performed using a Canberra S 100 computer analyzer. Standard of natural origin were prepared in the same manner as the samples, these standards are uranyl nitrate $(UO(2)_2$. $(NO_3)_2$ $6H_2O)$ 502.18 mol/g, potassium chloride (Kcl) 74.55 mol/g and thorium nitrate (Th $(NO_3)_4.5H_2O)$ 570.13 mol/g. One gram of each of the standard was taken and dissolved into a 200 ml distilled water to form a standard solution. It is subtle that 1g of uranyl nitrate contains 0.474g of uranium which has activity of 0.0294 Bql^{-1}, also 1 g of potassium chloride contains 0.534g of potassium which has activity of 0.706 Bql^{-1} and 1 g of thorium nitrate contains 0.859 g of thorium with activity of 0.0175 Bql^{-1}.

Spectrum were accumulated for background for a period of 2900s at volts to produce strong peaks at gamma emitting energies of 1460 Kev for ^{40}K; 609 Kev of ^{232}Bi and 911 Kev of ^{228}Ac, which were used to estimate the concentration of ^{238}U and ^{232}Th respectively. The detector was calibrated with cesium-137 and cobalt-60 sources and the energy resolution is 39.5 and 22.2% respectively. The configuration and geometry was maintained throughout the analysis. The individual radionuclide concentration was calculated using relative method as in the Equation below:

$$\frac{Activity\ of\ U1}{Acivity\ of\ S1} = \frac{\Sigma U1 - \Sigma b}{\Sigma s1 - \Sigma b} \quad (1)$$

Where U1 = the unknown sample activity concentration in the unit of Bql^{-1}, S1 =activity of the standard source, $\Sigma U1$= sum under the peak of UI in cps $\Sigma S1$= the sum under the peak S1 in cps.

3. RADIOLOGICAL RISK ASSESSMENT

The annual effective dose from ingestion of radionuclide in water samples was estimated on the basis of the mean activity concentration of the radionuclides. This was done for different age brackets. In this work the intake rates and dose conversion factors for the radionuclides based on the International commission on radiological protection [12] publication are used: 0.5 L/day and 1.0 l/day for infants (age ≤ 1yr) and Children (age 1-12 years) respectively. And 2 L/day for teenagers (≤ 17yr) and adult (> 17 yrs) as presented in Table 1.

The annual effective dose from ingestion of ground water was computed by the following equation [13].

$$H_{ing}\ (w) = \sum DCF_{ing\ (i)x\ A_{spi}\ x\ I} \quad (2)$$

DCFing is dose conversion coefficient of a particular radionuclide ith in Sv/Bq for a particular age category, Aspi is the specific activity concentrations of radionuclide ith in the water samples in Bq/l and I is radionuclide intake in litres per year for each age category.

In addition to the estimated annual effective dose, the cancer and hereditary risk due to low dose without any threshold dose known as stochastic effect were estimated using the ICRP cancer risk model [14]. Radiation risk to population result from exposure to low dose radiation are normally known as chronic risk of somatic or hereditary damage of human tissues, thus much emphasis is always placed on the reduction of these radiological risks to natural radiation.

The nominal lifetime risk coefficient of fatal cancer recommended in the 2007 recommendations of the ICRP for members of the public is 5.5 x 10^{-2} Sv^{-1}. For hereditary effects, the detriment adjusted nominal risk coefficient for the whole population as stated in ICRP [14] for stochastic effects after exposure at low dose rates is estimated at 0.2 x 10^{-2} Sv^{-1}.

The risk to population was then estimated using the recommended risk coefficient in ICRP report and assumed 70 years lifetime of continuous exposure of population to low level radiation. According to the ICRP methodology:

Cancer Risk = Total annual Effective Dose (Sv) x cancer risk factor (3)

Hereditary Effects = Total annual Effective Dose (Sv) x hereditary effect factor (4)

3.1 Radium Equivalent Activity, Ra_{eq}

This single quantity was introduced as a common radiological index that represent the activity levels of ^{232}Ra, ^{232}Th and ^{40}K, when considering the radiation hazards associated with them (Diab et al., 2008). This Index called Radium Equivalent activity (Ra_{eq}) is mathematically defined by (UNSCEAR, 2000):

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_K \quad (5)$$

Where C_{Ra}, C_{TH} and C_K are the activity concentrations of ^{226}Ra, ^{212}Th and ^{40}K respectively, assuming that 10 Bqkg^{-1} of ^{226}Ra, 7 Bqkg^{-1} of ^{232}Th and 130 Bqkg^{-1} of ^{40}K produce equal gamma dose, the maximum value of Ra_{eq} in soil must be less than 370 Bqkg^{-1} (Zarie, 2007).

4. RESULTS AND DISCUSSION

The specific activity concentrations of ^{40}K, ^{226}Ra, and ^{228}Ra (^{232}Th) identified in hand dug well water samples from the selected coastal communities in Tai Local Government area of Rivers State as well as their radium equivalent (Raeq) are presented in Table 2. From Table 2, the activity concentration of ^{40}K varies distribution of the radionuclide identified from 5.68±4.59 to 88.99±3.01 Bql^{-1} with an average value of 25.90 Bql^{-1}. The specific activity concentration of ^{226}Ra ranged from 4.51±2.9 to 44.73 ± 3.64 Bql^{-1} with average value of 19.21 Bql^{-1}. The activity concentration of ^{228}Ra (^{232}Th) varied between BDL to 221.81 ±2.61 Bql^{-1} with an average value of 18.50 Bql^{-1}.

This variation in activity concentration of ^{40}K, ^{226}Ra, and ^{228}Ra (^{232}Th) observed in the samples indicate that the origins of this water are not the same and they come from different depths and pass through different geological layers. Also this irregular distribution of the radionuclides identified could be due to industrial activities in these communities and their content in solid aquifers in the area of study. These variations in activity concentration of ^{40}K, ^{226}Ra, and ^{228}Ra (^{232}Th) strongly depend on the physical and chemical properties of each water sample.

Activity concentration for ^{40}K, ^{226}Ra, and ^{232}Th were high in all the samples except in Borobara 2 where the activity concentration of ^{232}Th where below the detectible limit. This could be due to agrochemical which include nutrients of plants, fertilizers, and discharge of oil and gas products into the environments. The increase in the activity concentration across all communities could be a result of effluent production from the oil and gas drilling companies which might have concentrated potassium and radium at those locations. The highest activity concentration of ^{40}K (88.99±3.01 Bql^{-1}.) was recorded at Kira 2. This could be due to massive use of NPK fertilizer in the area to improve the crop yield which might get into the water bodies and ground water. Also the highest activity concentration of ^{228}Ra (^{232}Th) was recorded in Borobara 1 (24.81±2.61 Bql^{-1}), ^{40}K, ^{232}Th and ^{26}Ra was detected in all the well water and this could be because of the frequent and constant discharge of oil and gas into ground water and other maritime activities which has concentrated the activity concentration of these radionuclides.

The results obtained shows that the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in sampled hand dug well water were higher than safe recommended value set by the environment protection agency and World Health Organization as shown in Figs. 2 to 4. The range of thorium (^{232}Th) in natural water is set at 1.0-10.0 mBql^{-1} and uranium (^{226}Ra) range from 1.0- 10 Bql^{-1} but the range for ^{40}K was not specified by Environmental Protection Agency and WHO, [15] recommended the maximum allowable committed effective dose equivalent of 4 mrem/y for annual intake for adult.

Table 1. Committed effective dose conversion factor (Sv/Bq) for members of the public (ICRP, 2012)

S/N	Radioisotope	Infant ≤ 1 yr	Children (1-12 yr)	Teenage (12-17)	Adult ≥ 17 yr
1	^{226}Ra	4.7 E-06	6.2 E-07	1.5 E-06	2.8 E-07
2	^{232}Th	3.0E-05	3.4 E-06	5.3 E-06	6.2 E-07
3	^{40}K	6.2 E-08	2.1 E-08	7.6 E-09	6.2 E-09
	H_2O Intake	0.5 L	1.0 L	1.5 L	2.0 L

Table 2. Specific activity concentrations of radionuclide in various sampling locations and its radium equivalent

S/N	Sampling code	Activity concentration in Bql^{-1}			Ra_{eq} (Bql^{-1})
		^{40}K	^{226}Ra	$^{228}Ra(^{232}Th)$	
1	KPITE1	16.42±3.13	37.36±1.83	23.43±1.74	72.13
2	KPITE2	14.36±2.56	9.50±2.32	16.11±3,18	33.64
3	KPITE3	5.68±2.54	36.54±1.45	23.84±1.74	71.07
4	KPITE4	13.58±4.52	11.96±4.05	24.25±2.46	47.68
5	KIRA 1	12.00±2.06	4.59±2.54	22.62±2.67	37.86
6	KIRA 2	88.99±3.01	7.78±4.85	25.06±3.27	50.47
7	KIRA 3	10.79±4.72	10.65±3.89	27.77±3.58	51.19
8	KIRA 4	11.99±4.60	7.50±3.00	20.23±2.92	37.35
9	NONWA 1	26.99±4.50	4.59±3.12	27.73±1.92	46.32
10	NONWA 2	5.68±4.59	19.17±2.34	23.98±2.67	53.90
11	NONWA 3	14.58±4.21	31.63±2.67	27.37±1.55	71.89
12	NONWA 4	43.57±3.03	28.35±2.74	22.89±3.36	64.44
13	BOROBARA 1	30.15±4.79	11.31±2.24	221.81±2.61	45.35
14	BOROBARA 2	45.93±4.81	35.72±2.46	BDL	39.26
15	BOROBARA 3	32.52±4.41	28.27±2.74	23.98±3.18	65.07
16	BOROBARA 4	13.31±4.52	28.35±2.67	25.87±2.24	66.37
17	KOROKORO 1	38.73±5.25	44.73±3.64	23.30±2.61	50.14
18	KOROKORO 2	40.65±3.15	4.51±2.9	26.82±3.31	45.99
19	KOROKORO 3	34.72±3.67	15.77±2.67	27.91±4.40	58.35
20	KOROKORO 4	27.25±1.22	8.68±3.12	24.61±2.30	45.97
21	CONTROL 1	7.04±4.07	6.14±1.83	5.33±1.55	83.88
22	CONTROL 2	4.89±4.71	1.34±3.42	6.28±1.92	59.61
	Mean	25.90	19.21	18.50	54.43
	UNSCEAR, 2000	10.0	10.0	1.0	-

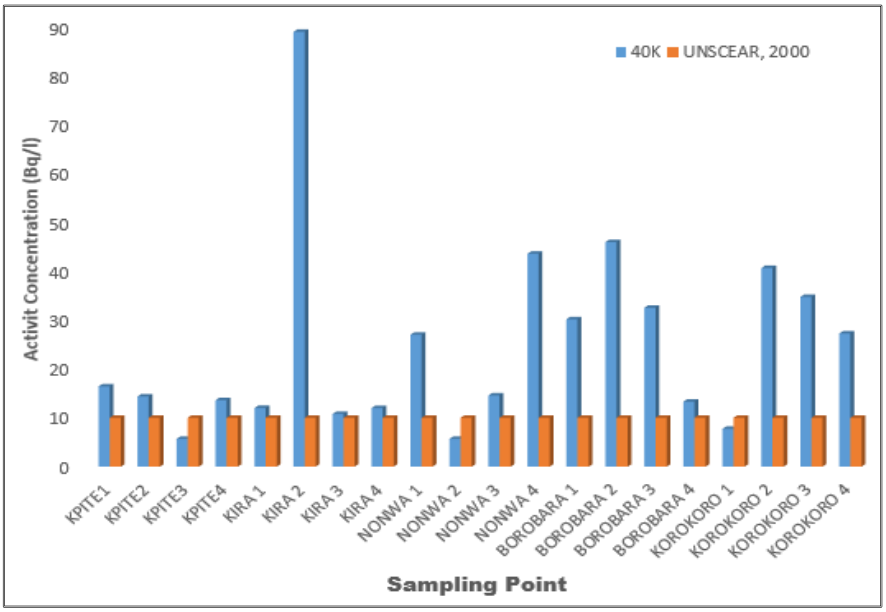

Fig. 2. Comparison of activity concentration of ^{40}K with UNSCEAR, (2000) recommendation

The average activity concentration of ^{40}K (25.90) Bql^{-1} in the present study is comparatively higher than the average value obtained in Cameron (0.107 Bql^{-1}) by Ndontchueng et al. [13]. It is also higher than the average values obtained in Italy (Milano) (0.05 Bql^{-1}) by Roscuni [16].

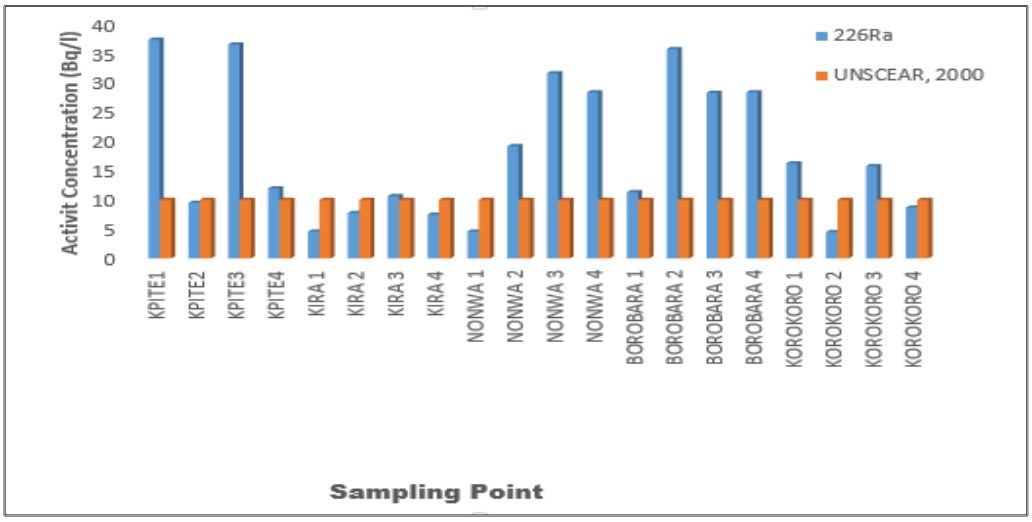

Fig. 3. Comparison of activity concentration of ^{226}Ra with UNSCEAR, (2000) recommendation

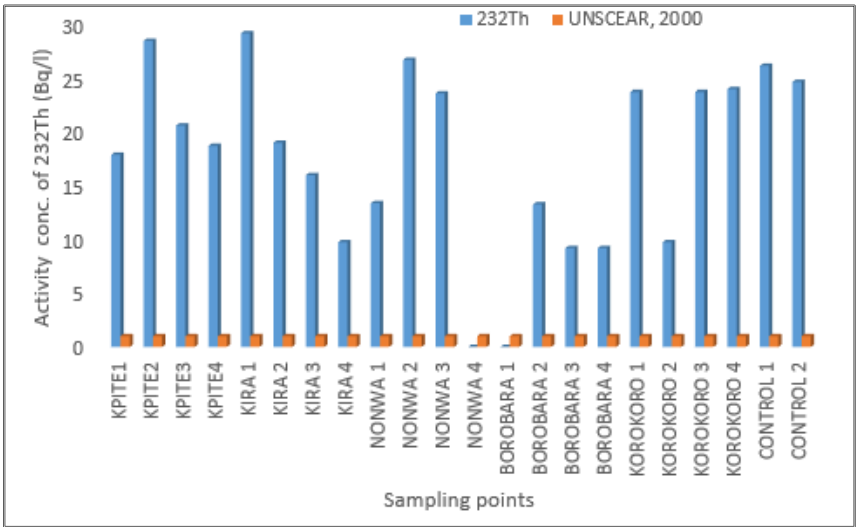

Fig. 4. Comparison of activity concentration of ^{232}Th with UNSCEAR recommendation

In the same way, the average concentration of ^{228}Ra (^{232}Th) 18.50 Bql^{-1} is comparatively higher than the value obtained in Cameroon (0.036 Bql^{-1}) by Ndontchueng et al. [13]. The values obtained in this work were thus compared favorably with the reported average values published by other authors. The activity concentration of ^{40}K, ^{226}Ra and ^{228}Ra (^{232}Th) obtained in this study were also compared with the guideline activity concentration values of the radionuclide in drinking water recommended by the World Health (WHO) and other data obtained from IAEA. This comparison showed that our results were found to be higher than the recommended safe value.

The annual effective dose due to ingestion of the monitored ground water was estimated for different age groups including infants, children, teenage and adults considering only the ingestion of ^{226}Ra and ^{228}Ra (^{232}Th) as shown in Table 3. Potassium (^{40}K) values were not considered during the calculation of the radiation dose because the absorption of the essential potassium element is under homeostatic control and takes place mainly from ingested food. Thus, the potassium contribution to the dose from ingestion in water, with its relatively low dose conversion factor will be much less than that of many other radionuclides.

Table 3. Annual effective doses for different ages and estimated cancer risks and hereditary effects on adult member of the public

S/N	Location	Total effective dose (Svy^{-1})				Cancer risk to adult		Hereditary effect in adult	
		E_T Infant	E_T Child	E_T Teenage	ET Adult	FCR $x10^{-3}$	LFCR $x10^{-3}$	SHE $x10^{-5}$	ELHE $x10^{-3}$
1	KPITE1	0.111	0.026	0.065	0.011	0.62	43.48	2.26	1.58
2	KPITE2	0.318	0.078	0.238	0.051	2.83	198.11	10.29	7.20
3	KPITE3	0.142	0.033	0.088	0.016	0.90	62.86	3.27	2.29
4	KPITE4	0.121	0.028	0.071	0.013	0.71	49.61	2.58	1.80
5	KIRA 1	0.185	0.043	0.109	0.019	1.06	73.97	3.84	2.69
6	KIRA 2	0.115	0.027	0.066	0.011	0.62	43.29	2.25	1.57
7	KIRA 3	0.088	0.020	0.046	0.007	0.40	27.94	1.45	1.02
8	KIRA 4	0.083	0.020	0.056	0.011	0.63	44.04	2.29	1.60
9	NONWA 1	0.104	0.025	0.068	0.013	0.73	51.17	2.66	1.86
10	NONWA 2	0.159	0.036	0.089	0.015	0.83	58.04	3.02	2.11
11	NONWA 3	0.138	0.032	0.076	0.013	0.71	49.39	2.57	1.80
12	NONWA 4	0.00007	0.00005	0.00004	0.00003	0.02	0.11	0.006	0.004
13	BOROBAR1	0.021	0.006	0.020	0.005	0.28	19.91	1.03	0.72
14	BOROBA 2	0.097	0.023	0.062	0.012	0.66	45.98	2.88	1.67
15	BOROBA 3	0.065	0.015	0.040	0.008	0.42	29.49	1.53	1.07
16	BOROBA 4	0.083	0.020	0.057	0.012	0.65	45.78	2.38	1.66
17	KOROKOR1	0.140	0.032	0.079	0.013	0.73	50.87	2.64	1.85
18	KOROKO 2	0.083	0.020	0.056	0.011	0.63	44.04	2.29	1.60
19	KOROKO 3	0.141	0.033	0.080	0.014	0.74	51.98	2.70	1.89
20	KOROKO 4	0.144	0.033	0.081	0.014	0.76	53.39	2.77	1.94
21	CONTROL 1	0.196	0.047	0.127	0.025	1.35	94.42	4.90	3.43
22	CONTROL 2	0.146	0.034	0.083	0.014	0.76	53.52	2.78	1.95
Mean		**0.11507**	**0.0271**	**0.07063**	**0.01343**	**0.74**	**0.05172**	**2.69**	**1.88**

E_T = Total Annual Effective, FCR = Fatality cancer risk to adult per year, LFCR = Lifetime fatality cancer risk to adult, SHE = Severe hereditary effect in adult per year, ELHE = Estimated lifetime hereditary effect in adult

The estimated effective dose for different age groups were ranged from 0.00007 to 0.318 Svy^{-1} for infants, between 0.00005 and 0.078 Svy^{-1} for children, varied from 0.00004 to 0.238 Svy^{-1} for teenagers and varied from 0.00003 to 0.051 Svy^{-1} for adults with average values of 0.115, 0.027, 0.071 and 0.013 Svy^{-1} respectively. It can be seen that radiation dose received by infants are relatively higher than that received for children, teenagers and adults. This result is an agreement with the work done in Cameroon by Ndontchueng et al. [13]. Comparing with the WHO, IAEA and UNSCEAR [15,11,17] recommended reference levels of the effective dose for infants, children, teenagers and adults corresponding to one year consumption of drinking water are 0.26, 0.2 and 0.1 $mSvy^{-1}$, respectively. The doses obtained in this study are higher than the recommended reference level and from radiation protection point of view, life-long consumption of these investigated hand dug well waters may cause significant radiological health risk.

In order to evaluate the radiation risk due to ingestion of the selected radionuclides, the ICRP methodology was adopted in this study and the results shown in Table 3. The results of the cancer and non-cancer risk components were evaluated from the estimated annual effective dose of the sampled water. The result of the evaluated fatal cancer risk to adult per year in each sample ranged from 0.02×10^{-3}(NONWA 4) to 2.83×10^{-3} (KPITE 2) with an associated lifetime fatality cancer risk of 0.11×10^{-3} (NONWA 4) to 198.11×10^{-3} (KPITE2). The evaluated lifetime hereditary effect to adult per year varied from 0.006×10^{-5} (NONWA 4) to 10.29×10^{-5} (KPITE 2) with an associated lifetime hereditary effect in adult of 0.004×10^{-3} (NONWA 4) to 7.20×10^{-3} (KPITE 2).

This means that in terms of the lifetime fatality cancer risk to adult, approximately 2 out of 1000 may suffer from some form of cancer fatality and for the lifetime hereditary effect, approximately 7 out of 1000 suffer some hereditary effects. The negligible cancer fatality risk value recommended by USEPA is in the range of 1.0×10^{-6} to 1.0×10^{-4} (ie 1 person out of 1 million or 10,000 suffering from some form of cancer fatality is considered trivial). Comparing the estimated results of the lifetime fatality cancer risk in this study with the acceptable risk factor, it can be inferred that all the estimated results of the lifetime fatality risk in adult citizen of selected communities of Tai Local Government Area of Rivers State, Nigerian population due to ingestion of radionuclide in hand dug well water are relatively higher than the range of acceptable risk values recommended by USEPA [18].

5. CONCLUSION

The annual effective dose and lifetime cancer risk due to natural radioactivity in hand dug well water of Tai Local Government Area of Rivers State, Nigeria has been estimated using Gamma spectroscopy techniques and some radiation models. The mean activity concentration of ^{40}K, ^{226}Ra and ^{228}Ra (^{232}Th) in hand dug well waters are 25.90, 19.21 and 18.50 Bql^{-1} respectively. Radium equivalent varied from 33.64 to 83.88 Bql^{-1}.

The average annual effective dose estimated for infants, children, teenager and adults were 0.115, 0.027, 0.071 and 0.013 Svy^{-1} respectively. It can be seen that radiation dose received by infants are relatively higher than that received for children, teenagers and adults. The lifetime fatality cancer risk to adult estimated show that approximately 2 out of 1000 may suffer from some form of cancer fatality while approximately 7 out of 1000 may suffer some hereditary effects.

The estimated annual effective dose and lifetime fatality risk in adult citizens of Tai, Rivers State due to ingestion of ^{226}Ra , ^{228}Ra(^{232}Th) and ^{40}K in hand dug well water sampled are higher than recommended safe values. Based on the findings of this work, we can conclude that hand dug well waters from area of study is not suitable for human consumption especially infants. The well water has been radiological polluted due to their shallow depths and effluents from oil and gas production activities. The result of this work serves as baseline radioactivity data for future studies in the study area since no radiological work has been done in the area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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