Original Research Article

Computation of radiation risk parameters due to gamma radiation doses from some rivers within oil producing communities of Abia State, Nigeria

ABSTRACT

Oil production involves the extraction of petroleum, gas and produced water, with some associated natural radionuclides from the sub-surface which could enhance background ionization radiation. This study presents the radiological analyses and computation of radiation risk parameters due to gamma radiation doses from some water samples around some oil producing communities in Abia State, Nigeria. The measurement was carried out using Sodium Iodide detector that is activated by thallium. The computed radiological risk parameters show that the annual effective dose of radiation due to ingested water by an individual ranged from 1.89 mSv y^{-1} to 3.52 mSv y^{-1} and exceeded 0.1 mSv/yr permissible limit by International Commission on Radiological Protection (ICRP). The Annual Gonadal Dose Equivalent ranged from 0.041 mSv y^{-1} to 0.075 mSv y^{-1} and is below the World average value of 0.3 mSv y^{-1}. The Excess Lifetime Cancer Risk ranged between 5.30 x 10^{-3} and 9.87 x 10^{-3} and is above the World permissible limit of 0.29 x 10^{-3}. The elevation of most of the radiological parameters may be attributed to oil production activities within these environments and may likely have negative impacts on inhabitants.

Keywords: Radiation risk parameters, gamma radiation, oil communities, Abia State

1. INTRODUCTION

The presence of natural radioactivity in crude oil has been known since the beginning of the 20^{th} century. There are data available in the literature indicating ^{226}Ra and ^{228}Ra activity concentrations in radioactive scales in the order of 1.0 × 10^3 kBq/kg [1]. Oil and gas production processing operations have been known to involve naturally occurring radioactive materials that lead to internal and external radiation hazards and thus a significant radiation dose to the workers [2]. This is because oil production involves the extraction of a combination of petroleum, gas and produced water together with the associated natural radionuclides from the sub-surface and these radionuclides contribute to enhancement of natural background ionization radiation. Oil equipment where NORM (Naturally Occuring Radioactive Materials) accumulates in oil production unit includes; seperators, oil shipment system, produced water dump, dehydrators, etc. Oil production associated radionuclides find their route into environmental components such as air, soil and water mostly in the course of oil spillages, oil disposal and gas flaring hence, personnels working near closed systems where NORM accumulations occur could be exposed to gamma rays and be subjected to their attendant consequences [3].

Researchers in the areas of Radiation and Medical Physics have been working hard to understudy the health impact of exposure to ionisation radiation- both nuclear radiations and continuous, but low level non-nuclear radiations. A detailed evaluation of excessive lifetime cancer risk due to natural radioactivity in the rivers sediments of Northern Pakistan was carried out and it was observed that the river sediments created a huge radiological threat when used as a building material because of the high value of their hazard indices [4].

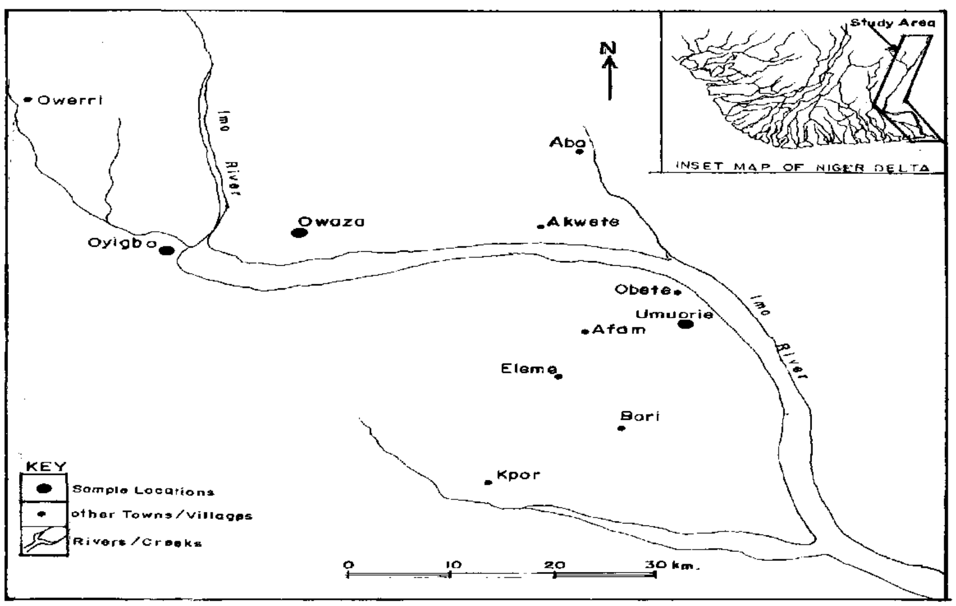
Measurements of indoor and outdoor ambient gamma dose rates in and around granite regions of Shimoga District were carried out using environmental radiation Dosimeter ER-709. The calculated indoor and outdoor annual effective dose rate ranged between 0.559 to 1.631 mSv/yr with an average value of 0.872 mSv/yr and 0.106 to 0.339 mSv/yr with an average value of 0.235 mSv/yr, respectively. These results were found to be higher than the world average [5].

One of the primary components of the environment whose background level of radiation could be affected by external sources is the river. For this reason, studies on the radioactivity content of some rivers close to some oil mineral producing sites in Abia State, Nigeria, was carried out in this study.

2. **MATERIALS AND METHODS**

2.1 Study Area

Radiological studies were conducted on water samples collected from three rivers around three selected oil mineral producing fields in Abia state, Nigeria in 2009. The surveyed oil communities are located in Ukwa West Local Government Area of Abia State. These oil wells belong to the Eastern division of Shell Petroleum Development Company and they contribute about five percent of the total barrels of oil per day produced in the division [6]. Map showing the study area is shown in Figure 1.



Map of Imo River showing sample locations.

Figure 1: Map Showing Sample Locations

2.2 Sample Collection and Analyses

Twenty one water samples were collected from surface water bodies within the three selected oil producing fields. The samples were carefully prepared according to International Atomic Energy Agency specifications for gamma radiation analyses [7]**.** The activity concentrations of gamma rays from the samples were computed after the count rates were obtained using a Sodium Iodide detector that is activated by thallium [NaI (Tl)]. The mean activity concentrations of the samples in Bq/l for the Identified Radionuclides (K-40, Ra-226 and Th-232) were calculated using the formula;

$$A_i = \frac{N_c}{\varepsilon_d . S_v . P_\gamma . t_c} \qquad (1)$$

Where $N_c = C_T - C_b$ (the net count rate of the samples), C_T = total measured count rate, C_b = background count rate, $\mathcal{E}_d$ = efficiency of the detector for the radionuclide of interest, S_v = sample volume (in Litre), P_γ = gamma emission probability (branch ratio), t_c = total counting time. The following gamma-emitting radionuclides were identified by the detector [NaI (TI)]; ^{226}Ra, ^{228}Ra and ^{40}K.

2.3 Methods of Computation of Radiological Risk Parameters

The gamma radiological risk parameters computed in this work and the formulae used for the computations are given below. These parameters are used to quantify the health impacts of environmental exposure to gamma radiation on humans.

(i) Effective Dose of Radiation due to Ingested Water

The annual effective dose of radiation due to ingested water by an individual (in mSv/yr) was calculated using the expression in [8], EDIW = $\sum_{i=1}^{3} A_i \times C_i \times D_i$ (2),

where A_i = Specific Activity of Identified Radionuclides (K-40, Ra-226 and Th-232), C_i= Annual Consumption Rate of Water (Approximately 730 L/yr) [7], D_i= Activity to Dose conversion factors for the Identified Radionuclides (D_k = 6.2 x 10^{-6} mSv/Bq, D_{Ra} = 2.8 x 10^{-4} mSv/Bq, D_{Th} = 2.2 x 10^{-4} mSv/Bq) [9].

(ii) **Annual Gonadal Dose Equivalent (AGDE)**

The AGDE due to specific activities of Ra-226, Ra-228 and K-40 was calculated using the following formula in [10];

$$AGDE_\gamma\ (\mu Sv\ y^{-1}) = 3.09_{Ra\text{-}226} + 4.18A_{Ra\text{-}228} + 0.314A_{K\text{-}40} \quad (3)$$

(iii) Excess Lifetime Cancer Risk (ELCR)

In this work, the total ELCR from gamma radiation was calculated using the following equation in [11];

$$ELCR_\gamma = AEDE_\gamma \times DL \times RF \quad (4)$$

where DL is the average duration of life (estimated to be 70 years), and RF is Risk Factor (Sv^{-1}), i.e. fatal cancer risk per Sievert given as 0.04 Sv^{-1} for public [12], which we converted to 4 x 10^{-5} $(mSv)^{-1}$ to facilitate our computation.

The percentage deviation of the computed radiological risk parameters from standard limits was computed to show the extent of deviation of the present results from the international limits and world average limits. We used the formula

$$\%\ Dev. = \frac{X - S}{S} \times 100 \quad (5)$$

Where X stands for the computed radiological risk parameters and S stands for international and world average limits.

3. RESULTS AND DISCUSSION

The results of the specific activity of the identified gamma radionuclides (K-40, Ra-226 and Th-232) and their associated Radiological Risk Parameters from the three surveyed rivers are presented in

Table 1. The results of the percentage deviation of the computed radiological risk parameters from standard limits are presented in Table 2. Bar charts comparing the maximum and minimum values of EDIW, AGDE and ELCR with permissible standards for the three surveyed rivers are presented in Figures 2 to 4.

Table 1. Specific activity of the identified gamma radionuclides and their radiological risk parameters

Sample I.D	^{40}K (Bq/l)	^{226}Ra (Bq/l)	^{232}Th (Bq/l)	EDIW (mSv/yr)	AGDE (mSv/yr)	ELCR x 10^{-3}
OWR1	33.31±7.03	8.18±1.23	7.6±2.43	3.04	0.068	8.52
OWR2	28.51±5.99	10.25±1.54	8.1±2.59	3.52	0.074	9.87
OWR3	35.23±7.39	9.18±1.38	8.5±2.72	3.40	0.075	9.52
OWR4	23.31±4.92	6.18±0.97	5.66±1.84	2.28	0.050	6.38
OWR5	25.25±5.30	7.12±1.07	5.89±1.88	2.52	0.055	7.04
OWR6	22.35±4.69	5.57±0.84	6.02±1.93	2.21	0.049	6.18
OWR7	20.75±4.36	6.55±0.98	5.25±1.68	2.28	0.049	6.37
IMR1	28.28±4.24	9.20±2.94	6.50±2.08	3.05	0.064	8.55
IMR2	30.35±4.55	8.75±2.80	5.75±1.84	2.85	0.061	7.98
IMR3	29.75±4.46	9.80±3.14	6.20±1.98	3.13	0.066	8.77
IMR4	24.97±3.64	6.22±2.08	3.37±1.07	1.93	0.041	5.39
IMR5	23.55±3.53	6.52±2.08	4.22±1.35	2.12	0.045	5.93
IMR6	20.65±3.09	6.05±1.94	3.50±1.12	1.89	0.040	5.30
IMR7	22.57±3.39	7.25±2.32	2.85±0.91	2.04	0.041	5.72
UMR1	28.75±3.16	8.25±2.64	7.57±2.42	3.03	0.066	8.49
UMR2	30.25±3.33	7.85±2.51	6.85±2.19	2.84	0.062	7.96
UMR3	25.05±2.76	9.25±2.96	7.35±2.35	3.18	0.067	8.91
UMR4	19.06±2.09	5.94±2.26	5.20±1.80	2.14	0.046	5.98
UMR5	21.02±2.31	6.12±1.96	5.15±1.65	2.17	0.047	6.08
UMR6	20.55±2.26	5.30±1.69	4.75±1.52	1.94	0.043	5.43
UMR7	22.35±2.46	5.75±1.84	5.03±1.61	2.08	0.046	5.84

Table 2: Percentage deviation of the computed radiological risk parameters from standard limits

Sample I.D	EDIW(mSv/yr)	% deviation*	AGDE (mSv/yr)	% deviation**	ELCR x 10^{-3}	% deviation***
OWR1	3.04	2940	0.068	-77.33	8.52	2838
OWR2	3.52	3420	0.074	-75.33	9.87	3303
OWR3	3.40	3300	0.075	-75.00	9.52	3182
OWR4	2.28	2180	0.050	-83.33	6.38	2100
OWR5	2.52	2420	0.055	-81.67	7.04	2328
OWR6	2.21	2110	0.049	-83.67	6.18	2031
OWR7	2.28	2180	0.049	-83.67	6.37	2097
IMR1	3.05	2950	0.064	-78.67	8.55	2848
IMR2	2.85	2750	0.061	-79.67	7.98	2652
IMR3	3.13	3030	0.066	-78.00	8.77	2924
IMR4	1.93	1830	0.041	-86.33	5.39	1759
IMR5	2.12	2020	0.045	-85.00	5.93	1945
IMR6	1.89	1790	0.040	-86.67	5.30	1728
IMR7	2.04	1940	0.041	-86.33	5.72	5430
UMR1	3.03	2930	0.066	-78.00	8.49	2828
UMR2	2.84	2740	0.062	-79.33	7.96	2645
UMR3	3.18	3080	0.067	-77.67	8.91	2972
UMR4	2.14	2040	0.046	-84.67	5.98	1962
UMR5	2.17	2070	0.047	-84.33	6.08	1997

UMR6	1.94	1840	0.043	-85.67	5.43	1772
UMR7	2.08	1980	0.046	-84.67	5.84	1914

* deviation of EDIW (mSv/yr) from 0.1 mSv [13]; ** deviation of AGDE (mSv/yr) from the world average value of 0.3 (mSv/yr) [14] ; *** deviation of ELCR from the world average value of 0.29 x 10^{-3} [15].

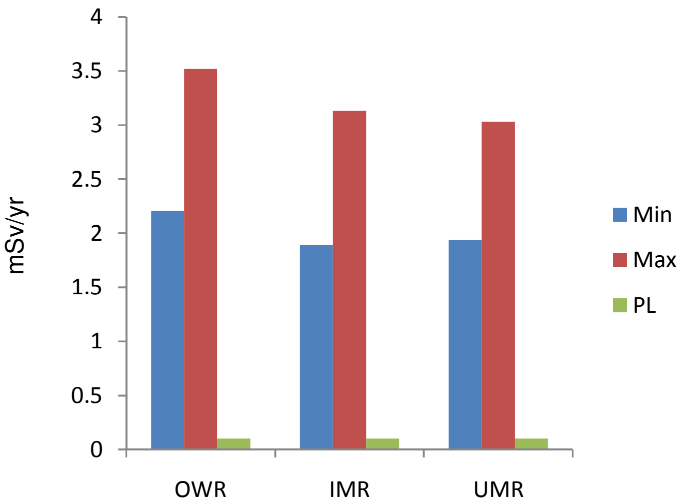


Figure 2. Bar chart comparing the maximum (Max) and minimum (Min) values of EDIW with permissible limit (PL) for the three surveyed rivers

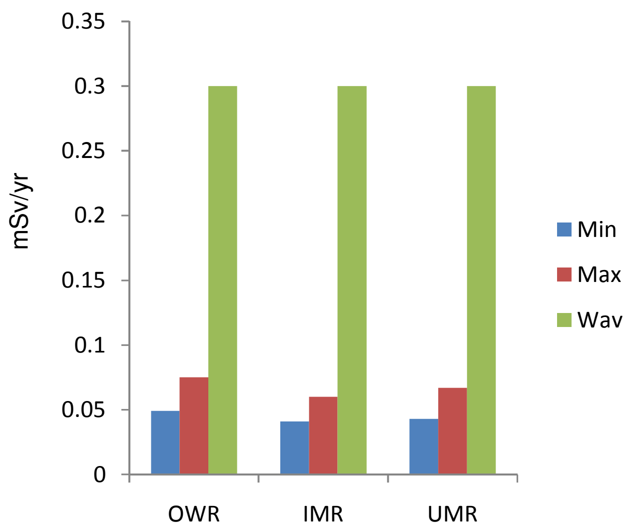


Figure 3. Bar chart comparing the maximum (Max) and minimum (Min) values of AGDE with world average value (Wav) for the three surveyed rivers

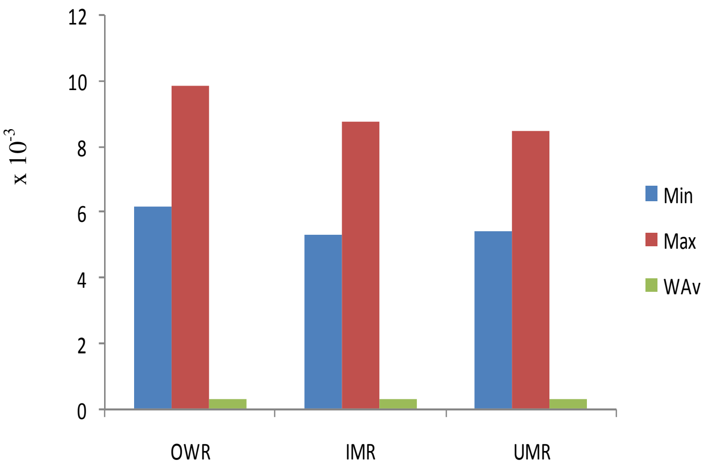


Figure 4. Bar chart comparing the maximum (Max) and minimum (Min) values of ELCR with world average value (Wav) for the three surveyed rivers

The results of annual effective dose of radiation due to ingested water (E.D.I.W.) show that for OW. River, E.D.I.W. ranged from 2.21 to 3.52 mSv/yr; for IM. River, E.D.I.W. ranged from 1.89 to 3.13 mSv/yr and for UM. River, E.D.I.W. ranged from 1.94 to 3.03 mSv/yr. The results of the annual effective dose of radiation due to ingested water (E.D.I.W.) for the three surveyed rivers exceeded 0.1 *mSv* per year which is the permissible limit set by International Commission on Radiological Protection (ICRP) for the total dose of radiation (artificial and natural) that should be received from the consumption of drinking water [13]. The comparison of the maximum (Max) and minimum (Min) values of EDIW with permissible limit (PL) for the three surveyed rivers is illustrated in the bar chart of Figure 2. These results are also greater than the permissible dose limit for radiation exposure which has been set at 1 *mSv* per year which is applicable to the total dose received from all internal and external sources excluding the natural background radiation [16].The results of Table 2 show that the deviations of the computed annual effective dose of radiation due to ingested water (E.D.I.W.) from the standard permissible limit of 0.1 *mSv* per year range from 1790% to3420%. These levels of deviation are so high and indicate that water collected from these sources for ingestion and other economic uses may have been negatively affected radiologically due to oil production activities going on around these areas.

The results of the Annual Gonadal Dose Equivalent (AGDE) due to gamma radiation is presented in Table 1. The values obtained ranged from 0.049 to 0.075 mSv/yr for OW. River; 0.041 to 0.06 mSv/yr for IM. River and 0.043 to 0.067 mSv/yr for UM. River. The AGDE values for all the samples collected are below the world average value of 0.3 mSv/yr. [14] Comparison of the maximum (Max) and minimum (Min) values of AGDE with world average value for the three surveyed rivers is illustrated in the bar chart of Figure 3. Consumption of water from the surveyed sources may not impact negatively on the gonads.

The Excess Lifetime Cancer Risk (ELCR) for gamma radiation as presented in Table 1 shows that the values range from 6.18×10^{-3} to 9.87×10^{-3} for OW. River; 5.30×10^{-3} to 8.77×10^{-3} for IM. River and 5.433×10^{-3} to 8.49×10^{-3} for UM. River. Comparison of the maximum (Max) and minimum (Min) values of ELCR with world average value for the three surveyed rivers is illustrated in the bar chart of Figure 4. These values are above the world average of 0.29×10^{-3}[15]. This implies that people who use water from these rivers may have enhanced their probability of developing cancer over their life time.

4. CONCLUSION

Radiological risk parameters due to gamma radiation have been computed for water samples collected from three rivers around the surveyed oil producing areas. The results of annual effective dose of radiation due to ingested water show very high deviation from the standard limit of 0.1 mSv/yr.

The results of the Annual Gonadal Dose Equivalent are below the World average value of 0.3 mSv/yr. The value of Excess Lifetime Cancer Risk exceeded the world average value of 0.29 x 10^{-3}. Continuous usage of water from these rivers for both water consumption and other economic activities may likely have adverse impacts on inhabitants of the surveyed environments who frequently make use of the water. The elevation of some of the radiological risk parameters computed in this work over the standard may be attributed to oil production activities within these environments.

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