RADIOLOGICAL RISK ASSESSMENT OF DRINKING WATER FROM IGNATIUS UNIVERSITY QUARTERS

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Abstract

The presence of radionuclide in water constitute health risks to humans. Ingestion of such water increases the likelihood of incurring cancer. Radiological risk analysis will enhance the detection of significant radionuclides and its associated health risk. The aim of this study was to assess the natural radioactivity and its associated health risk in Tap water from university quarters of Ignatius University of Education, Rivers State by means of gamma spectroscopy techniques and radiation models. The tap water was collected from residential quarters and class rooms and chemically treated by adding nitric acid and then pre-concentrated further by evaporating to certain levels. The residue were transferred to small cylindrical containers were kept sealed in order to ensure secular equilibrium between ^{238}U, ^{232}Th and their progenies for 28 days and counted with sodium iodide activated with thallium detector. The measured activity concentration of natural radionuclides such as ^{40}K, ^{226}Ra and ^{232}Th in drinking water were in the range of 4.14±3.61 to 48.30±3.88 Bql^{-1}, BDL to 188.51±2.69 Bql^{-1} and BDL to 29.17±3.42 Bql^{-1} respectively The specific activity concentration of ^{40}K, ^{226}Ra and ^{232}Th obtained were used to estimate the annual effective doses for different age categories by taking into consideration the ingested dose conversion factors as well as their yearly average water consumption. The annual effective dose due to ingestion of the sampled water were above the recommended values by WHO. 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 drinking water in the study area.

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Keywords: Radionuclide, Spectroscopy, lifetime cancer risk and hereditary effects.

1. Introduction

Life will not survive on earth without water. It is the most important resources to man after air. Various sources of water exist but the most accessible is that which is readily available to individual community [1]. Ground water harnessed as dug or drilled well, boreholes, is the major source of water for homes and the entire university community of the study area. Humans are constantly exposed to some levels of environmental radiation. According United Nations Scientific Committee on the Effects of Atomic Radiation [2] about 87% of the radiation doses

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received by human are from natural sources while the remaining is due to anthropogenic radiation. The natural source can be terrestrial or cosmic. The cosmic sources include radiations from extra-terrestrial origin while the terrestrial sources naturally from air, water, soil, rocks and building materials. The knowledge of natural sources of background radiation is the most important and immediate concern to the general population [3].

Natural radioactivity has always been present and broadly distributed in the earth's crust and the atmosphere, either as primordial radionuclides or uranium (^{238}U) and thorium (^{232}Th) decay series and radioactive potassium (^{40}K) or as cosmic radiations that are produced constantly in the atmosphere [3] in terms of radiation exposure, primordial radionuclide of ^{238}U and ^{232}Th decay series and ^{40}K which has extremely long half-lives of great concern due to their gamma ray emitting potential. The actual level of radiation caused by the radionuclide content of rocks and soil varies widely from place to place and the actual background radiation contributes to the external gamma dose rate at a given location which can be determined by measurement. The dose rate depends on the geological structure and geographical conditions and appears at different levels in the soil of each region of the world [4, 5, 6]. Higher radiation levels are associated with igneous rocks such as granite and lower level with sedimentary rocks; however, some shale's and phosphate rock have relative high content of radionuclide [7].

Water is a vital resource to mankind provided by God. The availability of clean water sources poses a problem to the present civilization and a concern to many researchers. Since water is essential to sustain life, a satisfactory supply must be available to all, and the primary interest of the World Health Organization to drinking water quality is to protect public health [8]. Improving access to safe drinking water can result in tangible benefits to human health [9]. Since water is an essential commodity to man, the quality of water ingested at every given time determine our health status, completely removing of radionuclide in our tap water before consumption, will probably reduce the cases of terminal diseases like cancer, cataract. The presence of radionuclide in drinking water poses health hazard when ingested into the body. Dumping of industrial, medical and domestic waste such as phosphogypsum, alum, shale's, scraps from oil and gas plant, waste from the hospital and discharge from nuclear fuel cycle, seepage can contaminate the soil, surface and underground water resources[10].

When water flows through rocks, soil cracked cement surrounding a water source; it can pick up radioactive materials, thereby contaminating the water source [11]. The predominant radionuclide found in water include radium (and its decay products) Uranium (and its decay products) radon (and its decay product), thorium (and its decay product). Natural radionuclide constitutes a treat to humans when ingested or inhaled in the body either through drinking water and food chain [12]. The effect can be chronic such as Terminal Diseases, Acute leucopenia, anemia, cancer [13]. Therefore, this work centered on the determination of the background radiation exposure rate and measurement of radioactivity level in drinking water from the staff quarters and class room with the aim of quantifying its radiological health implication.

2. Materials and Methods

2.1 Study Area

Study Area

The study area is Ignatius Ajuru University of Education residential quarters and its environs situated at Iwofe, Rumuolumeni in Obio/AkporLocal Government Area, Port Harcourt, Rivers State, Nigeria. It is located at the central part of Niger Delta. The study area lies between latitudes 4°45'N and 4°60'N and longitudes 6°50'E and 8°00'E. It lies in the tropical wet climate zone, characterized by abundant rainfall with little dry season. The monsoon season occurs between April and October, bringing heavy rainfall ranging from 2000 to 2500 mm with temperatures up to 25°C and a relatively constant humidity. Rumuolumeni is generally a lowland area with average elevation below 30 meters above sea level. Its geology comprises basically of alluvial sedimentary basin and basement complex. The thick mangrove forest, raffia palms and light rainforest are the major types of vegetation. Due to high rainfall, the soil in the area is usually sandy or sandy loam. It is always leached, underlain by a layer of impervious pan.

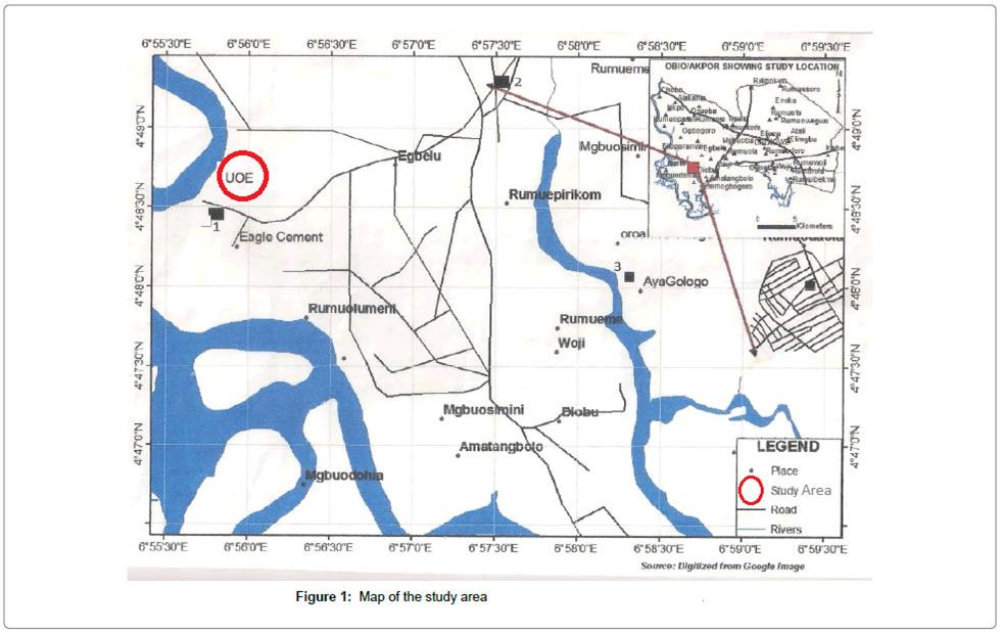

Figure 1: Map of the study area

Fig.1: Map of the study Area

Rumuolumeni axis of Port Harcourt play host to the eagle cement. The main operation of this industry involves the bulk importation of cement dust (clinker) through the new Calabar river, to the jetty, the clinker will then be stored in the tank farms and then transferred into Jumbo bags into the mixing machine in the ware house for proper blinding of the clinker with the shale ash and adhesive to form cement nous product, from the mixing unit it goes to the bagging machine where the cement is package and ready to be distributed to industrial and domestic users. Throughout this process, there will be constant emission of Co_2 as waste to the environment. The processes of heating, blending of the raw materials together and bagging of the product, there will be continuous emission of dust as waste to the environment, since cement contains some level of iron, aluminates and silicate component when introduce into the environment as waste could degrade soil and underground water. Some of the operation takes place in ships berthed in the river thereby degrading the surface water, farming, fishing and general buying and selling activities also takes place.

2.3 Sample Collection and preparation

A total of 23 water samples were collected, twenty within the university campus and the other three were collected outside the campus to serve as a control measure. At each sampling point, plastic containers of 1.5 litres were rinsed three times with the water being collected to minimize contamination from the original content of sample container; the amount collected was such that an air space of about 1% of container capacity was created for thermal expansion. Before collection of water samples, the taps were first turned down to reduce turbulent flow and to reduce radon loss before collection. The water samples were immediately acidified with nitric acid (HNO^{3}) to reduce the pH and minimize the absorption of radioactivity into the walls of the container [14]. Applying of nitric actually help to retain the element in the water from missing or being deficient. The samples were tightly covered and taken to the laboratory to be processed, to obtain equilibrium state for gamma spectroscopy. The samples were kept in marinelli beaker sealed. Sealed for one month, due to smaller life of the daughter radionuclide in the decay series of ^{232}Th and ^{238}U the ^{232}Th activity was determine from the average activities of ^{208}Ti at 583 Kev and ^{226}Ac at 911 Kev in the samples and that of ^{226}Ra was determined from the average activities of the decay product ^{214}Pb at 352 Kev and Bi at 609 Kev. The activity of ^{40}K was based on 1460 Kev peak [3].

2.3 Gamma Spectroscopy

A lead-shielded 76mm x 76mm Nal(TI) detector crystal (Model No. 802 series, Canberra Inc.) coupled to a Canberra Series 10 plus Multichannel Analyzer (MCA) (Model No. 1104) through a preamplifier was used for the radioactivity measurement. It has a resolution (FWHM) of about 8% at energy of 0.662 MeV (137Cs) which is considered adequate to distinguish the gamma ray energies of interest in the present study. The photon emitted by them would only be sufficiently discriminated if their emission probability and their energy were high enough, and the surrounding background continuum low enough. The samples were placed symmetrically on top

of the detector and measured for a period of 10 hours. The net area under the corresponding peaks in the energy spectrum was computed by subtracting counts due to Compton scattering of higher peaks and other background sources.
After background correlation, the net area count in each photo peak was used to estimate the specific activity concentration of each of the radionuclide in the samples using the relationship.

$$A_s = \frac{Aa}{P\gamma E\gamma tc \frac{Ms}{Vs}} \text{ (Bq/kg)}$$

Where A_s is sample concentration, A_a is net peak area of a peak at energy, E_γ is the efficiency of the detector $\frac{Ms}{Vs}$ is sample mass, P_γ is the abundance of gamma line in a radionuclide and t_c is total counting time. The specific activity concentrations of the parent nuclides were obtained using their daughter nuclide specific activity concentration assuming attainment of secular equilibrium within the period of storage. Background measurement and efficiency calibration of the system was made using ^{137}Cs and ^{60}Co standard sources from IAEA, Vienna, spectrum were accumulated for background for 29,000s at ^{900}v to produce strong peaks at gamma emitting energies of ^{1460}Kev for ^{40}K, ^{609}Kev of ^{214}Bi and all Kev of ^{228}Ac.

3. Standard Radiological Risks Assessment

Standard radiation hazard indices were used to evaluate the effects of radiation doses on the health of humans that are exposed to natural environmental radiation through ingestion and inhalation [15]. The indices to be evaluated are discussed below.

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 as presented in Table 1.

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

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

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 [16]. 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 [16] 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)

Table 1: Committed Effective Dose Conversion Factor (Sv/Bq) for members of the Public [16].

S/N	Radioisotope	Infant ≤ 1yr	Children (1-12yr)	Teenage (12-17)	Adult ≥ 17yr
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
	Annual water consumption	182.5 L	365 L	547.5 L	730 L

4. Result and Discussion

The measured activity concentration of natural radionuclides such as ^{40}K, ^{226}Ra and ^{232}Th in drinking water were in the range of 4.14±3.61 to 48.30±3.88 Bql^{-1}, BDL to 188.51±2.69 Bql^{-1} and BDL to 29.17±3.42 Bql^{-1} respectively. The mean activity concentration values ^{40}K, ^{226}Ra and ^{232}Th are 18.79±4.24, 27.55±5.99 and 17.79±2.89 Bql^{-1} respectively as presented in Table 2. The variation in the activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th observed in these samples indicate that their origins are not the same and that they came from different depths and pass through different geological layers. Likewise this irregular distribution of activity concentrations of the selected nuclides in the water may depend on their contents in rocks and may strongly depend on the physical and chemical properties of each water sample.

Comparing the results obtained in this work with results of other similar works, the activity concentration of ^{40}K, ^{226}Ra and ^{232}Th in drinking water were higher than that obtained in Cameroon mineral water by Ndontchueng *et al*., [17]. The mean activity concentration of ^{40}K obtained in this study are lower than the activity concentration of ^{40}K, in dam reservoir water obtained by Inikunle *et al*., [15] but the mean activity concentration of ^{226}Ra and ^{232}Th (27.55±5.99 and 17.79±2.89 Bql^{-1}) obtained in this work were higher than that obtained dam

water (9.00±3.34 and 7.13±2.63) by Inikunle *et al*.,[15]. This could be due to differences in their sources or origin which depends on the geological component of the area. The activity concentration of ^{40}K, ^{226}Ra and ^{232}Th in all the samples were higher than the WHO (2006) recommendation value of 10, 1.0 and 1.0 Bql^{-1} respectively as shown in figures 2,3 and 4..

The highest activity concentration of ^{226}Ra (188.51±2.69 Bql^{-1}) was recorded at AIT_2 which corresponds to staff quarter very close to Cement bagging industry and a large waste dump site. This might have contributed to very high value obtained. The mean activity concentration of ^{226}Ra (27.55±5.99 Bql^{-1}) obtained is higher than the mean values of ^{40}K and ^{232}Th (18.79±4.24 and 17.79±2.89 Bql^{-1}). This implies that this wide range of ^{226}Ra concentration is in relation to the geological structure and to the characteristics of the areas.

Table 2: Specific Activity Concentrations of Radionuclide in Various Sampling Locations and its Radium Equivalent.

S/N	LOCATION	Specific Activity Concentration ($Bqkg^{-1}$)			
		^{40}K	^{226}Ra	^{232}Th	Raeq ($Bqkg^{-1}$)
1	AIT_1	12.21±5.32	15.41±3.85	17.87±2.54	41.90
2	AIT_2	10.65±3.73	188.51±2.69	28.45±3.08	230.01
3	AIT_3	9.31±4.05	34.08±2.08	20.59±1.45	64.24
4	AIT_4	38.04±4.60	20.81±4.98	18.69±3.06	50.47
5	AIT_5	10.42±4.31	29.17±4.31	29.17±3.42	71.69
6	AIT_6	9.31±5.80	12.78±4.29	18.98±3.12	40.64
7	AIT_7	6.47±2.79	BDL	15.97±3.30	23.34
8	AIT_8	14.36±5.54	34.08±2.46	9.74±2.94	49.11
9	AIT_9	24.62±3.21	34.90±2.24	13.36±3.95	55.90
10	AIT_{10}	11.18±2.75	14.41±3.45	26.69±3.45	53.44
11	AIT_{11}	48.30±3.67	9.50±3.36	23.57±2.32	46.92
12	AIT_{12}	6.47±3.68	BDL	BDL	0.50
13	AIT_{13}	47.51±4.25	24.25±3.12	BDL	27.91
14	AIT_{14}	32.52±5.29	28.35±2.54	13.26±2.67	49.82
15	AIT_{15}	48.30±3.88	16.06±2.94	9.19±3.12	32.92
16	AIT_{16}	21.15±5.18	37.36±2.94	9.19±3.12	52.13
17	AIT_{17}	1.74±4.25	12.13±3.85	23.7±3.16	46.15
18	AIT_{18}	14.36±5.54	34.08±2.46	9.74±2.94	49.11
19	AIT_{19}	10.79±3.12	13.34±2.58	23.7±3.16	48.06
20	AIT_{20}	14.89±5.97	14.42±4.00	23.98±2.16	49.86
21	AIT_{21}	7.26±2.86	61.94±4.01	26.14±2.16	99.88
22	AIT_{22}	4.14±3.61	13.34±4.01	24.65±3.43	48.91
23	AIT_{23}	26.20±3.95	3.77±1.85	22.75±2.94	38.32
	AVERAGE	**18.79±4.4.24**	**27.55±5.99**	**17.79±2.89**	

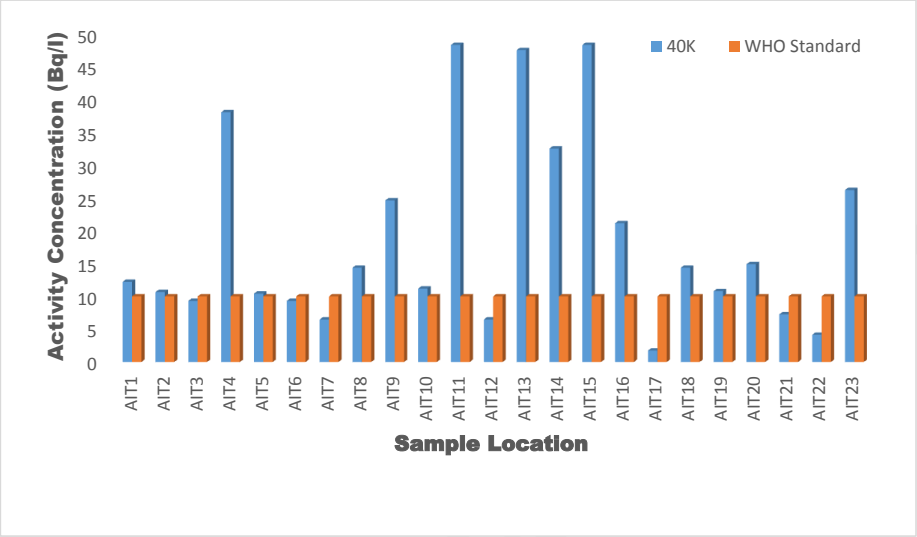

Fig. 2: Comparison of activity concentration of ^{40}K with WHO standard

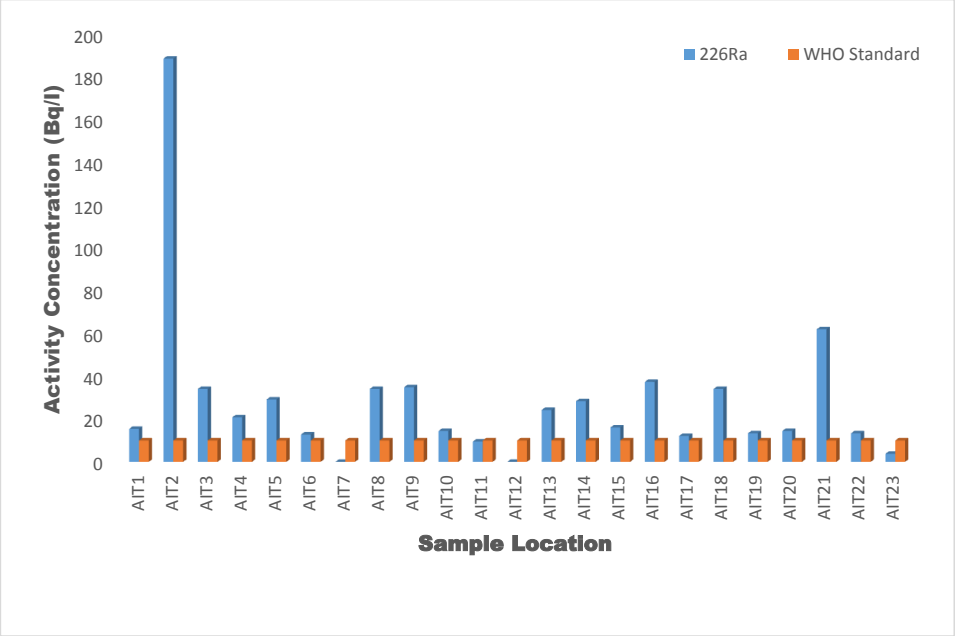

Fig. 3: Comparison of activity concentration of ^{226}Ra with WHO standard

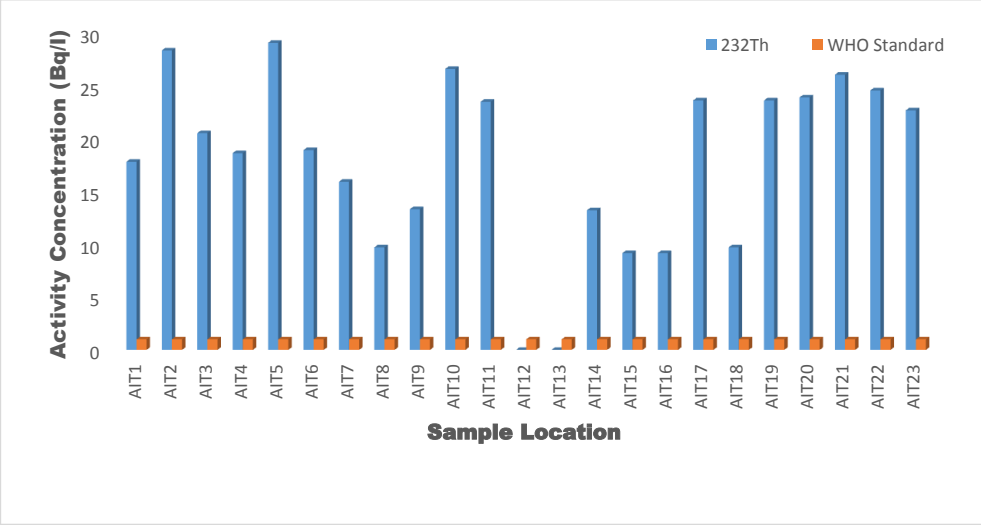

Fig. 4: Comparison of activity concentration of ^{232}Th with WHO Standard

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 Annual effective dose ($mSvy^{-1}$)				Cancer Risk and Hereditary Effect in Adult			
		E Infant	E Child	E Teen	E Adult	FCR X 10^{-4}	LFCR x 10^{-2}	SHE x 10^{-5}	ELHE x 10^{-3}
1	AIT_1	111.19	25.76	64.56	11.29	6.21	4.35	2.26	1.58
2	AIT_2	317.58	78.05	237.41	51.46	28.30	19.81	10.29	7.20
3	AIT_3	142.07	33.34	87.77	16.33	8.98	6.29	3.27	2.29
4	AIT_4	120.61	28.20	71.48	12.89	7. 09	4.97	2.58	1.80
5	AIT_5	184.84	42.88	108.64	19.21	10.57	7. 40	3.84	2.69
6	AIT_6	114.98	26.52	65.61	11.25	6.18	4.40	2.25	1.57
7	AIT_7	87.51	19.86	46.37	7.26	3.99	2.79	1.45	10.16
8	AIT_8	82.72	19.91	56.31	11.44	6.29	4.40	2.29	1.60
9	AIT_9	103.36	24.67	67.53	13.29	7.31	5.12	2.66	1.86
10	AIT_{10}	158.61	36.47	89.33	15.08	8.29	5.80	3.02	2.11
11	AIT_{11}	137.74	31.77	76.40	12.83	7.06	4.94	2.57	17.96
12	AIT_{12}	0.07	0.05	0.03	0.03	0.02	0.01	0.58	4.10
13	AIT_{13}	21.34	5.85	20.11	5.17	2.84	1.98	1.03	0.07
14	AIT_{14}	97.28	23.12	61.90	11.94	6.57	4.59	2.38	1.17
15	AIT_{15}	64.64	15.41	40.06	7.66	4.21	2.94	1.53	1.07
16	AIT_{16}	82.6	20.02	57.44	11.89	6.54	4.58	2.37	1.67
17	AIT_{17}	140.18	32.17	78.74	13.21	7.27	5.09	2.6	1.85
18	AIT_{18}	82.72	19.91	56.311	11.44	6.29	4.40	2.28	1.60
19	AIT_{19}	141.32	32.51	79.77	13.5	7.43	5.20	2.70	1.89
20	AIT_{20}	14.38	33.14	81.49	13.86	7.63	5.34	2.77	1.94
21	AIT_{21}	196.33	46.51	126. 75	24.524	13.49	9.44	4.90	3.43
22	AIT_{22}	146.48	33.641	82.501	13.9	7.65	5.35	2.78	1.95
23	AIT_{23}	128.09	29.28	69.22	11.18	6.15	4.31	2.24	1.57
	Mean	**110.07**	**25.918**	**68.435**	**12.85**	**7.07**	**4.95**	**2.57**	**1.80**

The annual effective dose due to ingestion of the sampled drinking water was estimated for different age groups including infants, children, teenagers and adults considering their dose conversion factors and annual ingestion rate of water as presented in Table 1 and using equation 2. The estimated effective dose for different age groups were ranged from 0.073 to 317.58 $mSvy^{-1}$ for infants, 0.050 to 78.05 $mSvy^{-1}$ for children, 0.027 to 237.41 $mSvy^{-1}$ for teenagers and 0.029 to 51.46 $mSvy^{-1}$ for adults with mean values of 110.07, 25.92, 68.44 and 12.85 $mSvy^{-1}$ respectively. It can be seen that radiation dose received by infants are relatively higher than that received for children, teenagers and adults. The teenagers also received higher radiation dose than children and adults.

WHO [18] recommended reference levels of effective dose for infants, children and adults corresponding to one year consumption of drinking water are 0.26, 0.2 and 0.1 $mSvy^{-1}$. The doses obtained in this present work are higher than the recommended reference levels and from radiation protection point of view, life-long consumption of the investigated water may pose significant radiological health risk.

In order to evaluate the radiation risk in adults due to ingestion of ^{40}K, ^{226}Ra and ^{232}Th in drinking water, the ICRP methodology was adopted and the result 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 results of the evaluated fatal cancer risk to adult per year in each drinking water ranged from 0.02×10^{-4} to 28.30×10^{-4} with the associated lifetime fatality cancer risk of 0.01×10^{-2} to 19.81×10^{-2}. The evaluated lifetime hereditary effect to adult per year varied from 0.58×10^{-5} to 10.29×10^{-5} with the associated lifetime hereditary effect in adult of 0.07×10^{-3} to 17.96×10^{-3}.

This means that the lifetime fatality cancer risk to adult approximately 19 out of 100 may suffer from some form of cancer fatality and for the hereditary effect approximately 18 out of 1000 may suffer some hereditary effect. The negligible cancer fatality risk value recommended by USEPA [19] is in the range of 1.0×10^{-6} to $1,0 \times 10^{-4}$ (ie 1 person out of one million or 10,000 suffering from some form of cancer fatality is considered trivial). Comparing the estimated results of the lifetime cancer risk in the present study with the acceptable risk factor, it can be concluded that all estimated results of the lifetime fatality risk in adult member of the university population due to ingestion of radionuclides in the sampled water are higher than the range of acceptable risk values recommended by USEPA.

5. Conclusion.

Radiological risk assessment of drinking water from Ignatius University quarters has been determined using gamma ray spectrometer. The activity concentration of ^{40}K, ^{226}Ra and ^{232}Th obtained in this study are higher than the recommended reference safe values. The annual effective dose estimated for different age groups showed that infants that ingest the sampled water are at higher risk than other age groups. The estimated lifetime cancer risk in adult member of the institution's population due to ingestion of radionuclides in the sampled water are above the range of the acceptable risk values recommended by USEPA.

From the findings of this work, we can conclude that tap water (drinking) in the University quarters are not suitable for human consumption at its present state and may pose significant radiological health risk related to its life- long consumption. Therefore, the management of the institution should incorporation reverse osmosis technology or ion exchange technology in the boreholes to reduce the radionuclide content of such drinking water. Furthermore the result of this work serves as radiation baseline data of the area since no such work has been done in the area and will help to monitor the radiological status of the drinking water of Rumu-olumeni Community as a whole.

References

[1] Justina Ada Achuka, Usikalu Mojisola Rachael and Oyeyemi Kehinde David (2017).Radiological Risks assessment of Ogun state drinking water. American Journal of Applied Sciences. 14(5): 540-550.

[2] UNSCEAR (2000). United Nations Scientific Committee on effects of Atomic Radiation Report to the General Assembly, Vol. 1, Sources and effects of Ionizing Radiation (New York: United Nations)

[3] Chandrashekara, M. S., Veda, S. M. and Paramesh, 1. (2012). Study on Radiation Dose Due to Radioactive Elements Present in Ground Water and Soil Around Mysore City, India. Radiation Protection Dosimetry, 149: 315-320.

[4] Abusini, M., Al-ayasreh, K. and Al-Jundi, J. (20070. Determination of Uranium, Thorium and Potassium Activity Concentrations in Soil Cores in Araba Valley, Jordan. *Radiation Protection Dosimetry*. 128920: 213-216

[5] Matiullah, A., Ur-Rehman, S., Ur-Rehman, A. and Feheem, M. (2004). Measurement of Radioactivity in the Soil of Behawalpur Division, Pakistan. *Radiation Protection Dosimetry*. 112(3): 443-447.

[6] Nwankwo H.O and Walter I.O (2012) Assessment of Groundwater quality in Shallow Coastal Aquifer of Okirika Island, Eastern Niger Delta Nigeria Ife . Journal of Science, 14(2): 21-29

[7] Tzortis, M.a nd Tsertos, H. (2004). Determination of Thorium, Uranium and Potassium Elemental Concentration in Surface Soils in Cyprus. *Journal of Environment and Radioactivity*. *77: 325-338.*

[8] Ononugbo, C. P. Avwiri G. O, Egieya, J. M. (2013). Evaluation of natural radionuclide content in surface and ground water and excess lifetime cancer risk due to gamma radioactivity. *Academic Research International*. 4(6): 636-647.

[9] WHO (2008). Guidelines for drinking water quality in cooperating First Addendum 1, Recommendations, 3rd edition Radiological Aspect Geneva: World Health organization

[10] Ugbede, F.O (2018): Measurement of background ionizing Radiation Exposure levels in selected farms in communities of Ishielu L.G.A, Ebonyi State, Nigeria. Journal of Applied Science Environmental Management 22(9) 1427-1483.

[11] Ajayi, J.O., Adedokun and Balogun, B.B. (2012). Levels of Radionuclide contents in stream waters of some selected Rivers in Ogbomoso land, south west Nigeria. Research

[12] Ononugbo, C.P. and Nwaka B.U. (2017). Natural radioactivity and radiological risk estimation of drinking water from Okposi and Uburu salt lake area, Ebonyi state, Nigeria. Physical Science International Journal . 15(3): 1-15.

[13] Avwiri, G. O., Egieya, J. M. and Ononugbo, C. P. (2013). Radiometric Assay of Hazard Indices and Excess Lifetime Cancer Risk Due to Natural Radioactivity in Soil Profile in Ogba/Egbema/Ndoni Local Government Area of Rives State, Nigeria. Academy Research International. 4(5).

[14] ICRP (2007). The 2007 Recommendations of the International commission on radiological protection. Annals of ICRP. Publication 103.

[15] Ibikunle S.B., Ajayi, O.S., Arogunjo, A.M. and Salami, A.A.(2016).Radiological assessment of Dam water and sediments for Natural Radioactivity and its overall Health detriment. *Ife Journal of Science 8(2):551-559.*

[16] ICRP, 2012. Annals of the ICRP (ICRP Publication 119). Compendium of Dose Coefficients Based on ICRP Publication 60. Volume 14 Supplement 1.

[17] Ndontchueng M.M., Simo A., Nguelem, E.J.M. Beyala, J.F. and Kryeziu (2013). Preliminary study of Natural Radioactivity and Radiological Risk Assessment in some Mineral Bottled water Produced in Cameroon. International Journal of Science and Technology 3(12):372 – 377

[18] WHO (2006). World Health Organization. Meeting the MDG Drinking Water and Sanitation Target. The Urban and Rural Challenge of the Decade, WHO, New York.

[19] US-EPA (2012) 2012 Edition of the Drinking Water Standards and Health Advisories. EPA 822-S-12-001. Washington DC.