Original Research Article

NATURAL RADIOACTIVITY LEVELS AND RADIOLOGICAL RISK ASSESSMENT OF SURFACE WATER FROM COASTAL COMMUNITIES OF NDOKWA EAST, DELTA STATE, NIGERIA.

ABSTRACT:

Aims: The aim of this study is to measure the natural radioactivity levels in surface water from coastal communities in order to assess the radiological health hazards associated with the use of such water. **Study design:** This study was purely an experimental work. **Place and Duration of Study:** Abalagada, Agwe-Etiti, Asemuku, Aboh and Okpai coastal communities of Ndokwa –East, Nigeria: between April – December, 2016. **Methodology:** 20 samples of stream water were collected from five coastal communities with pre-washed 2.0 l Polypropylene bottles. The bottles were rinsed with the water before collection and acidified immediately after collection with few drops of HCL. The bottles were sealed tightly with vinyl tapes and kept in the laboratory for 4weeks for secular equilibrium of the radionuclides. The activity concentration of the radionuclides were measured using Sodium Iodide detector. **Results:** Activity concentrations of ^{238}U, ^{232}Th and ^{40}K in stream waters in five communities ranges from BDL to 4.49±1.01 Bql^{-1} with an average value of 2.37±0.10 Bql^{-1}, BDL to 10.03± 1.04 Bql^{-1} with average value of 4.19±0.23 Bql^{-1} and 3.07±0.95 to 34.94±10.77 Bql^{-1} with an average value of 15.82±2.03 Bql^{-1} respectively. The activity concentration of ^{232}Th and ^{40}K were higher than their reference values of 1.0 and 10.0 Bql^{-1}. The total effective doses due to ingestion of radionuclides in water are 58.48, 3.195 and 6.243 $mSvy^{-1}$ for infants, children and adults respectively which are higher than the recommended reference level of 0.26, 0.2 and 0.1 mSv of committed effective dose from one year ingestion of water for infants, children and adults. The estimated lifetime fatality cancer risk to adult shows that approximately 442 out of 10,000,000 may suffer some form of cancer fatality and for the lifetime hereditary effect approximately 274 out of 1000,000,000 may suffer some hereditary effects. Statistical analysis shows that positive correlation exists between the three radionuclides indicating same origin. **Conclusion:** oil and gas production activities within the coastal communities has radiologically impacted the surface water of the area and could lead to radiation health risk of public that uses that water.

Keywords: Spectroscopy; Radioactivity; Effective dose; Lifetime fatality cancer risk; Ndokwa East.

1. Introduction

All individuals are exposed to radiation at low doses. The radioactivity level from the natural radionuclides is termed as background radiation which depends on the amount of the radioactive material in the environment. The background radiation can be high if the environment is polluted either from man-made or natural activities [1]. In environmental studies, water is considered important because of its daily usage by humans and ability to transport pollutants. Radionuclides in drinking water causes human internal exposure due to decay of radionuclides taken into the body through ingestion and inhalation indirectly when they are incorporated as part of the human food chain [2].

Water is the most important part of food for human beings. Access to safe drinking water is essential to health, a basic human right and a component of effective policy for health protection [3]. For this reason, its quality must be strictly controlled. Drinking water may contain some radionuclides that can pose health risk to humans. Radioactivity in surface water especially river water comes mainly from the radionuclide of the natural decay chains of ^{238}U, ^{232}Th and ^{40}K in soil and run-offs from industrial wastes/effluents and other maritime activities. Most rural communities depends on these surface water, river water, creeks and so on for their daily water needs. Consequently, radionuclides are also transported to food chain through irrigation waters from these surface waters.

The occurrence of natural radionuclide in drinking water poses a problem of health hazard, when these radionuclide are taken into the body by ingestion. The radionuclide contributing significantly to the ingestion dose via consumption of water is radium. Radium is a naturally occurring isotope found in the earth's crust, a member of the uranium ^{238}U decay series. The predominant radium isotopes in ground and surface water are ^{226}Ra, an alpha emitter with half-life of 1600 years and ^{228}Ra, a beta emitter with a half-life of 5.8 years [4]. Many salts of radium are soluble in water and therefore surface water may be enriched in radium and its descendant radon. ^{226}Ra is an earth alkaline element sharing the metabolic pathways of calcium in the human body. Due to their radiotoxicity especially those of ^{226}Ra, a contamination hazard for humans exists even at low concentration levels [5].

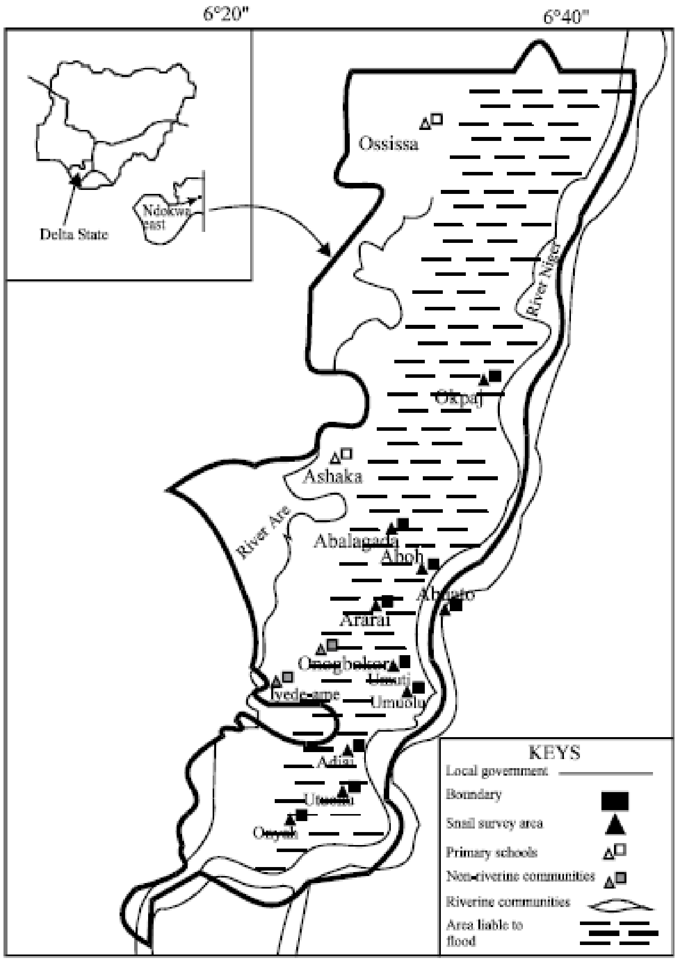
The levels of concentrations of radionuclides according to nature in surface waters and ground waters are mainly dependent on uranium and thorium bearing soil and rock mineral or with uranium, thorium and radium deposits. Therefore, the dispensation of natural radioactivity in water depend on the local geological characteristics of the source, soil or rock [6]. Potassium is a major element widely distributed in crustal rocks. Thus potassium occurs in various minerals and clays from which it may be dissolved through weathering processes and transferred into the liquid phase. ^{40}K decays directly to ^{40}Ca beta emission, it also decays through electron capture of ^{40}Ar [7], followed by a prompt 1.46 Mev gamma emission. As a consequence of water rock interaction, ^{40}K is released to water bodies.

Many studies have been done on radioactivity in various water samples (tap, spring, surface, river water) collected from some cities and rural communities in Nigeria and other countries of the world [8, 9, 10]. However the systematic data on the radioactivity of community surface water supplies in Ndokwa east of Delta state, Nigeria is not in literature. An estimation of the activity concentration of radionuclides in surface water supplies in coastal communities of Ndokwa east is extremely important for proper radiation risk assessment due to intake of such water. The main aim of this study is to determine the level of radioactivity in surface water from coastal communities of Ndokwa east and assess their radiological health risk due to intake of the water.

2.0 Experimental Procedure

2.1 Study Area

The study was conducted in Ndokwa-East Local Government Area (LGA) of Delta State, Nigeria. The LGA is bounded in the East by River Niger and West by the Ase Creek (Fig. 1). The coast communities of Ndokwa east is situated in the north east part of Ndokwa local Government Area between the latitudes of 5°32' and 5°40'N and longitudes of 6°31' and 6°36' E. The entire Delta state is a region built up by the sedimentation of the Niger Delta and consists of the delta in various stages of development. The River Niger drains the eastern-flank of the State and discharges into the sea through its several distributaries. The climate is tropical, rainfall is about 266.5 mm in the coastal areas and 190.5 mm in the extreme north, with maximum precipitation occurring in July. The two main seasons in this area include the rainy season (April to October) and the dry season (November to March). Fishing and subsistence farming are the major occupations of these communities; rice, yam and cassava are extensively cultivated by the inhabitants. The people in these communities make use of perennial and intermittent streams/rivulets as their sources of water supply for daily needs due to the absence of pipe-borne water. These streams and rivulets empty into the Ase Creek and River Niger, the main River in the state [11].



2.2 Sample Collection and Preparation

In order to measure the specific activity concentration of natural radionuclides in surface water, 20 samples of the water were collected from five coastal communities in Ndokwa east. All the water samples were collected with 2.0 litres linear polypropylene bottles which has been carefully washed before sampling. Containers for the samples were washed with a solution of detergent and then rinsed with freshly distilled Hydrochloric acid (HCl) to remove an inorganic material that might have stuck to the walls of the container before the samples were collected. About 2 L of each water sample were taken and 20 mL of 1 M HNo_3 added immediately [12]. This is necessary to fix the radioactive elements in the samples.

Fig.1: Map of the study Area

The containers were sealed tightly and wrapped with thick vinyl tapes around their screw necks. Some 250 mL of each water samples in tightly covered cylindrical containers were stored for 4 weeks to reach secular equilibrium between ^{238}U and ^{232}Th and their respective progeny.

2.3 Gamma-ray Spectrometry:

Activity measurements of radionuclides in surface water collected were performed at the national Institute of Radiation Protection and Research Centre (NIRP &R), university of Ibadan with a gamma-ray spectrometry system with a thallium activated 3˝ × 3˝ sodium iodide on a NaI(TI) detector connected to ORTEC 456 amplifier [13,14]. The detector in a 100 mm 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 measurements 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. 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) $_3$. $(NO_3)_2$ $6H_2O$) 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 1 g of uranyl nitrate contains 0.474 g of uranium which has activity of 0.0294 Bq/L, also 1 g of potassium chloride contains 0.534 g of potassium which has activity of 0.706 Bq/L and 1g of thorium nitrate contains 0.859 g of thorium with activity of 0.0175 Bq/L [15].

Spectrum were accumulated for background for a period of 29000 s at 900 volts to produce strong peaks at gamma emitting energies of 1460 Kev for ^{40}K; 63.0 Kev of ^{214}Bi and 92.5 Kev of ^{228}Ac, which were used to estimate the concentration of ^{238}U and ^{232}Th respectively[16]. 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.

3.0 Radiological Risk Estimation

3.1 Annual Effective Dose

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 categories. Assumptions on the rate of ingestion of water were made. In this work, the rate of water intake rates based on UNSCEAR [15] recommendation of 0.5, 1.0 and 2.0 l/d for infants, children and adults (≥ 17 years) respectively, were used for calculations. The conversion factors for ^{238}U, ^{232}Th and ^{40}K as reported by ICRP [19] and presented in Table 1 were used for all the age groups.
The total annual effective dose due to ingestion of water was computed using the following formula [20, 5].

$$H_{ing}\ (mSvy^{-1}) = \sum_{i=1}^{i=3} DCF_{ing}\ (i) \times Ai \times I \qquad (2)$$

Where DCF_{ing} (i) is the dose coefficient of a particular radionuclide in Sv/Bq for a particular age categories. A_i is the specific activity concentration of radionuclide in the water sample measured in Bq/l and I, the radionuclide intake in liters per year for each age categories.

3.2: Cancer Risk and Hereditary Effects

In addition to the estimated annual effective dose, the cancer and hereditary risk due to low dose without any threshold doses known as stochastic effect were estimated using the ICRP cancer risk methodology (ICRP- 2007). Radiation risks to members of the public results 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 members of the public is 5.5×10^{-2} Sv^{-1}. For hereditary effects, the detriment-adjusted nominal risk coefficient for the whole population as stated in ICRP (2007) for stochastic effects after exposure to low dose rates was estimated at 0.2×10^{-2} Sv^{-1}. The risk to population was then estimated using the 2007 recommended risk coefficient of ICRP report and assumed 70 years lifetime of continuous exposure of the population to low level radiation. According to ICRP methodology;

$$\text{Cancer Risk} = \text{Total annual Effective Dose (Sv)} \times \text{Cancer risk factor } (Sv^{-1}) \quad (3)$$

$$\text{Hereditary Effects} = \text{Total annual Effective Dose (Sv)} \times \text{Hereditary effect factor } (Sv^{-1}) \quad (4)$$

The recommended reference levels of the effective dose for infants, children and adults corresponding to one year consumption of water are 0.26, 0.20 and 0.1 $mSvy^{-1}$ respectively.

Table 1: Effective Dose Coefficients (Sv/Bq) for ingestion of Radionuclides for members of the public to 70 years of age (ICRP, 2012; Publication 119)

S/N	Radioisotopes	Infant $\leq$ 1 year	Children 10 years	Adult $>$ 17 years
1	^{238}U	1.4 E-07	6.8 E-08	4.5 E-08
2	^{232}Th	1.6 E-06	2.9 E-07	2.3 E-07
3	^{40}K	5.2 E-05	1.3E-08	6.2 E-09
Water intake		0.5 L/day	1.0 L/day	2.0 L/day

4.0 Results and Discussion

4.1 Activity concentration of ^{238}U, ^{232}Th and ^{40}K in stream water and its radiological parameters

The activity concentration of ^{238}U, ^{232}Th and ^{40}K determined in surface water from coastal communities of Ndokwa east and the associated annual effective dose to infant, children and adult population of the communities are presented in Table 2 while the estimated cancer risks and hereditary effects of adult member of the public are shown in Table 3. From Table 2, the result showed that ^{40}K was the prevalent radionuclide in the communities sampled. Activity concentration of ^{238}U and ^{232}Th were below detectable limit of the detector. This could be due to high drift velocity of the water that might have transported the uranium and thorium deposit to other parts of the region. The activity concentration of ^{40}K in surface water from Aboh community ranges from 3.07±0.95 to 25.52±7.86 Bql^{-1} with an average value of 12.33±1.02Bql^{-1}. The high concentration of ^{40}K in all the communities sampled may be due to the use of fertilizer in agricultural practices in the area.

The activity concentration of ^{238}U in Agwe-Etiti was detected only in one location (ETITI W1) of 0.52±0.11 Bql^{-1} while other locations, it was below detectable limit. The activity concentration of ^{232}Th and ^{40}K in surface water from Agwe-Etiti ranges from 2.07±0.16 to 8.20±0.61 Bql-1 with an average value of 5.28±0.24 and 12.21±3.79 to 16.76±5.17 Bql^{-1} with an average value of 15.20±3.21 Bql^{-1}. These variations in the activity concentrations of thorium and potassium could be as a result of effluent introduction from the oil and gas drilling companies which might have concentrated Thorium at those locations. The activity concentration of ^{238}U in Asemuku (MUKU) was detected only in one location (MUKU W_2) of 0.87±0.19 Bql^{-1} while other locations, it was below detectable limit. The activity concentration of ^{232}Th and ^{40}K in surface water from Asemuku ranges from 1.20±0.09 to 4.37±0.33 Bql-1 with an average value of 2.70±0.21 and 9.78±3.09 to 23.40± 7.22 Bql^{-1} with an average value of 15.93±3.11 Bql^{-1}.

The activity concentration of ^{238}U, ^{232}Th and ^{40}K in surface water from Abalagada community varies from location to location, ^{238}U was detected in only one location (GADA W2) of 4.49±1.01Bql^{-1}.Activity concentration of ^{232}Th varies from 0.09±0.007 to 6.23±0.45 with an average value of 1.70±0.01 while the activity concentration of ^{40}K varies from 3.67±1.14 to 21.20±6.56 Bql^{-1} with an average value of 13.94 Bql^{-1}. In Okpai Community, the activity concentration of ^{238}U, ^{232}Th and ^{40}K in surface water also varies from location to location, ^{238}U was detected in only one location (OKPAI W3) of 3.58±0.78Bql^{-1}. The activity concentration of ^{232}Th varies from BDL to 10.03±0.72 Bql^{-1} with an average value of 1.70±0.01Bql^{-1} while the activity concentration of ^{40}K varies from 8.68±2.69 to 34.94±10.77 Bql^{-1} with an average value of 21.59±2.36 Bql^{-1}.

It is evident that Okpai Community recorded the highest activity concentration of ^{238}U, ^{232}Th and ^{40}K in surface water. This could be due to effluent discharge into the surface water from oil and gas drilling companies and other maritime activities that has concentrated the activity concentration of these radionuclides. According to Oseji, [17], Ndokwa land seems to have local clay deposits in the second and fourth geoelectric layers which though are very thin and appear to create local confined conditions. Clayey soil are usually rich in natural radionuclide. Activity concentration of Uranium -238 in all the communities were below detectable level except in one location each of the five coastal communities. This might be due to the high mobility rate of ^{238}U in surface water.

The result of this study revealed that the activity concentration of ^{238}U, ^{232}Th and ^{40}K in sampled surface water were higher than the safe standard set by the environmental protection Agency and World Health Organization [18]. The range of thorium (^{232}Th) in natural water is set at 1.0 -10.0 mBql^{-1} and uranium (^{238}U) set range from 10 – 100 mBql^{-1} [15]. The new drinking water quality proposed by EPA does not include ^{40}K but specifies that the maximum allowable concentration for beta and photon emitters should correspond to committed effective dose equivalent of 4 mrem/y from annual intake at rate of two liters of water per day for adult. The calculated effective doses for different age groups, infants, children and adults are presented in Table 2. It should be noted that doses were ranged from 22.0 to 245.0 mSvy^{-1} for infant, 0.064 to 5.69 mSvy^{-1} for children and 0.014 to 115.0 mSvy^{-1} for adults. Figure 2 shows that doses received by infants are higher than doses received by children and adults and doses received by adults are higher than that received by children.

The effective doses obtained in this study except for infants, are within the recommended reference level of 0.26, 0.2 and 0.1 $mSvy^{-1}$ for infants, children and adults respectively which was published by IAEA[19], WHO [18] and UNSCEAR, [20] from one year ingestion of water. Consequently, the investigated surface water are not suitable for infant's consumption.

In order to determine the radiation risk due to ingestion of ^{238}U, ^{232}Th and ^{40}K in surface water, ICRP [21] methodology was adopted in the study and the results are shown in Table 2. The results of the cancer and non-cancer risk components were evaluated from the estimated total annual effective dose of the various age groups. The result of the estimated fatal cancer risk to adult per year that ingest the sampled surface water range from 0.77×10^{-9} to 632.50×10^{-9} with the associated lifetime fatality cancer risk of 0.54×10^{-7} to 442.50×10^{-7}. The estimated hereditary effect to adult per year varied from 0.28×10^{-10} to 230.0×10^{-10} with its associated lifetime hereditary effect in adult of 0.161×10^{-9} to 274.6×10^{-9}. This means that in terms of the lifetime fatality cancer risk to adult approximately 442 out of 10,000,000 may suffer some form of cancer fatality and for the lifetime hereditary effect approximately 274 out of 1000,000,000 may suffer some hereditary effects. The negligible cancer fatality risk value recommended by USEPA [22] is in the range of 1.0×10^{-6} to 1.0×10^{-4} (ie 1 person out of 1 million to 10,000 persons suffering from some form of cancer fatality is considered trivial). Comparing the estimated results of the lifetime fatality cancer risk in the present study with the acceptable risk factor, it can be seen that all estimated results of the lifetime fatality risk in adult member of the community due to ingestion of radionuclide in the studied surface water are within the range of acceptable risk value recommended by USEPA.

Table 2: **Activity Concentration of ^{238}U, ^{232}Th and ^{40}K in Water Samples and Total Annual Effective Dose for Different Age Categories**

S/N	Sample ID	Location	Activity Concentration (Bq/l)			Total Annual Effective Dose (mSv/y)		
			^{238}U	^{232}Th	^{40}K	Infant	Children	Adult
1	ABOH W1	N05^0 32′ 064″ E006^{0}31′ 554″	BDL	BDL	13.41±4.13	255.00	0.064	0.061
2	ABOH W2	N05^0 32′ 576″ E006^{0}31′ 745″	BDL	BDL	25.52±7.86	243.08	0.121	0.116
3	ABOH W3	N05^0 32′ 859″ E006^{0}31′878″	BDL	BDL	3.07±0.95	22.06	0.015	0.014
4	ABOH W4	N05^0 33′ 194″ E006^{0}32′016″	BDL	BDL	7.83±2.42	74.58	0.037	0.035
5	ETITI W1	N05^0 36′945″ E006^{0}36′753″	0.52±0.11	3.98±0.28	12.21±3.79	117.0	0.492	0.139
6	ETITI W2	N05^0 37′ 197″ E006^{0}37′115″	BDL	2.07±0.16	16.69±5.18	159.0	0.298	0.355
7	ETITI W3	N05^0 37′ 759″ E006^{0}37177″	BDL	8.20±0.61	15.14±4.68	146.0	0.940	1.45
8	ETITI W4	N05^0 38′ 946″ E006^{0}36′768″	BDL	6.85±0.48	16.76±5.17	160.0	56.9	115.0
9	MUKU W1	N05^0 39′ 381″ E006^{0}36′419″	BDL	1.44±0.11	9.78±3.02	93.0	0.152	0.286
10	MUKU W2	N05^0 39′ 526″ E006^{0}36′277″″	0.87±0.19	4.37±0.33	23.40±7.22	22.0	0.595	0.868
11	MUKU W3	N05^0 39′697″ E006^{0}36′156″″	BDL	3.80±0.29	9.92±3.09	10.0	0.449	0.683
12	MUKU W4	N05^0 40 055″ E006^{0}35′997″	BDL	1.20±0.09	20.61±6.36	200.0	0.225	0.295

13	GADA W1	N05^0 34′ 345″ E006^{0}35′ 16.1	BDL	6.23±0.45	20.36±6.32	200.0	0.756	1.14
14	GADA W2	N05^0 35′ 225″ E006^{0}35′ 16.1	4.49±1.01	0.09±0.007	3.67±1.14	35.0	0.138	0.179
15	GADA W3	N05^0 35′941″ E006^{0}35′ 126	BDL	BDL	21.20±6.56	202.0	0.101	0.096
16	GADA W4	N05^0 37′ 034″ E006^{0}35′ 322	BDL	0.48±0.07	10.52±3.26	100.0	0.101	0.128
17	OKPAI W1	N05^0 41′ 179″ E006^{0}35′ 913	BDL	BDL	22.52±6.97	214.0	0.107	0.102
18	OKPAI W2	N05^0 41′ 371″ E006^{0}35′ 815	BDL	7.18±0.53	20.22±6.22	109.5	0.856	1.30
19	OKPAI W3	N05^0 41′ 612″ E006^{0}35′ 817	3.58±0.78	10.03±0.72	34.94±10.77	336.0	1.320	1.96
20	OKPAI W4	N05^0 41′ 867″ E006^{0}35′ 819	BDL	2.7±8±0.21	8.68±2.69	83.0	0.335	0.506
	MEAN		**2.37±0.10**	**4.19±0.74**	**15.82±5.03**	**584.83**	**3.195**	**6.243**
	WHO, 2008		**10.0**	**1.0**	**10.0**	**0.26**	**0.20**	**0.10**

Table 3: Estimated Cancer Risks and Hereditary Effects of Adult Member of the Public

S/N	**Sample ID**	**Location**	**Total Annual Effective Dose (mSv/y)**			**Fatality cancer risk to Adult per year × 10^{-9}**	**Lifetime fatality cancer risk × 10^{-7}**	**Severe hereditary Effects in Adult per year × 10^{-10}**	**Estimated lifetime hereditary Effects × 10^{-9}**
			Infant	**Children**	**Adult**				
1	ABOH W1	N05^0 32′ 064″ E006^{0}31′ 54″	128.0	0.064	0.061	3.36	2.35	1.22	8.54
2	ABOH W2	N05^0 32′ 576″ E006^{0}31′ 45″	245.0	0.121	0.116	6.38	4.47	2.32	16.2
3	ABOH W3	N05^0 32′ 859″ E006^{0}31′878″	29.0	0.015	0.014	0.77	0.54	0.28	1.96
4	ABOH W4	N05^0 33′ 194″ E006^{0}32′016″	75.0	0.037	0.035	1.93	1.35	0.70	4.9
5	ETITI W1	N05^0 36′945″ E006^{0}36′753″	117.0	0.492	0.139	7.65	5.35	0.39	0.39
6	ETITI W2	N05^0 37′ 197″ E006^{0}37′115″	159.0	0.298	0.355	19.53	13.67	7.10.	4.97
7	ETITI W3	N05^0 37′ 759″ E006^{0}37177″	146.0	0.940	1.45	79.75	55.83	29.0	20.3
8	ETITI W4	N05^0 38′ 946″ E006^{0}36′768″	160.0	56.9	115.0	632.50	442.75	230.0	0.161
9	MUKU W1	N05^0 39′ 381″ E006^{0}36′419″	93.0	0.152	0.286	15.73	11.01	5.72	40.04
10	MUKU W2	N05^0 39′ 526″ E006^{0}36′277″ ″	22.0	0.595	0.868	47.74	33.42	13.60	95.20
11	MUKU W3	N05^0 39′697″ E006^{0}36′156″	10.0	0.449	0.683	37.57	26.30	1.37	95.62
12	MUKU W4	N05^0 40 055″ E006^{0}35′997″	200.0	0.225	0.295	16.23	11.36	10.14	70.97
13	GADA W1	N05^0 34′ 345″ E006^{0}35′ 6.1	200.0	0.756	1.14	62.70	43.83	22.8	159.6
14	GADA W2	N05^0 35′ 225″ E006^{0}35′ 6.1	35.0	0.138	0.179	9.85	6.89	3.58	25.06
15	GADA W3	N05^0 35′941″ E006^{0}35′ 126	202.0	0.101	0.096	5.28	3.70	1.97	13.44

16	GADA W4	N05^{0}37′ 034″ E006^{0}35′ 322	100.0	0.101	0.128	55.0	38.50	2.56	17.92
17	OKPAI W1	N05^{0}41′ 179″ E006^{0}35′ 913	214.0	0.107	0.102	5.61	3.93	2.04	14.28
18	OKPAI W2	N05^{0}41′ 371″ E006^{0}35′ 815	109.5	0.856	1.30	71.50	50.05	26.0	182.0
19	OKPAI W3	N05^{0}41′ 612″ E006^{0}35′ 817	336.0	1.320	1.96	107.80	75.46	39.2	274.4
20	OKPAI W4	N05^{0}41′ 867″ E006^{0}35′ 819	83.0	0.335	0.506	27.83	19.48	10.12	70.84

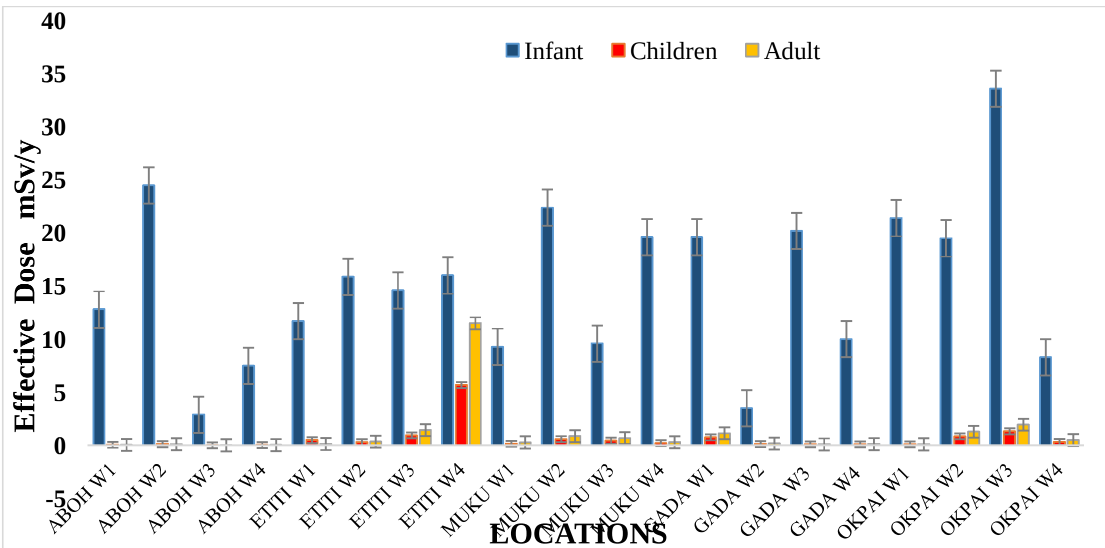


Fig. 2: Total Effective doses for infants, children and adults in mSvy^{-1} due to ingestion of ^{238}U, ^{232}Th and ^{40}K in surface water

4.2 Comparison of obtained Results with result of other works

The values of the activity concentration of ^{238}U, ^{232}Th and ^{40}K in surface water obtained in this study were compared with results obtained in other studies in a similar environment in other countries and presented in Table 4.

Table 4: **Comparison of obtained Results with result of other works**

COUNTRY/ samples	Mean Activity Concentrations (Bql-1) ^{238}U	^{232}Th	^{40}K	REFERENCES
Nigeria(Surface water)	2.37±0.10	4.19±0.74	15.83±5.03	**This Study**
Nigeria (surface water)	0.000838	0.0000504	0.4191	[15]
Egypt		0.13	5.29	[5]
Nigeria (stream)	0.59	1.8	27.7	[23]
Nigeria (Stream)	4.62	4.06	42.57	
Nigeria (River)	6.57	2.12	29.48	[24]
Egypt Qena	0.08	0.04		[25]
Sudan	0.007-0.014	0.001 -0.4191		[26]

4.2: Statistical Analysis

In order to demonstration the distribution and behavior of the measured radionuclide in surface waters from coastal communities of Ndokwa East, Nigeria, basic statistics used with statistical software package SPSS version 11.0 for windows and presented in Table 5. The statistical parameters determined includes the range (minimum-maximum), arithmetic mean (AM), arithmetic standard deviation (SD), median, mode, skewness, kurtosis and the type of frequency distribution for the three radionuclides for all the water samples.

The frequency distribution curves of ^{238}U, ^{232}Th and ^{40}K are shown in Figure 3. From Table 5, all the radiological parameters have positive skewness which shows that ^{238}U, ^{232}Th and ^{40}K have asymmetric distribution and only ^{232}Th has a negative kurtosis indicating relatively flat distribution. Pearson's correlation analysis was also carried out to ascertain if there are mutual relationship between the pairs of variables by calculating their linear correlation coefficient R^2. It is important to note that a positive correlation among variables indicates similar source and behavior in the given environment [27].

Results of the Pearson correlation coefficient among all the three studied radionuclide and the associated radiological parameters are presented in Table 6. From Table 6, it can be observed that positive correlation exists among the three radionuclides and all the radiological parameters except ^{238}U having a negative correlation with $AEDE_{children}$ and $AEDE_{adult}$ indicating that uranium did not contribute to gamma emission on children and adult. Strong correlation were observed between ^{232}Th and ^{40}K while ^{238}U is weakly correlated with ^{232}Th and ^{40}K.

The strong positive correlation between ^{232}Th and ^{40}K shows that their origin and behavior in the coastal environment are the same while weak positive relationship between ^{238}U and the other two indicates that they may have the same origin but their behavior in the stream environment differs. All the three radionuclides have strong positive correlation coefficient with the radiological parameters except for Uranium-238 that showed negative correlation with AEDEchildren and AEDEadult. This means that two of the radionuclide only contributed significantly to gamma-ray emission at the sampling points.

Table 5: Descriptive statistics of radiological parameters

	238U	*232Th*	*40K*	*AEDE Infant*	*AEDE Children*	*AEDE Adult*
Mean	0.473	2.931	15.8225	133.175	3.2001	6.23565
Standard Error	0.278762	0.721872	1.776454	18.70003078	2.827436604	5.72578283
Median	0	1.755	15.915	122.5	0.2615	0.2905
Mode	0	0	#N/A	200	0.101	#N/A
Standard Deviation	1.246663	3.22831	7.944545	83.62908003	12.6446809	25.6064793
Sample Variance	1.554169	10.42199	63.1158	6993.823026	159.887955	655.691781
Kurtosis	7.059778	-0.50955	0.239423	0.256826768	19.96282164	19.9780959
Skewness	2.81248	0.840816	0.431435	0.546886441	4.466230096	4.46865318
Range	4.49	10.03	31.87	326	56.885	114.986
Minimum	0	0	3.07	10	0.015	0.014
Maximum	4.49	10.03	34.94	336	56.9	115
Sum	9.46	58.62	316.45	2663.5	64.002	124.713
Count	20	20	20	20	20	20

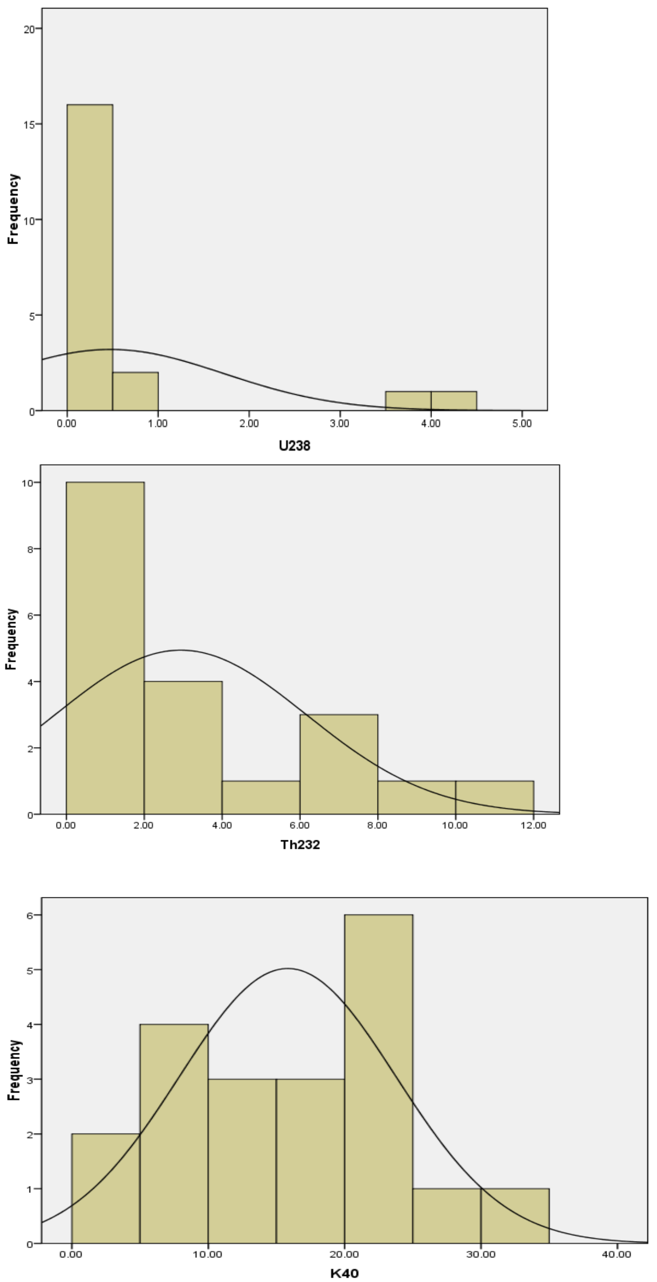


Fig 3: Frequency distribution of ^{238}U, ^{232}Th and ^{40}K in stream Water Samples

Table 6: Pearson Correlation Coefficients between radioactive variables in stream water samples

	238U	*232Th*	*40K*	*AEDEInfant*	*AEDEChildren*	*AEDEAdult*
238U	1					
232Th	0.189044	1				
40K	0.098788	0.460985	1			
AEDEInfant	0.090956	0.28596	0.804079	1		
AEDEChildren	-0.08065	0.312423	0.04339	0.085356706	1	
AEDEAdult	-0.083	0.305662	0.039447	0.082524901	0.999960287	1

5.0 Conclusion

The natural radioactivity levels of ^{238}U, ^{232}Th and ^{40}K in surface water samples from coastal communities of Ndokwa East, Delta State, Nigeria have been measured using gamma ray spectroscopy. The result showed that the activity concentration of ^{232}Th and ^{40}K were higher than their stipulated safe values in natural water of 1.0 and 10.0 Bql^{-1} respectively. The activity concentration of ^{238}U, ^{232}Th and ^{40}K were used to calculate the annual effective dose for different age groups. The total effective doses due to ingestion of radionuclides in water are 58.483, 3.195 and 6.243 $mSvy^{-1}$ for infants, children and adults respectively which are higher than the recommended reference level of 0.26, 0.2 and 0.1 mSv of committed effective dose from one year ingestion of water for infants, children and adults. The estimated lifetime fatality cancer risk to adult shows that approximately 442 out of 10,000,000 may suffer some form of cancer fatality and for the lifetime hereditary effect approximately 274 out of 1000,000,000 may suffer some hereditary effects.

The result of this study shows that there is radionuclide build-up in the surface water of the five coastal communities of Ndokwa east due the oil and gas production activities and other anthropogenic activities along the coast. There is no immediate radiological impact on the users of the sampled surface water but long term consumption of the sampled water could lead to significant health hazards, therefore the inhabitants of the coastal communities of Ndokwa East, Delta state should desist from drinking surface water from their community.

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