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RADIOLOGICAL AND CHEMICAL RISK ASSESSMENT OF URANIUM-238 IN WELL, BOREHOLE AND RIVER WATERS IN SELECTED RURAL OIL PRODUCING COMMUNITIES IN DELTA STATE, NIGERIA

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Abstract

The assessment of radiological and chemical risk associated with uranium in hand dug wells, boreholes and river waters samples within oil and gas producing communities in Delta state have been carried out using gamma-ray spectroscopy operated on a Canberra 3"x3" NaI(TI) detector while the BIR absorbed dose rate from the environment was measured using Geiger Muller (exploranuim GR-135 model) detector. Measured average absorbed dose rate is 1.0mSvyr^{-1}for the three sources of water examined which is within the permissible limit. Average uranium activity concentrations in the water samples is7.2±0.8, 5.5±0.7 and 5.5±0.7Bql^{-1}for wells, boreholes and river water samples respectively while the mass concentration average values are 324.3±33.9,221.5±25.4 and 620.4±56.1µgl^{-1} respectively. These average activity and mass concentrations of the three sources of water sampled was found to be relatively higher compared with control values and the recommended safe limits by various international organizations. The estimated cancer mortality and morbidity risk values are in agreement with other reported values within the country and are well below acceptable standard. The chemical toxicity risk of uranium in the three water sources (well, borehole and river) samples estimated using lifetime average daily dose (LADD) were found to be 8.9, 5.9 and 17.0 µgkg^{-1}.day^{-1}which are above the reference level of 0.6µgkg^{-1}.day^{-1}. The study revealed that human risk due to uranium content in water supplies that will result from ingestion in the study area may be attributed to chemical toxicity of uranium as heavy metals, rather than radiological risk. Possible reduction techniques of uranium concentration in water samples were recommended.

***Keywords*:** Risk Assessment, Uranium, water, Oil Fields.

1.0 Introduction

In most of the oil and gas producing rural communities in the Niger Delta region of Nigeria, availability of clean and safe drinking water has been a critical and uphill task to achieve and could be seen as a luxury. This could be attributed to the insensitivity of the government and high poverty rate of about 54.6% in the oil rich region of Nigeria **[1,2,3]** and also, due to constant decline of portable water in the rural areas since the 1990s **[4]**.However, at the end of 2000 United Nations Millennium Summit, member states of which Nigeria is one adopted a set of eight (8) goals and related targets and indicators aimed at helping end to human poverty **[5].** Among these millennium Development Goals is a call to halve by the year 2015 the proportion of persons without sustainable access to safe drinking water and basic sanitation. Towards the end of March 2005, the UN launched the "International Decade for Action: Water for Life 2005- 2015" **[6,7]**. Success in reaching these targets will help achieve the other goals.

Uranium in water is one of the major contaminant that is treating the attainment of the MDG goals of sustainable access to safe drinking water. Uranium salt is the most soluble of the long- lived radionuclides and forms ions with oxidation state of +4 (UO_2 and U^{+4}) and +6 (UO_3 and UO_2^{2+}) **[8,9]**. Uranium will bond with oxygen to form the uranyl ion, or uranium oxide, which is soluble in ground water under aerobic conditions. It has been established that high concentration of uranium greater than 15µgl^{-1} in drinking water may present harmful biological effects in humans **[10]**. It toxic effects have been studied extensively in kidney **[11,12,13]** and other organs of the body **[14,15]**. The chemical toxicity effects on the human kidney by chronic ingestion of uranium through drinking water in the range of 0.004 to 9.0µgl^{-1} per body weight per day may produce interference with kidney functions **[16]**. Kurttio*et al.***[17]** in a study on human, found nephrotoxic effects of uranium in

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drinking water even for low concentrations without a clear threshold. Most result from uranium studies in drinking water suggest that it's safe concentration may within the range of proposed guideline values of 2- 30µgl^{-1}**[10,12]**. Moreso, because uranium is more of alpha- emitting radionuclide, there is a growing concern about the potential DNA damage, if the emitted alpha particles reach the cell nuclei of the body through water ingestion. Attempts by cells to repair this damage, if it occurs may result repair errors, producing gene mutations or chromosomal aberrations. These effects, when sufficiently severe may be manifested as cancer and possibly as developmental malfunctions in children and developing foetus**[9]**.

The rural communities of the study area depend on hand dug wells, boreholes and river waters as major sources of drinking water. Natural uranium is classified as both a radiological and a chemo- toxicological agent and it is the only radioactive substance for which chemical toxicity is the limiting factor in risk assessment **[11]**. Utilization of water from these sources of water supplies has raised concerns of potential radiological and toxicological risks to human consumers. There have been various claims and counterclaims of cancer, leukemia, eye cataracts and other health related radiation induce sicknesses attributing to oil and gas exploration and exploitation activities by the host communities in the study area **[18,19]**. But there are little or no data on the radiological and chemical health effects of uranium in drinking water and domestic water supplies in the area. This study is therefore considered relevant in order to provide data on the concentration of uranium in the water sources and the associated radiological and chemical risk it may pose to the populace of OML30.

2.0 Material and Methods

2.1 Study Area

The study area is located in Oil Mining Lease 30 (OML 30) onshore of Niger Delta **[20]**. It transit five local government areas (Isoko North and South, Ughelli North and South and Ethiope East L.G) in Delta State and comprise often oil fields. It lies within latitude $5^0$18" N and 5°86" N and longitude $5^0$33"E and $6^0$40 E", South-west of Niger Delta region of Nigeria **[2]**. Oil production from these oil fields average 65,000bbls/d at 70% Bs$W and approximately 3.8million cubic meters annually **[20]**. This put the area as one of the highest in oil and gas production area onshore of Niger Delta with about 172 oil wells, 10 flow stations and 14 flare stack sites. The area has population of about 0.95million people.The area is criss-cross with network of pipelines carrying oil or gas to the flow stations from the various oil and gas wells **[2,18]**, See figure 1. Oil exploration activities started in the area in mid-1959 and it has since been a continuous operation with increase in the number of exploration activities.Gas flaring and oil spillage due to pipe leakage, as a result of rupture and corrosion has been the major environmental pollution problem in this area in the last two and half decades. Over 120 cases of oil spillage have been reported in the study area in the last three year **[19,21]**.

2.2 *Sample Collection and Preparation*

In order to assess the reliability of samples collected, the background ionization radiation (BIR)/ equivalent dose rates of the environment where water samples are collected were measured in-situ using Geiger Muller (exploranuim GR-135 model) detector and a Geographical Positioning System (GPS) for coordinate measurement. Thirty water samples were collected from community public water supply (tapes and wells water) in the major oil fields host communities and three from a control site (community). At each sampling point 1.5-liters plastic container was used for the collection of the sample from source with about 1% air space of the container left for thermal expansion. Sample containers which has been previously washed and rinsed with dilute acid (0.1M HCl) to minimize contamination from the original content of sample container. Well water samples were collected manually at the early hours of the day from community wells of varying depths (5-10m). While tap water were collected at laminar flow rate after first turn on at full capacity for 2 minutes to purge the plumbing system of any water which might contaminates sample, to reduce radon loss **[22]**. Sample collection procedure for river/stream water is as reported by Avwiri and Agbalagba, **[23]**. After the collection, immediate addition of 10ml of 65% HNO_3at collection point was made to avoid changes in the state of the ions that are present in the samples. The samples were subsequently taken to the laboratory for preparation prior to gamma spectroscopy. All water samples were evapourated (avoid boiling) in a furnace temperature at 60^{o}C to reduce their volume from approximately 1.5-litres to 1.0 litre and poured into 1.0 litre cylindrical plastic container of the detector geometry. The samples were properly sealed and stored for about 30 days to reach radioactive equilibrium.

2.3 Sample analysis

The method employed for the analysis of the radioactivity in the water samples was the gamma- ray spectroscopy and the standard procedure of this method has been described elsewhere **[24,25]**. The detector used for the radioactivity measurements is a lead shielded 7.6 x 7.6cm (3x3 inches) NaI(TI) detector crystal coupled toORTEC 456 amplifier. The detector was connected to a computer program MAESTRO window that matched gamma energies to a library of possible isotopes. The cylindrical plastic containers holding the samples were put to sit on the high geometry 7.6cm x 7.6cm NaI(TI) detector. High level shielding against the environmental backgroundradiation was achieved by counting in the Canberra 100mm thick lead castle. Since the accuracy of the quantitative measurements is depended on the calibration of the spectrometry system and adequate energy, detector background measurement and efficiency calibration of the system was

made possible using Cs-137 standard source from IAEA, Vienna, The detailed calibration procedures of the detector has been reported **[25,26]**. It has a resolution Full Width at Half Maximum (FWHM) of 9% at energy of 0.662 MeV (^{137}Cs) which is considered adequate to distinguish the gamma ray energies of interest in this study. The photons emitted by them would only be sufficiently discriminated if their emission probability and their energy are high enough and the surrounding background continuum was low enough. The activity concentration of ^{214}Bi (determined from its 1.760 MeV γ- ray peak) was therefore used to estimate for ^{226}Ra (^{238}U) in the samples. 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 from the total area of the peaks. From the net area, the activity concentrations in the samples were obtained using**[9,24]**:

$C\ (Bql^{-1}) = kC_n$ (1)

Where $k = \frac{1}{\varepsilon P \gamma V s}$, C is the activity concentration of the radionuclide in the sample given in Bql^{-1}, C_n is the count rate under the corresponding peak, ε is the detector efficiency at the specific $\gamma - ray$ energy, P γ is the absolute transition probability of the specific $\gamma - ray$ energy, and Vs is the volume of the sample. Using equation1, the activity concentrations of uranium in each of the water samples were determined.

A) Conversion Factor

The data for the activity concentrations of the uranium were converted to the uranium mass concentration ($\mu g.l^{-1}$) using the following conversion factors:

$1Bql^{-1} = 0.037pCil^{-1}$; $1\mu gl^{-1} = pCil^{-1}/0.67$ (2)

B) Radiological risk assessment

The lifetime cancer risks R, associated with intake of a given radionuclide were estimated from the product of the applicable risk coefficient *r* and the per capita activity intake *I* expressed in equation (3).

$R = rxI$ (3)

According to WHO and UNDP **[2,10]**, the average life expectancy at birth in Nigeria and in the Niger Delta region of Nigeria is 45.5 years and, an annual consumption of water for an individual is about 730litres. This brings the lifetime intake of water to 33,215litres. The cancer risk coefficients of uranium of $1.13 \times 10^{-9} Bq^{-1}$ and $1.73 \times 10^{-9}\ Bq^{-1}$for **mortality** and **morbidity** respectively were obtained from literature **[27,28]**. Using equation 3 and these coefficients the cancer mortality and morbidity risks of uranium over lifetime consumption of water were calculated.

C) Chemical toxicity risk assessment

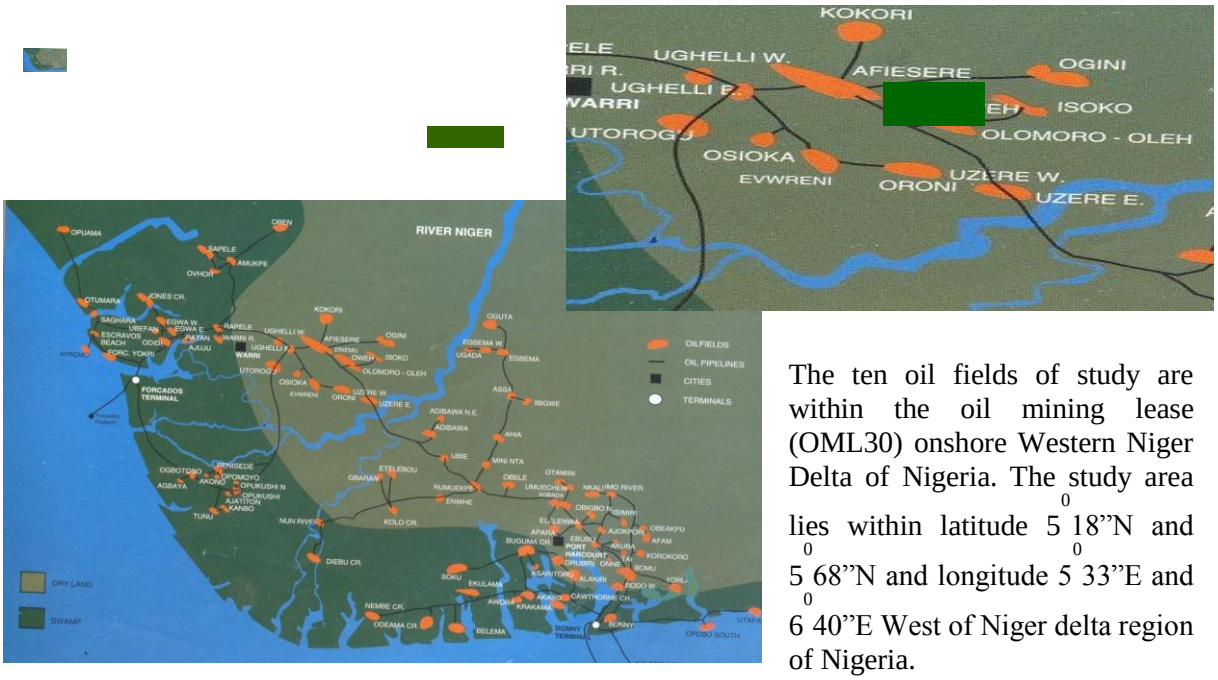
The chemical toxicity risk was evaluated using the lifetime average daily dose of uranium through drinking water intake, and compared it with the reference dose(RFD) of 0.6 $\mu g.kg^{-1}day^{-1}$**[29]** used as a standard criteria for uranium in several foreign organizations and thereby produce a hazard quotient(Equation 4).

Hazard quotient = $\frac{LADD}{RFD}$ (4)

And

Ingestion LADD of drinking water=$\frac{EPC\ x\ IR\ x\ EF\ x\ ED}{AT\ x\ BW}$ (5)

Where LADD, lifetime average daily dose ($\mu g.kg^{-1}.day^{-1}$); EPC is the exposure point concentration ($\mu g.l^{-1}$); IR is the water ingestion rate ($l.day^{-1}$); EF is the exposure frequency (days.year1); ED is the total exposure duration(years); AT is the average time (days) and BW is the body weight (kg). Using therefore, IR = 2 $litre.day^{-1}$; EF = 350 days, ED = 45.5 years, AT = 16,607.5 (obtained from45.5 × 365) and BW = 70 kg (for a standard man) the chemical toxicity risk of uranium over a life time consumption was estimated.



The ten oil fields of study are within the oil mining lease (OML30) onshore Western Niger Delta of Nigeria. The study area lies within latitude $5^{0}18$"N and $5^{0}68$"N and longitude $5^{0}33$"E and $6^{0}40$"E West of Niger delta region of Nigeria.

Fig 1: A map showing network of pipes of oil fields in onshore of the Niger Delta.

3.0 Results and Discussion

3.1 Results

Table 1: Gamma Dose Rate ($mSvy^{-1}$) in Air and Specific activity of ^{238}U (Bql^{-1}**)** in well, Borehole and River water samples from oil fields environment

S/N	A REA CODE	SAMPLED OIL FIELD HOST COMMUNI-TIES	Geographical coordinate	WATER SAMPLE ACTIVITY CONCENTRATION (Bql^{-1})					
				Well Water		Borehole Water		River Water	
				EQ. DOSE $mSvy^{-1}$	^{238}U/ Bql^{-1}	EQ. DOSE $mSvy^{-1}$	^{238}U/ Bql^{-1}	EQ. DOSE $mSvy^{-1}$	^{238}U/ Bql^{-1}
1	**UZE**	Uzere	***N05' 20 E006' 14***	1.0	2.4±0.4	1.1	3.0±0.2	0.9	10.2±0.7
2	OLO	Olomoro	***N05' 26 E006' 11***	0.7	3.5±0.4	0.5	0.7±0.1	1.0	4.3±0.4
3	OWH	Oweh	***N05' 29 E006' 06***	1.6	12.4±1.6	1.4	7.4±1.3	1.4	4.6±0.2
4	EVN	Evwreni	***N05' 24 E006' 03***	0.8	2.7±0.1	1.1	4.9±0.3	1.3	12.0±1.3
5	EGA	Gana	***N05' 38 E006' 03***	1.2	6.4±0.8	1.3	14.1±1.7	1.3	36.4±2.9
6	KER	Erhoike	***N05' 38 E006' 04***	1.3	15.2±1.3	0.7	4.3±0.7	1.2	8.1±0.9
7	AEM	Emeragha	***N05' 32 E005' 01***	1.3	11.9±0.9	1.3	6.2±0.4	0.8	13.5±1.2
8	UER	Eruemukohwarie n	***N05' 31 E005' 56***	1.1	9.2±1.0	1.0	4.4±0.5	0.7	26.4±2.1
9	U EK	Ekakpamre	***N05' 31 E005' 54***	0.5	8.4±0.8	0.8	4.8±0.5	0.8	28.4±2.6
10	OUT	Otujeremi	***N05' 25 E005' 52***	0.8	8.3±1.1	1.0	5.1±0.6	0.9	10.1±1.6
AVERAGE				**1.0**	**7.2±0.8**	**1.0**	**5.5±0.7**	**1.0**	**5.5±0.7**
Control				0.6	2.7±0.2	0.6	1.3±0.2	0.7	3.6±0.4

Table2: Computed mass concentration, Cancer mortality and morbidity risk values and Life Average daily dose

Risk Assessment	Well Water Sample			Borehole Water Sample			River Water Sample		
	Max.	**Min.**	**Ave.**	**Max.**	**Min.**	**Ave.**	**Max.**	**Min.**	**Ave.**
Mass Concentration(μgl^{-1})	**613.2±52.4**	**108.9±4.0**	**324.3±33.9**	**568.8±68.6**	**28.2±4.0**	**221.5±25.4**	**1460.3±117.0**	**173.5±16.1**	**620.4±56.1**
Cancer Mortality Risk $x10^{-5}$	**57.1**	**9.0**	**30.2**	**52.9**	**2.6**	**20.6**	**136.6**	**16.1**	**57.8**
Cancer Morbidity Risk $x10^{-5}$									
Lifetime Average daily Dose(LADD) ($\mu gkg^{-1}.day^{-1}$)	**87.3**	**13.8**	**46.2**	**81.0**	**4.0**	**31.5**	**209.2**	**24.7**	**88.5**
	16.8	**2.7**	**8.9**	**15.6**	**0.8**	**5.9**	**40.0**	**4.8**	**17.0**

3.2 Discussion

The result of the absorbed equivalent dose rate and the activity concentration of Uranium in each of the water samples are presented in Table1. The background equivalent dose rate in the hand dug well environment ranged from 0.5 to 1.6$mSvyr^{-1}$with an average value of 1.0$mSvyr^{-1}$. Within the communities' borehole areas, dose rate ranged from 0.5 to 1.4 $mSvyr^{-1}$ with an average value of 1.0 $mSvyr^{-1}$, while within the communities' stream/ river background dose rate varied from 0.7 to1.4 $mSvyr^{-1}$and an average of 1.0$mSvyr^{-1}$. These values obtained agree satisfactorily with reported values within similar environment in this region **[18,30,31]**. Though these values are slightly above values obtained in the control sample area and values reported in other parts of the country **[32,33]**, but average values are within the 1.0$mSvyr^{-1}$recommended by ICRP,**[34].**

In well water samples, the activity concentration of ^{238}U ranged from 2.4±0.4 to 15.2±1.3Bql^{-1} with an average value of 7.2±0.8Bql^{-1}. In borehole waters, ^{238}U activity concentration ranged from 0.7±0.1 to 14.1±1.7Bql^{-1} with an average value of 5.5±0.7Bql^{-1}. While Uranium activity concentration in river water varied between 4.3±0.4 and 36.4±2.9Bql^{-1} with an average value of 15.4±1.4Bql^{-1}. Uranium activity concentration in the control sample is 2.7±0.2Bql^{-1}, 1.3±0.2 and 3.6±0.4 for hand dug well, borehole and river water respectively. The error in these reported values are combined uncertainties in the counting error, efficiency determination etc. These values obtained are slightly above the reported values for boreholes and well water in Ogun state, Nigeria **[9]**. These values obtained are above the values reported by Nour K.A.**[35]** in ground and surface drinking(well and tap) water in Upper Egypt. It is also above those reported by Vesterbacka, Pia**[36]** in Finland drinking water. This value is also higher than the similar average value of 0.5Bql^{-1} reported in Sweden, Ukraine and Spain **[37,38,39,40]**. But this result is within the reported values in South-West Nigeria **[22]** and North- West of Nigeria **[41]**. More so, this result agrees satisfactorily with the values reported in Biseni flood plain lake, a similar oil exploitation environment in the Niger Delta by Agbalagba and Onoja, **[42]**. This result agreed slightly with the values of 10.2±1.7Bql^{-1} for ^{226}Ra, reported in drinking water in Belgrade by Rajkovic*et al.***[43]**. A comparison of the activity concentration of the three water sources with the control samples, revealed that all the water sources radionuclide activity concentration are higher than the values of the control, which implies that water sources from these oil fields may have been polluted with the activity of the oil exploitation companies.

The data for the activity concentrations of the uranium were converted to the uranium mass concentration (μgl^{-1}) using equation (2), the mass concentration values are presented in table 2. As could be seen, the mass concentration values ranged from 108.9±4.0 to 613.2±52.4 μgl^{-1} with average value of 324.3±33.9 μgl^{-1} for hand dug well water. For borehole water the value ranged from 28.2±4.0 to 568.8±68.6 μgl^{-1} with an average value of 221.5±25.4 μgl^{-1} while the mass concentration ranged from 173.5±16.1 to 1460.3±117.0 μgl^{-1} with an average of 620.4±56.1μgl^{-1} in river water samples. Various health and environmental protection agencies have set different safety limit for uranium in drinking water for man. These values obtained are higher than the 3.05±0.9pCi/l in Safaga- Quseir (Egypt) ground water **[35]**, the 0.34pCi/l mean value obtained in Fujian Province ground water in China **[44]**, the 0.27-1.35pCi/l in Lodz Poland underground water **[45]** and the 1.12pCi/l in Austria domestic bottle water **[46]**, but the obtained values are within the range of values reported by Somlai*et al.***[47]** in bottled mineral water in Hungary,Labidi, et al. in Springs water in Tunisia**[48]**. The World Health Organization (WHO)**[4]**, United State Environmental Protection Agency (USEPA)**[49]** and Health Canada **[50]** have recommended 15μgl^{-1}, 30μgl^{-1} and 20μgl^{-1} respectively for safe limit of uranium in public water supplies. These levels were set to represent the concentration that would not result in any significant risk to health over a lifetime's drinking of water. Comparing uranium mass concentrations obtained in the various sources of water supplies in the study area with the (USEPA)**[49]**, it could be seen that only borehole water sample from Olomoro oil field had a value about USEPA safe limit while others exceeded the limits. These high values may be attributed to the fact that the oil and gas activities in the area have increase the uranium concentration with the surface water sources most impacted. This result is in agreement with the obtained dose rate in the study area to which uranium and thorium decay series are major contributors **[9]**.

The radiological risk assessment associated with the consumption of these three sources of water supplies were evaluated using equation 3, the result obtain is presented in Table 2. The cancer mortality risk ranged from 9.0 $x10^{-6}$ to 57.1$x10^{-6}$ with average value of 30.2$x10^{-6}$ in hand dug wells water samples. In borehole water samples the cancer mortality risk ranged from 2.6$x10^{-6}$ to 52.9$x10^{-6}$ and an average value of 20.6$x10^{-6}$ while in river water samples, it ranges from 16.1$x10^{-6}$ to 136$x10^{-6}$

with average value of $57.8x10^{-6}$. The cancer morbidity risk in hand dug well water samples ranged from $13.8x10^{-6}$ to $87.3x10^{-6}$with an average value of $46.2x10^{-6}$. Borehole water samples value ranged from $4.0x10^{-6}$ to $81.0x10^{-6}$ with an average value of $31.5x10^{-6}$, while in the river water samples, the cancer morbidity risk ranged from $24.7x10^{-6}$ to $209.2x10^{-6}$ with average value of $88.5x10^{-6}$. These values obtained for both mortality and morbidity risk level agreed totally with the values report by Amakom and Jibiril in South-western Nigeria**[9]**. The cancer risk level obtained which average $\sim10^{-4}$ is lower compared to the acceptable level of 10^{-3} for the radiological cancer risk **[9,29]**. The chemical toxicity risk of uranium in the three water sources sample were evaluated using equations 4 & 5. Table 2 also present the estimated lifetime average daily dose (LADD) results. The LADD value obtained for hand dug well water samples ranged from 2.7 to 16.8$\mu gkg^{-1}.day^{-1}$ with average value of 8.9$\mu gkg^{-1}.day^{-1}$, for borehole water samples the value ranged from 4.0 to 15.6$\mu gkg^{-1}.day^{-1}$ and average value of 5.9$\mu gkg^{-1}.day^{-1}$ while the value ranged from 4.8 to 40.0$\mu gkg^{-1}.day^{-1}$ with average value of 17.0$\mu gkg^{-1}.day^{-1}$ for river water. The LADD values were observed to be higher in river water samples than the boreholes and hand dug well water samples which are in contrast to the result obtained by Amakom and Jibiril**[9]**. It is expected that the borehole values be higher due to the depth of the water source (underground water) and the geochemistry of ground water. Thus the high value obtained for river water samples in relation to the hand dug well and borehole water samples can be attributed to the frequent oil spill into these water bodies which may have enhance the uranium concentration hence the chemical toxicity of the water samples. A comparison of the lifetime average daily dose (LADD) obtained in this study and the reference dose (RFD) of 0.6$\mu gkg^{-1}.day^{-1}$which the acceptable level, the chemical toxicity risk due to uranium in the water samples were all above the reference dose. This shows that there may be health risks associated with uranium in the water samples which will mainly due to chemical toxicity. The overall result shows that the radioactivity concentration in the three examined sources of water supplies to the populace of the studied area in the following order of magnitude; Borehole < Well < River water. This shows that there are terrestrial anthropogenic activities that may have enhances the levels of radioactivity in surface water, which can be attributed to the impact of activities of the oil and gas exploration and exploitation companies on the water samples. An ion exchange pretreatment and reverse osmosis treatment technique is recommended for all sources of water studied to reduce and removal of heavy metals/ radionuclides from water sources

4.0 Conclusion

The activity concentration of uranium in hand dug wells, boreholes and river waters samples within oil and gas field communities in Delta state have been carried out using gamma-ray spectroscopy while the environmental BIR was measured using dosimeter. The activity concentrations were related to the mass concentrations of uranium in the samples. The BIR was found to be within permissible limit, the average mass concentration of the three sources sampled was found to be relatively higher compared with the recommended safe limits by various international organizations. Cancer mortality and morbidity risk values are in agreement with other reported values within country and are well below acceptable standard. The chemical toxicity risk of uranium in the three water sources sample estimated using lifetime average daily dose (LADD) were found to be above the reference level of 0.6$\mu gkg^{-1}.day^{-1}$ which the acceptable level. It could therefore be concluded that human risk due to uranium content in water supplies that will result from ingestion in the study area may be attributed to chemical toxicity of uranium as heavy metals rather than radiological risk. This study represent an area useful radiometric data that could be of great importance in diagnosis, prognosis and radio- epidemiological assessment of uranium- induced sickness and diseases to the local population of the study area.

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