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Assessment of Environmental Radioactivity Level and its Health Implication in Imiringi Community Bayelsa State, Nigeria

[*1]ANEKWE, UL; [2]ONOJA, RA

*[*1]Department of Physics, Federal University Otuoke, Nigeria.*
[2]Centre for Energy Research and Training, A.B.U. Zaria, Nigeria.
**Corresponding Author Email: uzanekwe@yahoo.co.uk; raonoja@yahoo.com*

ABSTRACT: A total forty two (42) sampled points were investigated for radioactivity level and health implication using standard method. The exposure dose rate ranged from 14 to 32μRh^{-1} with an average value of μ23Rh^{-1}. Dose rate and equivalent dose rate ranged from 121.8 to 278.4nGyh^{-1} and 1.18 to 2.69mSvy^{-1} respectively. The average value of the indoor annual effective dose equivalent (AEDE), outdoor AEDE, and excess lifetime cancer risk (ELCR) were computed to be 0.936 mSvy^{-1}, 0.311 mSvy^{-1} and 0.810 x 10^{-3} respectively. Analysis of dose to human organs; testes and ovaries, were 0.61 and 0.43 mSvy^{-1} respectively. Exposure rate, dose rate and ELCR exceeded the recommended values. All the outdoor AEDEs were within the permissible value of 1.0 mSvy^{-1} for general public and below the limit of 20 mSvy^{-1} for radiological workers as recommended by International Commission on Radiation Protection (ICRP).

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Man has been known to be exposed to ionizing radiation emanating from the naturally occurring radioactive materials (NORMs) and through artificial means called the technologically enhanced naturally occurring radioactive materials (TENORMs). Sources and effects of these materials had in recent time been attracting attention of environmental physicists and medical scientists. Ionizing radiation in its smallest amount is undesirable yet radiation application is useful to mankind but its safety depends on exposure level. Ionizing radiation is radiation that has sufficient energy to remove electrons from atoms. An atom is composed of a positively charged nucleus surrounded by negatively charged electron. Radiation is energy which can be particles or photons given off by heavy isotopes (Radionuclides) to become stable. Researchers have previously stated correlation between radiation exposure and health hazard on natural ecosystem and in that regard radiation is a health risk. It therefore follows that there is level of threshold above which regulation becomes very necessary. These regulations are however already in place as prescribed by the international commission on radiation protection (ICRP), united nation scientific committee on the effects of atomic radiation (UNSCEAR), world health organization (WHO), Nigerian nuclear and regulatory authority (NNRA), United State environmental protection agency (US EPA), etc. Imiringi community like so many others in the Niger Delta region of Nigeria has quite a number of oil and gas activities. Research has shown this and also evident in media documentaries that such activities result to environmental degradation. All these provide the source of radiation such as alpha, beta and gamma radiation often found in the petroleum matrix. A World Bank Study showed that Nigeria flares about 76% of all Natural gas from petroleum production, this is contrast to 0.6% in United States, 4.2% in United Kingdom, 21%, 20% and 19% in Libya, Saudi Arabia and Iran respectively (Taskin *et al.,* 2009). In 1994, the Nigerian conservation foundation revealed that Nigeria released 34 million tone of methane to the atmosphere, that year alone with 15% of it been radon gas. This implied that Nigeria oil fields contribute more to global warning than rest of the world (Aghalino *et al.,* 2001). In the coastal region, mangrove which was a good source of fuel wood and habitat for biodiversity has been destroyed (UNSCEAR, 2000), such as in Imiringi. Gas flaring is another destructive effect of the oil and gas industry. Gas flaring releases toxic component into the environment, which includes methane majorly and other greenhouse gases like carbon monoxide (Jibiri, 2009). Nigeria flares gases more than any other country. The level of natural background radiation is generally between 1 and 2mSv/year (Hunt, 1987). The

**Corresponding Author Email: uzanekwe@yahoo.co.uk; raonoja@yahoo.com*

main contribution is the gamma ray absorbed dose arising from territorial radon (55%), cosmic ray (8%), natural radioactivity of environmental rocks (containing uranium, actinium, radium and thorium) and the potassium – 40 activities within human bodies (Klement *et al.,* 1972). Human beings are exposed to these radioactive materials through the air, the soil, water hence they ultimately exit in human body. The reason why it is believed that crude oil activities increase the natural background radiation of any environment is that, the by-products of hydrocarbon compounds (oil and gas), the chemicals used in searching for crude oil may contain radioactive particulates (Sigalo and Briggs, 2014). Since naturally occurring radioactive materials (NORMS) can contaminate the environment and may pose a risk to human health, these risks can be alleviated by the adoption of controls to identify where NORMS are present. This will ensure the reduction or elimination of negative impact on the populace and the environment. It therefore becomes necessary to evaluate the level of induced technological Enhanced – Natural occurring radioactive materials (TENORM) that lead to radiological burden on degraded areas in a view to determine the health hazards indices. 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% recovered according to NEPDG, 2001. These have led to the destruction of arable of farmland, crops and contamination of groundwater and soils. Also, health issues reported in the area include breathing problems and skin lesions, according to United Nations Development Programme, Niger Delta Human Development Report (2006). The water in these 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.

Wastes associated with the various industrial activities, with enhanced levels of the natural radioactivity as a result of industrial process cause what is called TENORMs which may be injurious to the environmental (Attalah *et al.,* 2012). A good example of the high risk associated with oil spill and the high cost of remediation is the case of Kolo Creek oil spill. Acute health effects such as skin burns or acute radiation syndromes can occur when doses of radiation exceed certain levels. Beyond certain threshold, radiation can cause certain effects such as skin redness, hair loss, radiation burns or acute radiation syndromes and epidemiological studies indicate that the cancer risk after fetal exposure to radiation is similar to the risk after exposure in early childhood (WHO, BSS, 2012). In view of the known industrial activities in Imiringi community, this study has a striking significance of providing reliable radiation risk level. Therefore, the objective of this paper is to assess the environmental radioactivity level and its health implication in Imiringi Community Bayelsa State, Nigeria.

MATERIALS AND METHODS

Study Areas: The study area is Imiringi Community in Ogbia Local Government Area of Bayelsa State of Nigeria. Oil and gas activities in Immiringi community has span over 40 decades. The community is one of the semi urban communities situated in Ogbia Local Government Area of Bayelsa State in the Niger Delta region of southern part of Nigeria. It has a total number of eleven kindreds namely: Otu-Aba, Otu-Anle, Itokopiri, Ologbo, Otu-Onuema, Otu-Ekurugha, Otu-Ekafa, Otu-Ezi, Ebolo, Ayan and Otu-Arugu. Imiringi hosts a number of oil and gas facilities which include but not limited to forty-six (46) oil wells, five planning sites, manifold flow station, field logistic base etc. The population of Imiringi was about eight thousand three hundred and fifty one (Olokoya, 2015). For convenience the community was considered in seven (7) sections or areas, field logistic station area (FLS), main bridge area (MBR), ring road area (RNR), gas flare area (GFL), shell petroleum area (SPD), Otopiri oil well area (OTW) and Egbema area (EGB).

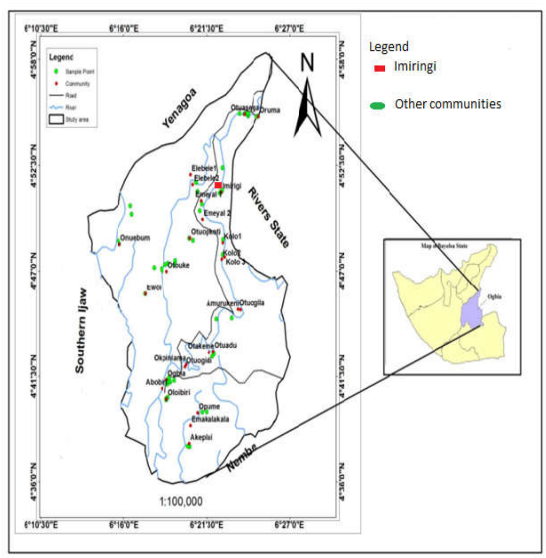

Fig. 1: Map of Ogbia LGA showing the study area

Measurement of Background Ionizing radiation: The procedure and method was adopted from Loagun, (Loagun et al., 2006). During each measurement the radiation meter was held at a standard distance of one metre (1.0 m) above the ground. Background ionizing radiation (BIR) was measured *in-situ* between 10.00 and 16.00 hours using digilert nuclear radiation monitoring meter. The radiation meter was calibrated with a 137Cs source of specific energy with an accuracy of ±15%. The meter detects radiation by means of a Geiger-Mueller tube in-built. Ionization takes place each time radiation passes through the Geiger-Mueller tube by generating a pulse of electric current. Each pulse is electronically detected and registers as a count. The count is then displayed in a chosen mode such as milli-Roentgen per hour ($mRhr^{-1}$) used in this study. The Geographical position System (GPS) was used to record the geographical location of the sites. Four readings were taken at each point and average recorded. A total of forty two sample points were investigated meaning that one hundred and sixty eight measurements were carried out. The value of the average background ionizing radiation converted from milli Roentgen to micro Roentgen was used to compute the health risks in terms of absorbed dose, effective dose rate (EDR), annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR).

Computation of absorbed dose: Absorbed dose was computed as reported by Arogungoe et al., (2004)

$1\ \mu Rh^{-1} = 8.7\ nGyh^{-1}$ (1)

Equivalent dose: Whole body equivalent dose rate over a period of one year, the National Council on Radiation Protection and Measurement's recommendation was used Ononugbo et al., (2011).

$1\ mRh^{-1} = \frac{0.96 \times 24 \times 365}{100}\ mSvy^{-1}$ (2)

Computation annual effective dose equivalent: The annual effective dose equivalent for outdoor and indoor were computed using the relations

AEDE (outdoor) (mSv/y) = Absorbed dose (ηGy/h) x 8760 h x 0.7Sv/Gy x 0.2 …. (3)

AEDE (indoor) (mSv/y) = Absorbed dose (nGy/h) x 8760 h x 0.7 Sv/Gy x 0.75 … (4).

Computation excess lifetime cancer risk: Excess Life Cancer Risk (ELCR) was calculated using the equation below.

ELCR (mSvy-1) = AEDE x Average Duration of Life (DL) x Risk Factor (RF) …. (5)

Where, AEDE is the annual effective dose equivalent, DL is duration of life taken as 52 years (NCP, 2019) and risk factor of 0.05 for BIR stochastic effects.

The effective dose rate delivered to body organs was computed using the following expression

Dorgan/tissue dose (mSvy-1) = O × *AEDE* × F (6)

Where A*EDE* is annual effective dose, O is the occupancy factor 0.8 and F is the conversion factor of organ dose from ingestion.

RESULTS AND DISCUSSIONS

Results of the background ionizing radiation at different sampled points with corresponding computed hazard indices for Imiringi community are presented in Tables 1 and 2.

Different parameters were investigated for the purpose of analyzing health indices. In this regard the radiation level was drawn hence the health implication of living in that community was revealed. This was done following best known procedure and standard which also provided results in similar studies in different locations such as in Avwiri et al., 2013. In other to achieve the investigation the following hazard indices were calculated; absorbed dose rate, equivalent dose, the annual effective dose equivalent, excess lifetime cancer risk and dose to different organs.

Background Ionizing Radiation (BIR) Exposure Levels: The results of average background ionizing radiation were considered based on the forty two sample points in the seven sections of the community. At Field logistic site area (FLS) the average BIR ranged from $16\mu Rh^{-1}$ to $23\mu Rh^{-1}$. Around the Main bridge area (MBR) it ranged from 21 to 32 μRh^{-1}. In Ring and seminary road area (RNR) it ranged from 14 to 23 μRh^{-1}. At the gas flow area (GFL) it ranged from 18 to 23 μRh^{-1}. Within the Shell petroleum site (SPD) it ranged from 20 to 27 μRh^{-1}. At Otopiri oil well area (OTW) it ranged from 24 to 32 μRh^{-1}.

In Egbema (EGB) area it ranged from 22 to 32 μRh^{-1}. This means that over all BIR ranged from 14 to 32 μRh^{-1}. This minimum range exceeded the world recommended value of 13 μRh^{-1}, and the same maximum value was recorded at MBR, OTW and EGB. These values are in agreement with values recorded at selected oil spill communities in Delta State (Audu et al., 2019). Mean BIR ranged from 19.83±2.3 (FLS) to 27.67±2.42 μRh^{-1} (OTW).

The highest value differs significantly with the highest BIR of 43 μRh^{-1} recorded at Onyeama mine site by Agbalagba and Anekwe, 2018 which they attributed to the trace quantities of naturally occurring primordial radionuclides (NORM) arising from the U and Th series, and ^{40}K. This means that BIR elevation is more at the coal mining site than in Imiringi community even with its very many oil and gas activities.

Table 1: Background ionizing radiation and computed hazard indices of Imiringi Community Bayelsa State

S/N	Sample PT Code	Lat. (°)	Log. (°)	Av. BIR μRh⁻¹	Dose (nGyh⁻¹)	EDR (mSvy⁻¹)	Indoor AEDE (mSvy⁻¹)	Outdoor AEDE (mSvy⁻¹)	ELCR x10⁻³
1	FLS1	4.0868	6.3696	16.00	139.2	1.350	0.640	0.213	0.550
2	FLS2	4.0867	6.3694	17.00	147.9	1.430	0.680	0.227	0.590
3	FLS3	4.0867	6.3684	23.00	200.1	1.930	0.920	0.307	0.800
4	FLS4	4.0865	6.3698	20.00	174.0	1.680	0.800	0.267	0.690
5	FLS5	4.0861	6.3702	21.00	182.7	1.770	0.841	0.280	0.730
6	FLS6	4.0859	6.3702	22.00	191.4	1.850	0.880	0.293	0.760
7	MBR1	4.0858	6.3704	21.00	182.7	1.770	0.840	0.280	0.730
8	MBR2	4.0855	6.3704	32.00	278.4	2.690	1.280	0.427	1.110
9	MBR3	4.0854	6.3706	26.00	226.2	2.170	1.040	0.347	0.900
10	MBR4	4.0858	6.3716	24.00	208.8	2.020	0.960	0.320	0.830
11	MBR5	4.0857	6.3716	21.00	182.7	1.770	0.840	0.280	0.730
12	MBR6	4.0857	6.3720	24.00	208.8	2.020	0.960	0.320	0.830
13	RNR1	4.0857	6.3718	19.00	165.3	1.600	0.760	0.253	0.660
14	RNR2	4.0853	6.3727	24.00	208.8	2.020	0.960	0.320	0.830
15	RNR3	4.0853	6.3735	24.00	208.8	2.020	0.960	0.320	0.830
16	RNR4	4.0850	6.3738	29.00	252.3	2.440	1.160	0.387	1.010
17	RNR5	4.0851	6.3740	14.00	121.8	1.180	0.560	0.187	0.490
18	RNR6	4.0849	6.3740	23.00	200.1	1.930	0.928	0.307	0.800
19	GFL1	4.0842	6.3745	23.00	200.1	1.930	0.928	0.307	0.800
20	GFL2	4.0854	6.3745	22.00	191.4	1.850	0.880	0.293	0.760
21	GFL3	4.0850	6.3742	23.00	200.1	1.930	0.928	0.307	0.800
22	GFL4	4.0878	6.3734	18.00	156.6	1.510	0.720	0.239	0.620
23	GFL5	4.0883	6.3737	22.00	191.4	1.850	0.880	0.293	0.760
24	GFL6	4.0886	6.3738	21.00	182.7	1.770	0.840	0.280	0.730
25	SPD1	4.0886	6.3739	21.00	182.7	1.770	0.840	0.280	0.730
26	SPD2	4.0897	6.3775	23.00	200.1	1.930	0.928	0.307	0.800
27	SPD3	4.0894	6.3769	21.00	182.7	1.770	0.840	0.280	0.730
28	SPD4	4.0868	6.3781	20.00	174.0	1.680	0.800	0.267	0.690
29	SPD5	4.0887	6.3779	27.00	234.9	2.270	1.080	0.360	0.940
30	SPD6	4.0887	6.3775	26.00	226.2	2.190	1.040	0.347	0.900
31	OTW1	4.0891	6.3772	27.00	234.9	2.270	1.080	0.360	0.940
32	OTW2	4.0928	6.3772	29.00	252.3	2.440	1.160	0.387	1.000
33	OTW3	4.0930	6.3770	24.00	208.8	2.020	0.960	0.320	0.830
34	OTW4	4.0956	6.3766	28.00	243.6	2.350	1.120	0.373	0.970
35	OTW5	4.0966	6.3762	26.00	226.2	2.190	1.040	0.347	0.900
36	OTW6	4.0964	6.3748	32.00	278.4	2.690	1.280	0.427	1.110
37	EGB1	4.0976	6.3744	26.00	226.2	2.190	1.040	0.347	0.900
38	EGB2	4.0837	6.3742	23.00	200.1	1.930	0.928	0.307	0.800
39	EGB3	4.0837	6.3742	24.00	208.8	2.020	0.960	0.320	0.830
40	EGB4	4.0882	6.3731	29.00	252.3	2.440	1.160	0.387	1.000
41	EGB5	4.0884	6.3740	25.00	217.5	2.100	1.000	0.333	0.870
42	EGB6	4.0885	6.3744	22.00	191.4	1.850	0.880	0.293	0.760
	Mean			**23.38**	**203.41**	**1.960**	**0.936**	**0.311**	**0.810**

Table 2: Mean values of Background ionizing radiation and computed hazard indices of Imiringi Community Bayelsa State

S/N	Sample Point Code	Mean BIR (μRh⁻¹)	Dose (nGyh⁻¹)	EDR (mSvy⁻¹)	Indoor AEDE (mSvy⁻¹)	Outdoor AEDE (mSvy⁻¹)	ELCR (x10⁻³)
1	FLS	19.83±2.30	172.55±24.24	1.67±0.12	0.79±0.05	0.26±0.05	0.69±0.02
2	MBR	24.67±1.86	214.60±19.34	2.07±0.09	0.99±0.08	0.32±0.06	0.84±0.04
3	RNR	22.17±1.87	192.85±18.68	1.87±0.12	0.89±0.07	0.30±0.02	0.77±0.01
4	GFL	21.50±2.18	187.05±23.21	1.81±0.08	0.86±0.07	0.29±0.03	0.75±0.04
5	SPD	23.00±2.00	200.10±19.26	1.93±0.11	0.92±0.09	0.31±0.02	0.80±0.03
6	OTW	27.67±2.42	240.70±25.12	2.33±0.08	1.11±0.08	0.37±0.03	0.96±0.05
7	EGB	24.83±1.91	216.05±18.61	2.09±0.10	0.99±0.09	0.33±0.04	0.86±0.04

It was observed that the background ionizing radiation exceeded the world recommended value of 13 μRh^{-1} as shown in Fig.2. *Absorbed Dose Rate and Equivalent dose rate:* The absorbed dose rate ranged from 121.8 to 278.4nGyh^{-1} with mean range of 172.55±24.24 (FLS) to 240.70±25.12 nGyh^{-1} (OTW). The estimated whole body equivalent dose rate ranged from 1.18 to 2.69mSvy^{-1} over a period of one year. Also the mean EDR ranged from 1.67±0.12 to 2.33±0.08 mSvy^{-1} meaning that all the computed equivalent doses exceeded the permissible limit of 1.0mSvy^{-1}.

The Annual Effective Dose Equivalent (AEDE): All the AEDEs outdoor were within normal and AEDEs indoors exceeded permissible limit at twelve different points with maximum value at OTW6. Interestingly, the overall average value of outdoor and indoor annual effective dose equivalents were computed to be 0.311 $mSvy^{-1}$ and 0.936 $mSvy^{-1}$ respectively and these values are within the world permissible value of 1.0 $mSvy^{-1}$. The figure 3 showed that annual effective dose equivalent exceeded the world standard at OTW only and almost equal to standard at the main bridge area of the community.

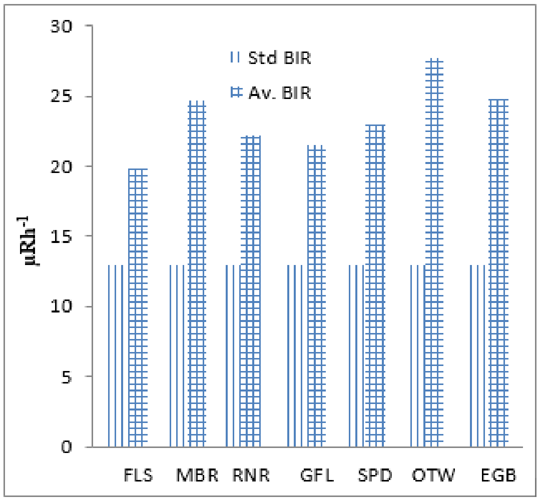

Fig. 2: Comparison of measured BIR with standard BIR

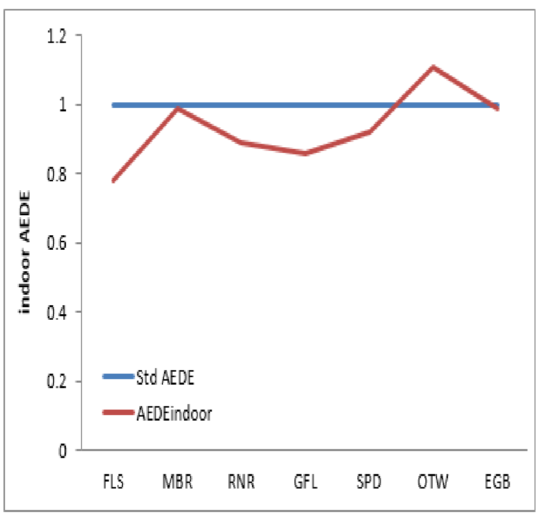

Fig 3: Comparison of indoor AEDE with Standard permissible AEDE

Excess Lifetime Cancer Risk (ELCR): At FLS, MBR, RNR, GFL, SPD, OTW and EGB locations, excess lifetime cancer risk ranged from 0.640 to $0.920 x 10^{-3}$, 0.730 to $1.110 x 10^{-3}$, 0.490 to $0.830 x 10^{-3}$, 0.620 to $0.800 x 10^{-3}$, 0.730 to $0.940 x 10^{-3}$, 0.830 to $1.110 x 10^{-3}$ and 0.800 to $0.900 x 10^{-3}$ respectively. Mean values of ELCR ranged from 0.69±0.02 to 0.96±0.05 $x 10^{-3}$. These values are higher than the world permissible value of 0.29 x 10^{-3} but are in agreement with results of previous studies in similar environment for example as reported by Audu *et al.,* 2019.

Effective Dose to human Organ or Tissue: Bone marrow, Lungs, Ovaries, Testes, Liver, Kidney and Whole body were considered and their respective calculated values are 0.52, 0.48, 0.43, 0.61, 0.34, 0.46 and 0.51 $mSvy^{-1}$. These values are far below the standard value of 1.0 $mSvy^{-1}$.

*Conclusion***:** Environmental Radioactivity Level and its Health Implication in Imiringi were assessed. The maximum background ionizing radiation (BIR) recorded was $32 \mu Rh^{-1}$ and a minimum effective dose rate of $1.35 mSvy^{-1}$. Long-term effects may not be ruled out in consideration of the excess lifetime cancer risk average value of 0.810 x 10^{-3} against 0.290 x 10^{-3} which is the universal allowable value. However, despite the elevated BIR the level of exposures to human organs does not suggest any short term health effects.

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