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EVALUATION OF RADIATION HAZARD INDICES IN AN OIL MINERAL LEASE (OIL BLOCK) IN DELTA STATE, NIGERIA

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ABSTRACT

The radiation hazard indices in an Oil Mineral Lease (OML) in Delta State have been evaluated. Soil/sediment and water samples were collected from ten oil fields in the Oil Block and the concentrations were measured using gamma ray spectrometric system. For soil samples, the mean value of Annual Gonnadal Equivalent Dose (AGED) of the ten oil fields was 380.37±38.4mSvy^{-1} and that for Annual Effective Dose Equivalent (AEDE) (Outdoor and Indoor) were 66.95±6.9µSvy^{-1} and 267.79±27.5µSvy^{-1} respectively. The Excess Lifetime Cancer Risk mean value was 0.234±0.02 x 10^{-3}. These show that the mean value for AGED is above the permissible value which is an indication of radiological elevation in the areas. Some of the areas have values of AGED, AEDE (Outdoor) and ELCR that were higher than the recommended limits. The radiation indices sources of water supply in the areas were also calculated. Mean values for AGED were 55.26±5.25 mSvyr^{-1}, 47.84±5.13 mSvyr^{-1} and 104.18±9.28 mSvyr^{-1} for well, tap and river water samples respectively while the mean values for AEDE (Outdoor), AEDE (Indoor) and ELCR were 9.90±0.95 µSvy^{-1}, 8.56±0.92 µSvy^{-1} and 18.78±1.68 µSvy^{-1}, 39.60±3.78 µSvy^{-1}, 34.24±3.68 µSvy^{-1} and 75.14±6.69 µSvy^{-1} and 0.0346 x 10^{-3}±0.003 x 10^{-3}, 0.0300 x 10^{-3}±0.0300 x 10^{-3} and 0.0657±0.006 x 10^{-3} for well, tap/borehole and river water samples respectively. Although, most of the calculated hazard indices in water were lower than the permissible limits, they were still higher than the values from non oil producing areas which shows that the oil and gas activities could have impacted negatively on the radiological status of the environment. It can be concluded that there is significant radiological hazards to the people in the areas from soil/sediment samples which can be attributed to the oil activities in the area.

Keywords: ***Gamma spectroscopy, radiation hazard, Oil activity, Delta State***

Introduction

Radiation is energy, which can be particles or photons, given off by heavy isotopes (radionuclides) to become stable. Radionuclides are found all around us in our environment, in the atmosphere, beneath the earth and even within us. Sources of radionuclides include those that exist before the creation of the earth (primordial sources), those that result from cosmic ray interactions (cosmogenic sources) and those that result from human activities.

There are many radionuclides in the earth and in the atmosphere. However, only those with half lives in the range of the age of the earth and their decay products are of interest because the gamma radiations from these constitute the main source of external exposure to humans (Kolo et al., 2012). Humans are constantly exposed to these natural radiation, however the activities of oil exploitation and exploration in the oil producing regions in Nigeria have led to higher level of exposure to radiation due to activities like drilling, oil spillage, gas flaring etc. Oil spills lead to the contamination of surface water with hydrocarbons and trace metals, though most areas in the Niger Delta have mostly clay soils which provide protection for the groundwater aquifers, however this cannot provide sufficient protection during oil spillage (Best and Seiyefa, 2013).

Oil spillage in the Niger Delta region is caused by different factors. These include pipeline vandalism, corroded pipelines, sabotage, oil production

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operations and faulty production equipment. An estimated 6817 oil spills were recorded between 1976 and 2001, that implies a loss of about three million barrels of oil, with over 70% unrecovered (UNDP, 2006). These have lead to the destruction of arable farmland, crops and contamination of groundwater and soils. Also, health issues reported in the areas include breathing problems and skin lesions. The water in the areas is not fit for drinking due to contamination from oil and most of the dwellers that are farmers and fishermen have been put out of work due to contamination from oil spills. In the coastal region, mangrove which was a good source of fuel wood and habitat for biodiversity has been destroyed.

Gas flaring is another destructive effect of the oil and gas industry. Gas flaring releases toxic components into the environment, which includes methane majorly and other green house gases like carbon monoxide. Nigeria flares gas more than any other country. A World Bank study showed that Nigeria flares about 76% of all natural gas from petroleum production, this is in contrast to 0.6 percent in United States, 4.2 percent in United Kingdom, 21, 20 and 19 percents in Libya, Saudi Arabia and Iran respectively. In 1994, the Nigerian Conservation Foundation revealed that Nigeria released 34 million tones of methane to the atmosphere that year alone with 15% of it been radon gas (Agbalagba et al., 2012). This implied that Nigeria oil fields contribute more to global warming than the rest of the world (Aghalino, 2001).

Several studies have been carried out on the radiological hazard indices in soil/sediment and water samples in different parts of the country and the world at large(Ajayi et al., 2013, Kolo et al., 2012, Avwiri et al., 2012, Agbalagba et al., 2012, Jibiri et al., 2009, Jibiri and Okeyode, 2012, El-Taher and Uosif, 2006, Almayahi et al., 2012, Degerlier, 2013, Zubair et al., 2013, Masitah et al., 2008, Yasir et al., 2007, Yii et al., 2011). But, very few of the studies have been dedicated to the Niger Delta region of Nigeria.

This study is therefore aimed at assessing the activity concentration of radionuclides in this environment (soil and water) and to evaluate the radiation hazard indices of samples for robust estimation of the hazard impact on man and the environment. The results obtained from the evaluation will be compared with that in literature and the standard recommended limits.

Materials and Methods

Study area

The study area lies within Delta State, South West of Niger Delta region of Nigeria. It covers 1097 square kilometers and lies 45 kilometres East of Warri. It includes eight producing field and the associated facilities. The location and geology have been reported elsewhere (Agbalagba et al., 2012, Taiwo and Akalia, 2009)

Sample collection and preparation

The bulk soil and sediment samples were collected from ten oil fields of the Oil Mineral Lease areas. The collection was done in various areas including field soil, flow station soil, oil spilled soil, sediment from the flare stack or field sediment. Each sample was collected randomly from an area of approximately 100 m^2 and up to a depth of 0.3 to 0.50m. The samples, collected in black polythene bags, were oven dried at 60^0C for about 24 hours. The dried samples were ground with mortar and pestle and then allowed to pass through a 2mm-mesh sieve, the larger particles discarded. The filtered soil/sediment was then sealed for at least 28 days in air tight plastics containers previously washed and rinsed with diluted tetraoxosulphate (VI) acid (H_2S0_4) before analysis with the gamma-spectrometer (IAEA, 1989). This was done in order to maintain radioactive equilibrium. Control sample was also collected from a non oil bearing environment.

Water samples (borehole water, well water and river water) were collected from the oil field areas. The water samples were acidified with HCl at the rate of 10ml per litre of sample immediately after collection to avoid adsorption of radionuclide on the walls of the containers (IAEA, 1989).

All the storing containers were washed with diluted tetraoxosulphate (VI) acid (H_2S0_4) and dried to prevent contamination and filled with about 1litre of water sample. A control water samples were collected from a non oil bearing community and from rain water. The samples collected were sealed for a period of one month to ensure that loss of radon does not occur and secular equilibrium is established before the γ-ray analysis. When this equilibrium state is attained, the activity of each nuclide in a given series will be equal to the activity of the parent nuclide.

Sample Analyis

The gamma spectrometric measurement was carried out using Gamma ray spectrometric system at the Centre for Energy, Research and Development (CERD), Obafemi Awolowo University, using a thallium activated 3"x3" Sodium iodide [NaI(TI)] detector connected to ORTEC 456 amplifier. The detector, enclosed in a 100mm thick lead shield, was connected to a computer program MAESTRO

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window that matched gamma energies to a library of possible isotopes. Since the accuracy of the quantitative measurements is depended on the calibration of the spectrometry system and adequate energy. The energy calibration was made possible using Cs-137 and Co-60 standard sources from IAEA, Vienna, while the efficiency calibration was performed using the reference water sources of (^{238}U, ^{226}Ra, ^{228}Ra, ^{232}Th and ^{40}K) obtained from IAEA laboratory, Vienna.. Spectrum were accumulated for background for 29000s at 900volts to produce strong peaks at gamma emitting energies of 1460keV for ^{40}K; 609keV of ^{214}Bi and 911keV of ^{228}Ac, which were used to estimate the concentration of ^{226}R and ^{232}Th, respectively. The energy resolution of the detector using Cs-137 and Co-60 standards is 9% and 10.5% respectively while the activity of the standards at the time of calibration is 25.37KBq for Cs-137 and 4.84KBq for Co- 60. 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 background spectra, measured under the same conditions for both the standard and sample measurements, were used to correct the calculated sample activities concentration in accordance with Arogunjo, et.al. 2005. The activity concentration (C) in Bql^{-1} of the radionuclides in the samples was calculated after subtracting decay correction using the expression:

$$C_S = \frac{M_{St}A_S}{M_S A_{St}} C_{St} \qquad 1$$

Where C_S is the concentration of radionuclide in the sample (BqKg^{-1}), C_{St} is the concentration of radionuclide in the standard (BqKg^{-1}), M_{St} is the weight of the standard (g), M_S is the weight of the sample (g), A_{St} is the counts of standard (cps) and A_S is the counts of sample (cps).

The absorbed dose due to the concentrations of the radionuclides in the samples was calculated from

$$D(nGyh^{-1}) = 0.462C_{Ra} + 0.621C_{Th} + 0.0417C_K \qquad 2$$

Radiation Hazard Indices Calculation

Standard radiation hazard indices are used to evaluate the effects of radiation on the health condition of people exposed to radiation and the environment. The indices to be evaluated are discussed below.

The Annual Gonnadal Equivalent Dose is a measure of the threat to sensitive cells like the gonads, bone marrow, surface cells from exposure to a particular level of radiation. Given activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, AGED is calculated using the equation (Avwiri et al., 2012):

(a) Annual Gonnadal Equivalent Dose (AGED)

$$AGED\ (Svyr^{-1}) = 3.09C_{Ra} + 4.18\ C_{Th} + 0.314\ C_K \qquad 3$$

Where $C_{Ra,}$ $C_{Th,}$ C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively. The standard UNSCEAR value for AGED is 300mSvyr^{-1}.

(b) Annual Effective Dose Equivalent (AEDE)

Annual Effective Dose Equivalent can be calculated for outdoor or indoor.

AEDE (Outdoor) (µSvy^{-1}) = Absorbed dose (nGyh^{-1}) x 8760h x 0.7SvGy^{-1} x 0.2 x10^{-3} 4

AEDE ((Indoor) (µSvy^{-1}) = Absorbed dose (nGyh^{-1}) x 8760h x 0.7 SvGy^{-1} x 0.8 x 10^{-3} 5

The standard AEDE (Outdoor) value is 70µSvyr^{-1} and that for AEDE (Indoor) is 450µSvyr^{-1}.

These indices measure the risk of stochastic and deterministic effects in the irradiated individuals.

(c)

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Excess Lifetime Cancer Risk (ELCR)

This gives the probability of developing cancer over a lifetime at a given exposure level, considering 70 years as the average duration of life for human being. It is given as (Taskin et al., 2009):

$$ELCR = AEDE \times DL \times RF \qquad 6$$

Where AEDE is the Annual Effective Dose Equivalent, DL is the average Duration of Life (estimated to be 70 years) and RF is the Risk Factor (Sv) i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for the public.

The percentage risk analysis associated with this index is then given by (Avwiri et al., 2012):

$$\left[\frac{Calculated\ ELCR - Standard\ ELCR}{Standard\ ELCR}\right] \times 100\% \qquad 7$$

Where Standard ELCR is given as 0.29×10^{-3}.

RESULTS AND DISCUSSIONS

Table 1: Radiation Indices in soil samples

Location	^{226}Ra $Bqkg^{-1}$	^{232}Th $Bqkg^{-1}$	^{40}K $Bqkg^{-1}$	D ($nGyh^{-1}$)	AGED (mSvy-1)	AEDE (outdoor) (μSvy^{-1})	AEDE (indoor) (μSvy^{-1})	ELCR ($\times 10^{-3}$) (μSvy^{-1})
Uzere E&W	31.7	28.3	288.6	44.2	306.9	54.3	217.1	0.190
Oleh/Olomo	30.7	17.1	240.4	34.8	241.8	42.7	170.8	0.149
Oweh	36.9	30.4	454.8	54.9	383.9	67.3	269.3	0.236
Evwreni	45	28.9	559.6	62.1	435.6	76.1	304.5	0.266
Eriemu	60.4	47.5	496.5	78.1	541.1	95.8	383.2	0.335
Kokori	64	39.6	597.1	79.1	550.8	97.0	387.8	0.339
Afiesere	32.4	22.1	331.7	42.5	296.6	52.2	208.6	0.183
Ughelli East	34.9	25.6	440.2	50.4	353.1	61.8	247.1	0.216
Ughelli West	46	34.6	450.5	61.5	428.2	75.5	301.8	0.264
Otorogu	28	23	266.2	38.3	266.2	47.0	188.0	0.164
Mean Value	**41±5**	**29.7±4**	**412.5±20**	**54.6±5.6**	**380.4±38.4**	**66.9±6.9**	**267.8±27.5**	**0.234±0.02**

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Table 2 : Summary of Specific Activities in water samples

SAMPLED OIL FIELD	WATER SAMPLE ACTIVITY CONCENTRATION (Bql^{-1})								
	Host Comm.Well water			Host Comm.Tap Water			Field River Water		
	^{226}Ra	^{228}Ra	^{40}K	^{226}Ra	^{228}Ra	^{40}K	^{226}Ra	^{228}Ra	^{40}K
Uzere East&West	2.4±0.4	1.3±0.2	27.6±2.8	3.0±0.2	0.9±0.1	32.1±3.0	10.2±0.7	3.2±0.1	30.2±1.8
Olomoro/Oleh	3.5±0.4	2.7±0.2	24.4±2.2	0.7±1.0	1.5±0.1	12.1±0.6	4.3±0.4	4.4±0.5	24.2±2.2
Oweh	12.4±1.6	8.3±0.8	8.3±0.8	7.4±1.3	6.6±0.4	32.5±3.0	4.6±0.2	8.5±0.2	40.3±5.4
Evwreni	2.7±0.1	12.7±0.1	31.3±2.6	4.9±0.3	7.2±0.8	24.4±2.0	12.0±1.3	7.2±0.8	17.2±2.0
Eriemu	6.4±0.4	6.3±0.6	101.1±2.7	14.1±1.7	12.2±1.3	79.2±7.9	36.4±2.9	31.5±2.4	113±9.7
Kokori	15.2±1.3	8.2±1.0	28.4±2.1	4.3±0.7	3.1±0.1	16.2±2.2	8.1±0.9	6.0±0.5	29.4±2.2
Afiesere	11.9±0.9	4.3±0.5	26.7±2.4	6.2±0.4	4.0±0.2	22.5±1.8	13.5±1.2	6.4±1.1	32.6±3.7
Ughelli East	9.2±1.0	5.5±0.6	28.6±2.7	4.4±0.5	4.3±0.3	30.9±3.4	26.4±2.1	11.6±1.2	48.1±3.5
Ughelli West	0.4±0.8	0.5±0.3	16.7±1.4	4.8±0.5	6.2±0.7	19.7±1.8	28.4±2.6	18.3±1.5	56.3±6.2
Otorogu	8.3±1.1	5.6±0.6	26.2±2.1	5.1±0.6	6.0±0.4	20.7±2.4	10.1±1.6	6.4±0.8	26.7±3.2
Mean	**7.2±0.8**	**5.5±0.5**	**31.9±2.2**	**5.5±0.7**	**5.2±0.5**	**29.0±2.8**	**15.4±1.4**	**10.4±0.9**	**41.8±3.8**
Control	**2.7±0.2**	**2.4±0.3**	**19.4±1.9**	**1.3±0.2**	**0.7±0.1**	**6.3±1.1**	**3.6±0.4**	**2.9±0.6**	**21.0±1.7**

Table 3: Radiation Indices for well water in host community

Location	AGED ($mSvyr^{-1}$)	AEDE(outdoor) ($\mu Svyr^{-1}$)	AEDE(indoor) ($\mu Svyr^{-1}$)	ELCR X 10^{-3} ($Svyr^{-1}$)
Uzere E&W	21.52	3.76	15.05	0.0132
Oleh/Olomo	29.76	5.29	21.15	0.0185
Oweh	75.62	13.77	55.09	0.0482
Evwreni	71.26	12.80	51.21	0.0448
Eriemu	77.86	13.59	54.38	0.0476
Kokori	90.16	16.31	65.24	0.0571
Afiesere	63.13	11.38	45.53	0.0398
Ughelli East	60.40	10.86	43.46	0.0380
Ughelli West	8.57	1.46	5.85	0.0051
Otorogu	57.28	10.31	41.23	0.0361
Mean	**55.26±5.25**	**9.90±0.95**	**39.60±3.78**	**0.0346±0.003**
Control	**24.47**	**4.35**	**17.40**	**0.0152**

Table 4: Radiation Indices for Tap Water in host community

Location	AGED ($mSvyr^{-1}$)	AEDE(outdoor) ($Svyr^{-1}$)	AEDE(indoor) ($Svyr^{-1}$)	ELCR X 10^{-3} ($Svyr^{-1}$)
Uzere E&W	23.11	4.03	16.11	0.0141
Oleh/Olomo	12.23	2.16	8.63	0.0076
Oweh	60.66	10.88	43.53	0.0381
Evwreni	52.90	9.51	38.03	0.0333
Eriemu	119.43	21.33	85.32	0.0747
Kokori	31.33	5.63	22.50	0.0197
Afiesere	42.94	7.71	30.84	0.0270
Ughelli East	41.27	7.35	29.39	0.0257
Ughelli West	46.93	8.45	33.80	0.0296
Otorogu	47.34	8.52	34.07	0.0298
Mean	**47.84±5.13**	**8.56±0.92**	**34.24±3.68**	**0.0300±.0.03**
Control	**8.92**	**1.59**	**6.37**	**0.0056**

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Table 5: Radiation Indices for Field River Water in host community

Location	AGED ($mSvyr^{-1}$)	AEDE(outdoor) (Svyr-1)	AEDE(indoor) (Svyr-1)	ELCR X 10^{-3} (Svyr-1)
Uzere E&W	54.38	9.76	39.04	0.0342
Oleh/Olomo	39.28	7.02	28.10	0.0246
Oweh	62.40	11.14	44.56	0.0390
Evwreni	72.58	13.16	52.65	0.0461
Eriemu	279.63	50.39	201.57	0.1764
Kokori	59.34	10.66	42.65	0.0373
Afiesere	78.70	14.19	56.76	0.0497
Ughelli East	145.17	26.25	105.01	0.0919
Ughelli West	181.93	32.91	131.63	0.1152
Otorogu	66.34	11.96	47.85	0.0419
Mean	**104.18±9.28**	**18.78±1.68**	**75.14±6.69**	**0.0657±0.006**
Control	**29.84**	**5.32**	**21.29**	**0.0186**

Table 6: Percentage risk analysis for Excess Lifetime Cancer

Location	ELCR (x 10^{-3})	Percentage Risk (%)
Uzere E&W	0.190	-34.48
Oleh/Olomo	0.149	-48.62
Oweh	0.236	-18.62
Evwreni	0.266	-8.28
Eriemu	0.335	15.52
Kokori	0.339	16.90
Afiesere	0.183	-36.90
Ughelli East	0.216	-25.52
Ughelli West	0.264	-8.97
Otorogu	0.164	-43.45
Mean Value	**0.234±0.02**	**-19.31±6.90**
Control	**0.099**	**-65.86**

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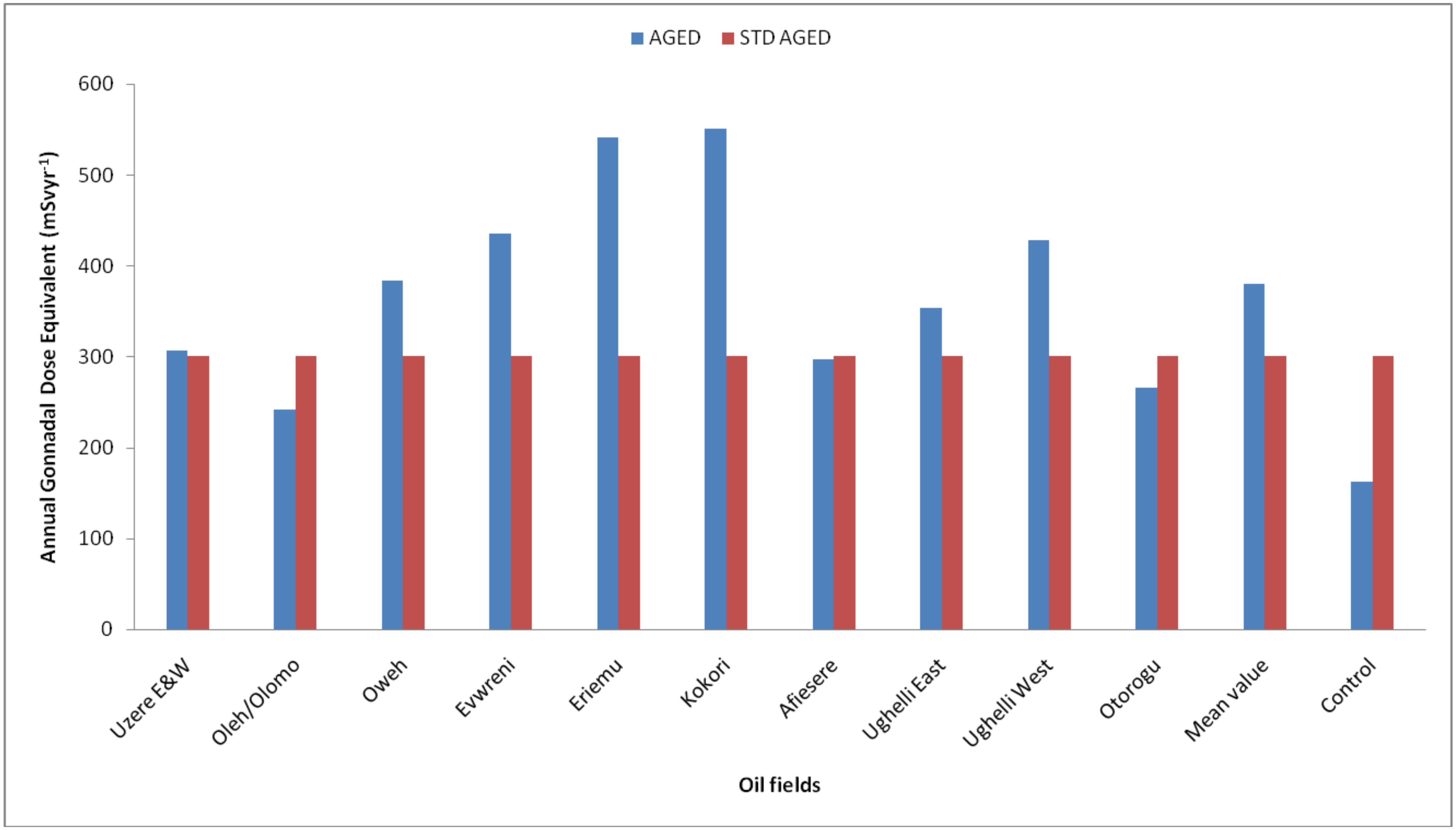

Figure 1: Annual Gonnadal Equivalent Dose compared with standard for soil samples

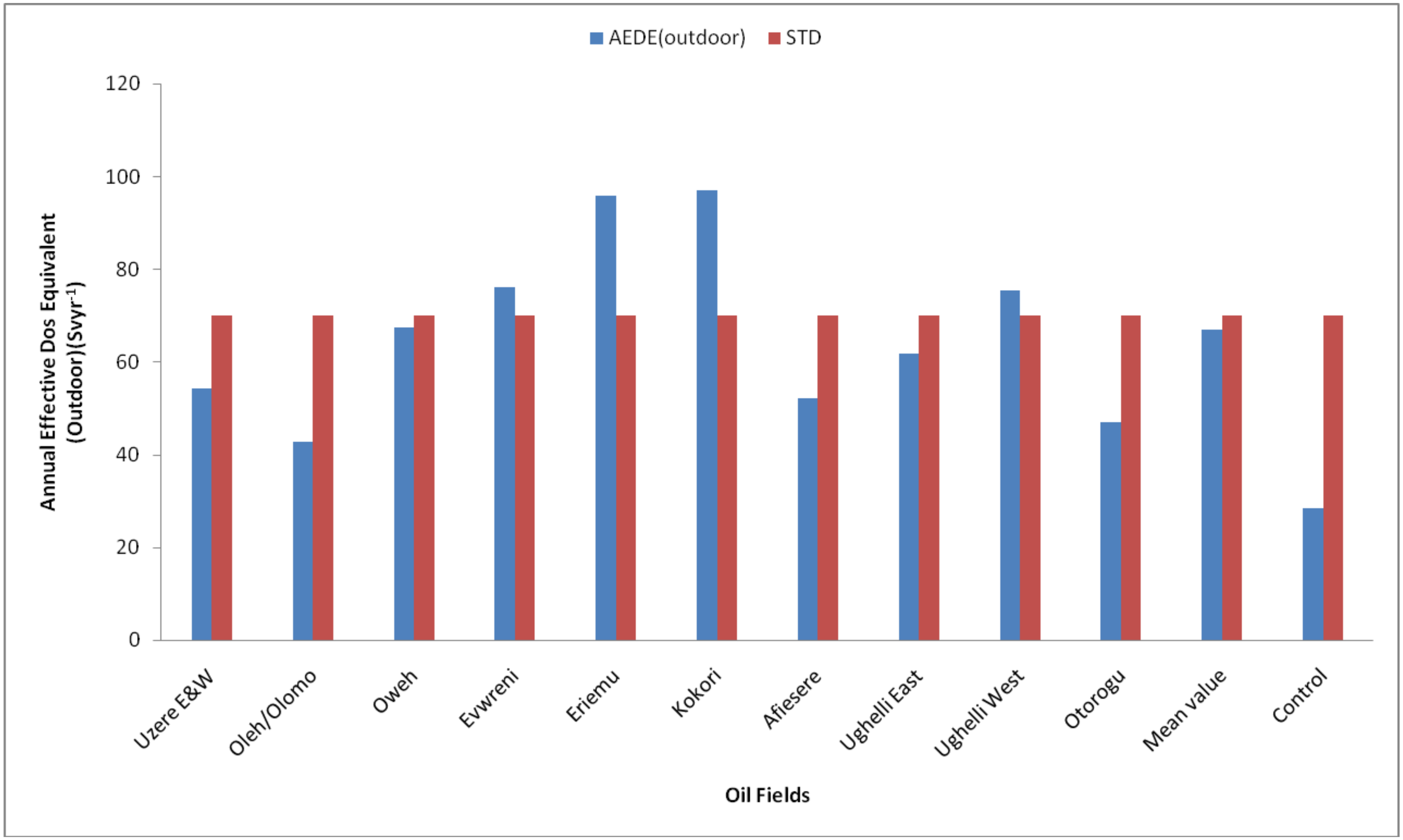

Figure 2: Annual Effective Dose Equivalent (Outdoor) compared with standard for soil samples

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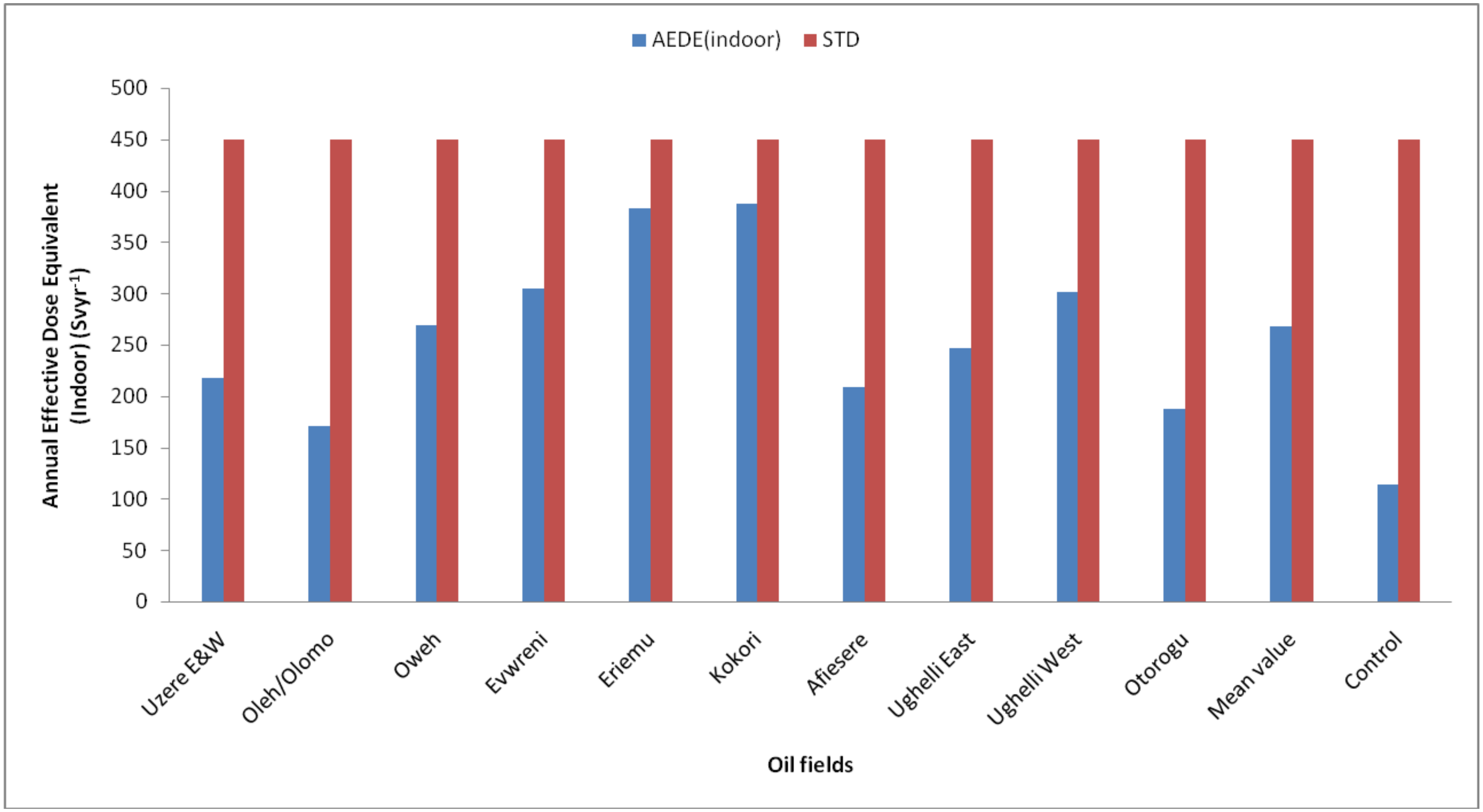

Figure 3: Annual Effective Dose Equivalent (Indoor) compared with standard for soil samples

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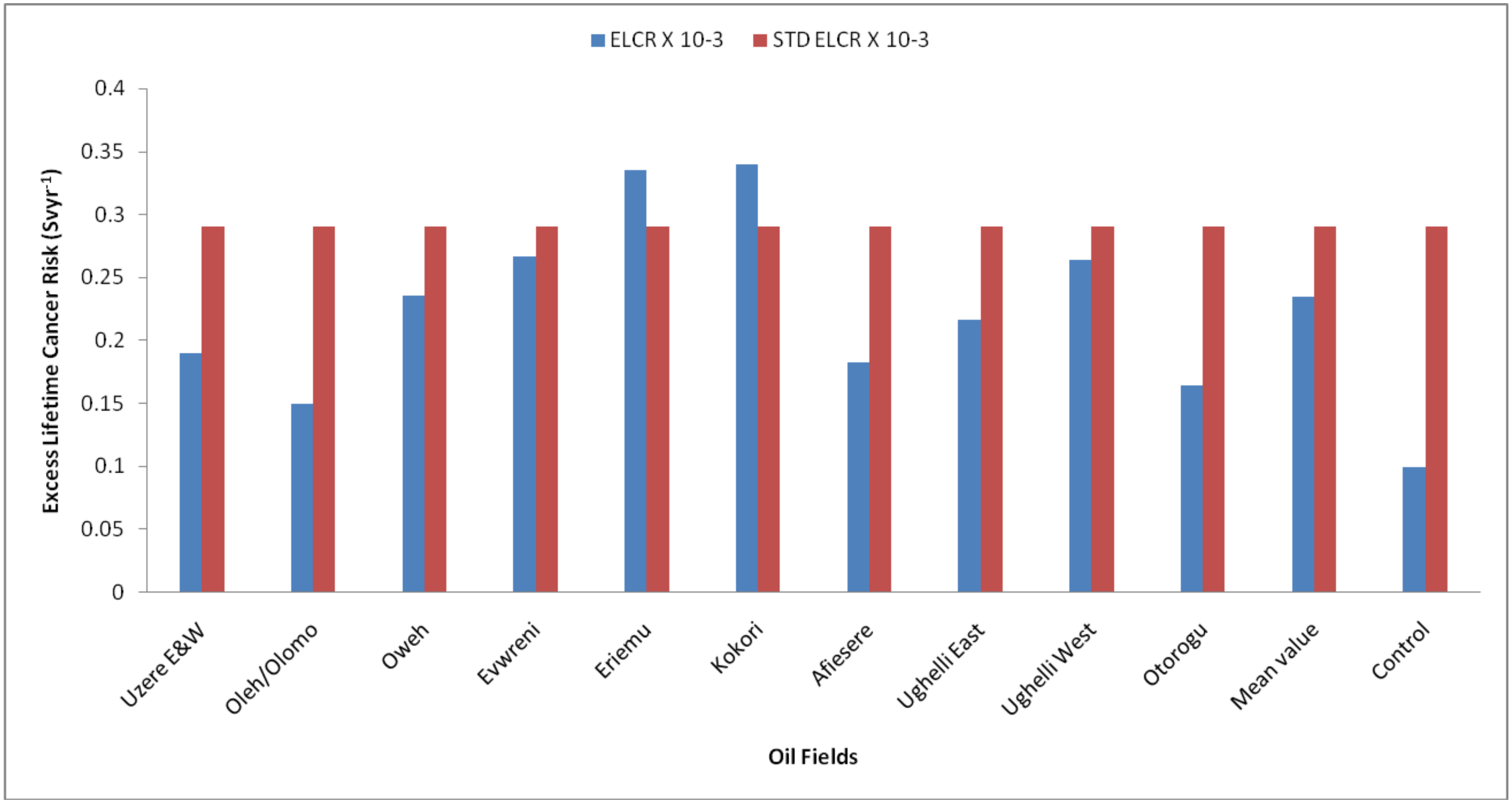

Figure 4: Excess Lifetime Cancer Risk compared with standard for soil samples

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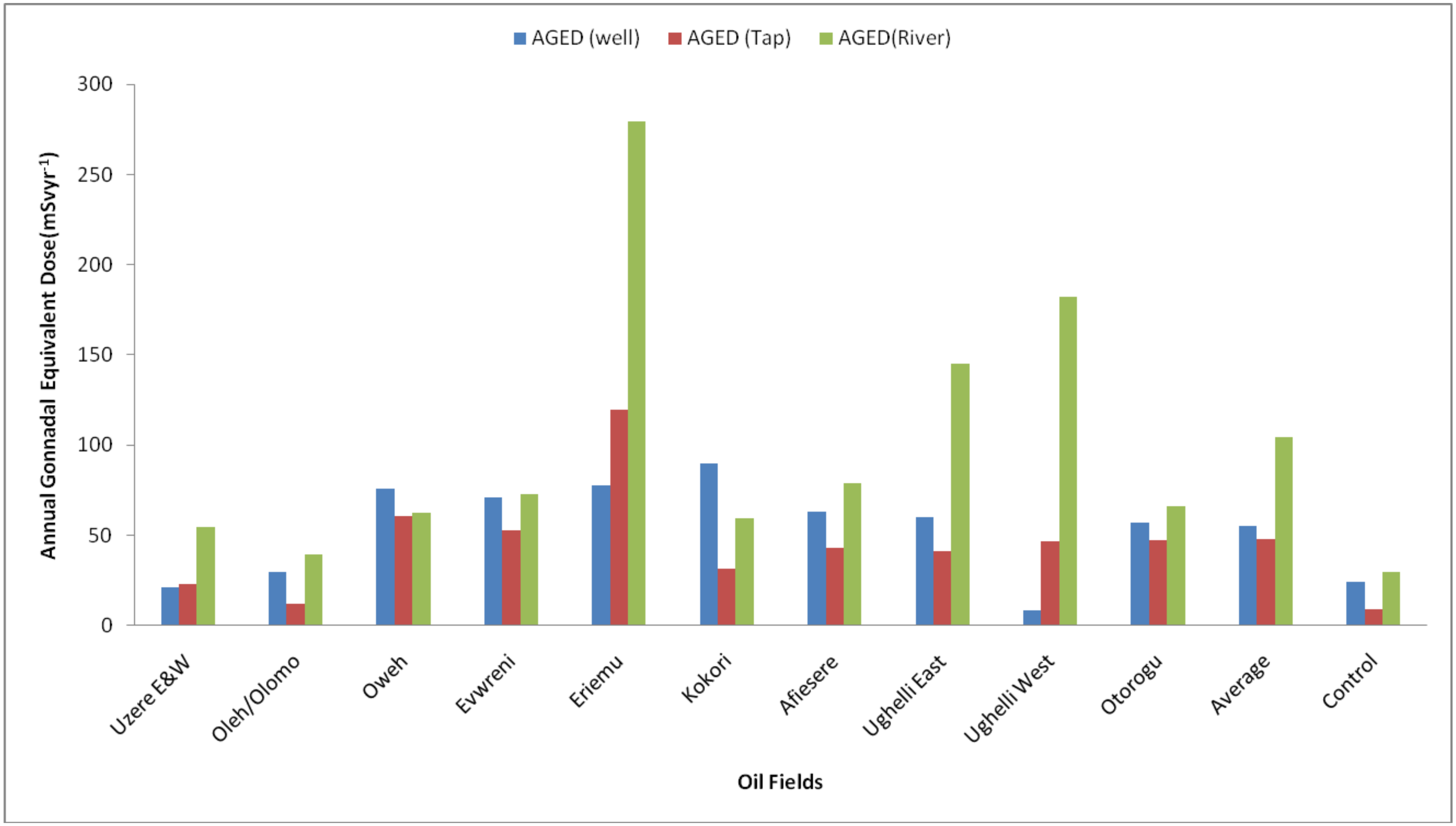

Figure 5: Annual Gonnadal Equivalent Dose compared for water samples

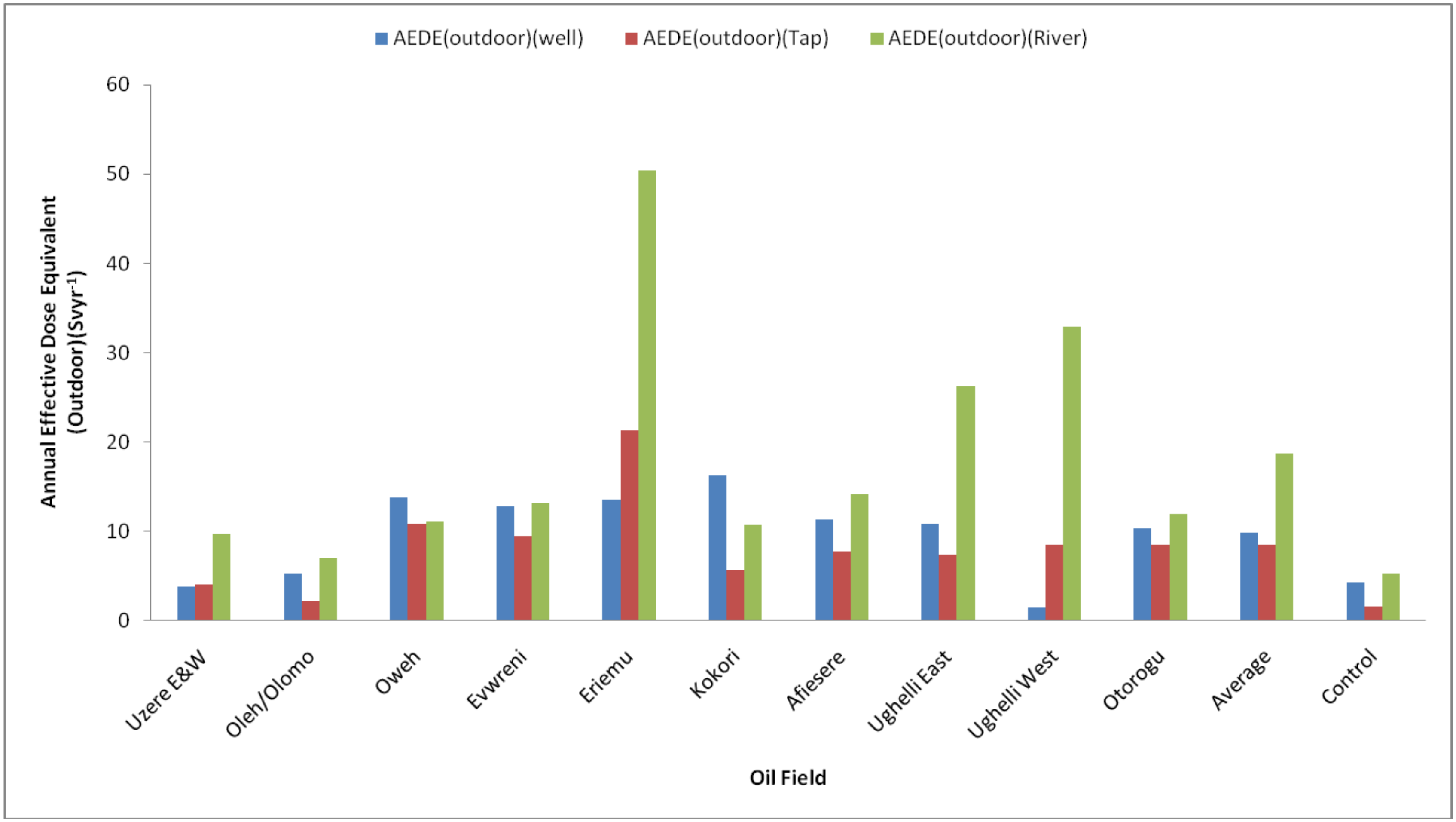

Figure 6: Annual Effective Dose Equivalent (Outdoor) compared for water sample

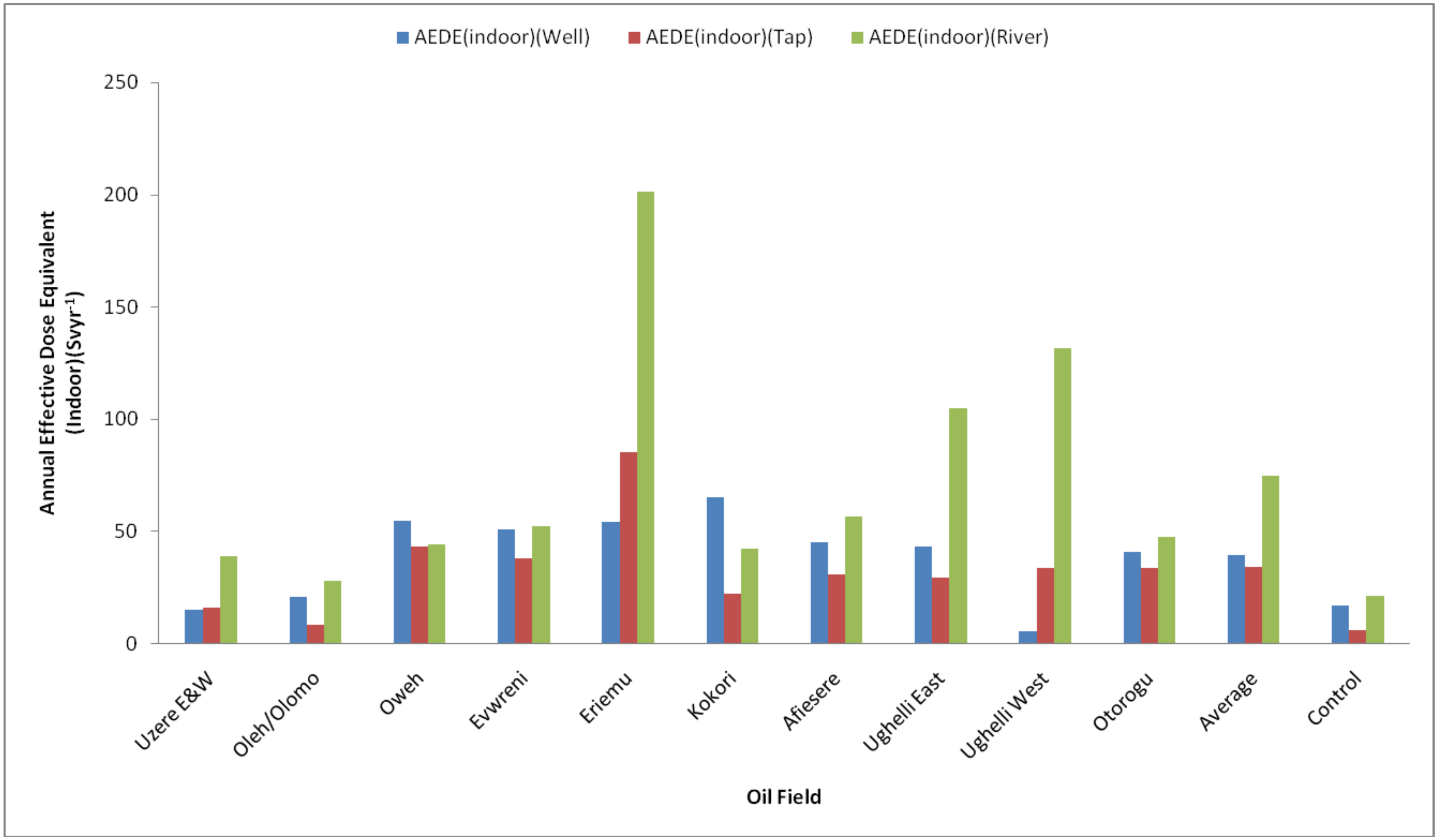

Figure 7: Annual Effective Dose Equivalent (Indoor) compared for water samples

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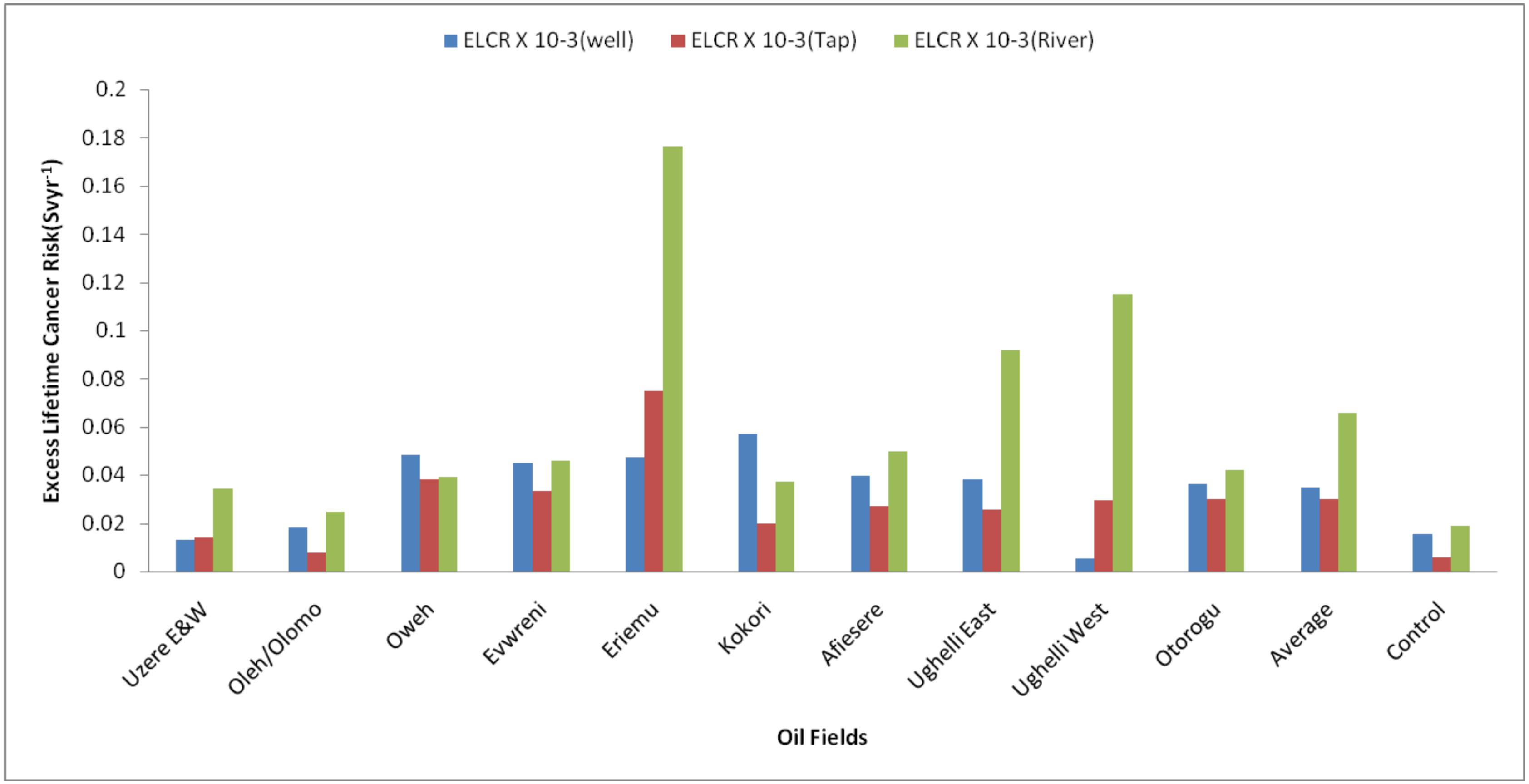

Figure 8: Excess Lifetime Cancer Risk compared for water samples

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The average Annual Gonnadal Equivalent Dose (AGED) was calculated from equation (3) and the values for the ten oil fields range from 241.83mSvy^{-1} for Oleh/Olomo to 550.78mSvy^{-1} for Kokori with a mean value of 380.37±38.4mSvy^{-1}. The contribution to the mean value from ^{40}K was 34.05% which is the highest while that from ^{226}Ra was 33.31% and 32.64% for ^{232}Th. The mean value of AGED was higher than the permissible limit of 300mSvy^{-1}. The calculated AGED values were compared with the UNSCEAR 2000 standard values in Figure1. High values of AGED were observed in Kokori (highest), Eriemu, Evwreni and Ughelli West. This could be attributed to the increased activities of oil exploration in these areas compared to Oleh/Olomoro. This shows a high level of threat to the sensitive cells like the gonads, bone marrow, surface bone cells of oil workers and dwellers in these areas. The AGED for the control area was calculated to be 162.6 mSvy^{-1}, this low value could have resulted from lack of oil exploration activities in the area. This further confirmed that the presence of oil and gas activities has enhanced the NORM values of the area under study.

The average Annual Effective Dose Equivalent (indoor and outdoor) values were calculated from Equations (4) and (5) respectively. The outdoor values ranged from 42.71µSvy^{-1} also for Oleh/Olomoro to 96.96µSvy^{-1} for Kokori with a mean value of 66.95±6.9µSvy^{-1} and the indoor values varied from 170.85µSvy^{-1} to 387.83µSvy^{-1} with a mean value of 267.79±27.5µSvy^{-1}. The mean values for both outdoor and indoor were below the world average values of 70µSvy^{-1} and 450µSvy^{-1} respectively. The mean value for AEDE (Outdoor) was higher than that reported for tertiary institutions in Minna, Niger State (Kolo et al., 2012) and that reported for different places in the city of Uttah Pradesh in India (Zubair et al., 2013). However, high values above the average for AEDE (outdoor) were observed in Eriemu, Kokori and Ughelli West. An increased activity of oil exploration in these areas, for the production of more barrels of oil, could be responsible for this elevation since the soil is not known to contain radiation bearing minerals.

The AEDE (indoor) values were all below the permissible limit of 450 µSvy^{-1}, though, high values were observed in Kokori (387.83µSvy^{-1}) and Eriemu (383.2µSvy^{-1}) compared with Oleh/Olomoro (170.85µSvy^{-1}). The mean value for AEDE (Indoor) was found to be higher than that reported for volcanic tuff stones used as building and decoration material in the Cappadocia region of Turkey (Degerlier, 2013) and that reported for different places in the city of Uttah Pradesh in India (Zubair et al., 2013). The control values for both outdoor and indoor were 28.4µSvy^{-1} and 113.5µSvy^{-1} respectively. No oil exploration activities in the area, hence the low values.

The average Excess Lifetime Cancer Risk values, calculated from Equation (7), ranged from 0.149 x 10^{-3} to 0.339 x 10^{-3} with a mean value of 0.234 x 10^{-3} ±0.02 x 10^{-3}. These values were higher than those obtained by Avwiri et al., (2012) in the soil of Udi and Ezeagu Local Government areas of Enugu State. The mean ELCR value was below the standard value of 0.29 x 10^{-3} and all the areas had ELCR values below permissible limit except Eriemu (0.335) and Kokori (0.339). Table 6 also shows radiological elevation of 15.52% and 16.90% for these two areas respectively from the percentage risk analysis. Oleh/Olomoro community had the lowest value aside the control area. This could be attributed to reduce oil activities in the area. Also, the radiological elevation could be attributed to increase oil exploration activities in the area and also to oil spillage. Therefore, the probability of developing cancer is high for oil workers and people living in these communities. The value in the control area was calculated as 0.099, which was low, possibly as a result of non-oil activity.

Figure 5 presents a comparison of AGED for well, tap and field river water in the oil field areas. Eriemu field river water had the highest value of 279.63 mSvyr^{-1} followed by Ughelli West (181.93 mSvyr^{-1}) and Ughelli East (145.17 mSvyr^{-1}). These high values in the field river water could be attributed to oil spillage and incessant and intensive gas flares in these three areas. This had also affected the host communities' well and tap water especially in Eriemu with the highest value of AGED for tap water (119.43 mSvyr^{-1}). Kokori had the highest value for well water (90.16 mSvyr^{-1}).The spilled oil infiltrated into the ground, contaminating the groundwater aquifers and surface water bodies. Oleh/Olomoro communities recorded lowest values for both tap and river water samples while Ughelli West had the lowest value for well water (8.57 mSvyr^{-1}). Mean values were 55.26±5.25 mSvyr^{-1}, 47.84±5.13 mSvyr^{-1} and 104.18±9.28 mSvyr^{-1} for well, tap and river samples respectively. The control values were lowest for all the three water samples due, possibly to non oil activities in the area.

From Figure 6, it was also observed that the three areas (Eriemu, Ughelli West and Ughelli East)

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recorded the highest AEDE (Outdoor) values for river water compared with the other areas. Eriemu had the highest value of 50.39 $Svyr^{-1}$, followed by Ughelli West with 32.91 $Svyr^{-1}$ and Ughelli East with 26.25 $Svyr^{-1}$. These areas have increased oil activities compared to others which could have resulted in the high values. Also, Eriemu recorded the highest value for tap water (21.33 $Svyr^{-1}$). This could be attributed again to oil spills and incessant gas flares. Kokori has the highest value for well (16.31 $Svyr^{-1}$). The mean values were 9.90±0.95 $Svyr^{-1}$, 8.56±0.92 $Svyr^{-1}$ and 18.78±1.68 $Svyr^{-1}$ for well, tap and river water samples.

Figure 7 showed the AEDE (Indoor) for well, tap and river samples for all the areas. Eriemu, Ughelli West and Ughelli East still recorded the highest values of 201.57 $Svyr^{-1}$, 131.63 $Svyr^{-1}$ and 105.01 $Svyr^{-1}$ respectively for river water due to contamination of the oil fields. Eriemu had the highest value for tap water with 85.32 $Svyr^{-1}$ and Kokori had the highest for well water with 65.24 $Svyr^{-1}$. Oleh/Olomoro had the lowest values for both tap and river samples with 8.63 $Svyr^{-1}$ and 28.1 $mSvyr^{-1}$ respectively. Ughelli west had the lowest value of 5.85 $Svyr^{-1}$ for well water. The mean values were 39.6±3.78 $Svyr^{-1}$, 34.24±3.68 $Svyr^{-1}$ and 75.14±6.69 $Svyr^{-1}$ for well, tap and river water respectively. The control values were low for all the samples. All the values were lower than the recommended limit.

Figure 8 showed the comparison of ELCR for well, tap and river samples in all the areas. Though, all the values were lower than the recommended limit, Eriemu, Ughelli West and Ughelli East had the highest values of 0.176 $Svyr^{-1}$, 0.115 $mSvyr^{-1}$, 0.092 $Svyr^{-1}$for river samples respectively compared to the others. Kokori had the highest value of 0.057 $Svyr^{-1}$for well water while Eriemu had the highest value of 0.075 for tap water. However, Oleh/Olomoro had the lowest values of 0.007 and 0.025 respectively for tap and river water while Ughelli West had the lowest of 0.005 $Svyr^{-1}$ for well water. The mean values were 0.035±0.003 $Svyr^{-1}$, 0.03±0.03 $Svyr^{-1}$ and 0.066±0.006 $Svyr^{-1}$ .The control values were lower for all the areas.

From the results discussed above, it can be seen that some areas, like Eriemu, Kokori, Ughelli West and Ughelli East, have high radiation indices while others have lower values.

CONCLUSION

The radiological hazard indices in the Oil Mineral Lease in Delta State have been evaluated in the soil/sediment and water samples of the oil field areas. The results obtained showed that the areas radionuclide level has been elevated which could be attributed to the oil activities in the area.

The radiation indices for the soil and sediment/sludge samples were above the permissible values for some areas. Areas like Eriemu and Kokori with values for Annual Effective Dose Equivalent (Outdoor) and Excess Lifetime Cancer Risk above the recommended limits could have been impacted negatively by activities such as oil spillage and gas flaring as observed during sample collection. These areas also show radiological elevation from the percentage risk analysis signifying a radiological burden on the people and the environment of these areas and there is the possibility of one out of a million developing cancer before the age of 70 years by the workers and the people living in the areas.

All the calculated indices were less than the recommended limits for water samples. Although, the calculated indices were lower than the permissible limits, they are still higher than the values from non oil producing areas which shows that the oil and gas activities could have impacted negatively on the radiological status of the environment.

Therefore, care need to be taken to prevent an accumulation of doses over time especially in areas having indices markedly higher than other areas.

As a result of the conclusions above, we want to recommend the following:

(i) The oil companies should ensure adequate and regular maintenance of their pipelines and facilities to prevent incessant oil spillage.

(ii) Oil companies should be made to comply with international standard for best practices in the sector

(iii) Further studies should be carried out to investigate Eriemu and Kokori oil field with clinical collaborative study strongly recommended to determine the radioactive health burden on the people.

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