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GAMMA RADIATION AND RADIOLOGICAL RISK ASSESSMENT: A CASE STUDY OF ELEBELE COMMUNITY IN OGBIA, BAYELSA STATE NIGERIA

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ABSTRACT

Knowledge of environmental radiation status is very necessary in quantifying health risks. In this regard, the objective of this study was to obtain *in-situ* measurement of background ionizing radiation (BIR) level of Elebele community in Bayelsa State. This was carried out using a well calibrated radiation meter, Radalert-200. The results of BIR obtained in the four zones ranged from 0.009 to 0.035 mRh^{-1} with a mean value of 0.022 mRh^{-1}>0.013m Rh^{-1}. The mean value of BIR was used to compute hazard indices; absorbed dose (AD), annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR) and their means. Computed values of absorbed dose ranged from 104-743.5 $nGyh^{-1}$with a mean of 462.01$nGyh^{-1}$>84.0 $nGyh^{-1}$. Mean values of annual effective dose equivalents were 0.39, 0.611, 0.39 and 0.53 $mSvy^{-1}$ < 1 $mSvy^{-1}$. Also the mean values of excess lifetime cancer risk were $1.01x10^{-3}$, $1.19x10^{-3}$ $1.04x10^{-3}$ and $1.08x10^{-3}$>$0.29x10^{-3}$. These results exceeded the permissible limits therefore further study using gamma spectrometry is required on the soil and water samples of the area though the elevations may be attributed to the oil and gas exploitation activities within the area.

Keywords: Absorbed dose, baseline data, health effect, radalert-200, risk assessment.

INTRODUCTION

The health effects of background ionizing radiation cannot be overemphasized; these effects arise from different anthropogenic activities here on earth such as oil exploration, mining, fertilizer production, scientific research work on the application of radioactive sources in nuclear medicine, application of fertilizers during cultivation. Others include regular application of x-ray in medicine and handling of materials containing enhanced sources of naturally occurring radioactive materials (NORM). These materials which might be present in the soil as well as surface and ground water can lead to occupational and public exposure of individuals to ionizing radiations (Upton, 2003). The environment contains varied degrees of primordial materials such as naturally occurring radioactive materials (NORMs). NORMs are those materials that contain radionuclides arising from natural sources (Californian, 1996).All Living creatures are exposed to naturally occurring radioactive materials (NORMs) and technological enhanced naturally occurring radioactive materials (TENORMs) (Anekwe and Ibe, 2021). Naturally Occurring Radioactive Material is of great concern due to its health effects on human and the immediate environment when man is exposed to the varying amount with or without his consent.

Radiation may be natural radioactivity, artificial radioactivity or the combination of natural and artificial activity sources within the environment. The presence of radionuclides in the soil, food and water poses quite a number of health hazards, especially when these radioisotopes are deposited in the human body through consumption of contaminated food and water. The dissolved radionuclides in foods and water emit alpha particles, beta particles and photons (gamma) which gradually get to living tissues (Alam *et al.*, 1999; Gruber *et al.*,2009). In the present time human activities in milling and mining, processing, of uranium ores and mineral sands, drilling, manufacture of fertilizers and transportation, processing and burning of fossil fuels have raised the concentrations of naturally occurring radioactive materials in the environment (Pujol *et al.*,2000). In the Niger Delta of Nigeria oil and gas activities have in no small measure affected the natural ecosystem particularly the background ionizing radiation perturbation. The industrial activities within the environment which includes extraction and processing of minerals might cause the incorporation of radionuclides into the hydrosphere through surface or ground water (Mangset *et al.*,2014). Most of the soil contamination occurs by natural and fallout of

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radionuclides as a recurrent radiological effect since it is freely translated to human body via edible crops and drinking waters. Ingestion is the primary cause of human vulnerability to radiation leading to internal radiation (Saeed *et al.*,2012). Application of fertilizer to soil is a source of radiation exposure to the environment since fertilizer contains nucleide elements. Fertilizer application is also a means of the transfer and migration of radionuclide into the environment. Natural radioactivity in soil is mainly due to ^{238}U, ^{40}K, ^{226}Ra which cause external and internal radiological hazards due to emission of gamma rays and inhalation of radon and its daughters. The intensity of the radiation, its energy level, exposure time and the surface area exposed are determinant factors of radiation dose.

Previous studies such as Anekwe (2021), Agbalagba and Anekwe (2018) recorded that quantities such as the absorbed dose, the effective dose and the equivalent dose have been introduced to specify the dose received and the biological effectiveness of that dose. The biological effect depends on the total dose the tissue is exposed to and the rate at which the dose was received. The equivalent dose rate and the absorbed dose may not give an accurate indication of the harm that radiation can cause. This is because it is possible for equal absorbed doses to have different biological ionizing radiation effects. In this regard, an absorbed dose of 0.1Gy of alpha radiation is more harmful than an absorbed dose of 0.1Gy of beta or gamma radiation. Interestingly, when ionizing radiation interacts with medium such as air, tissue, water and plastic, energy is transferred from the radiation field to the medium and the quantity that describes this energy transfer is the absorbed dose and is measured by the concentration of absorbed energy (Cember, 2009). This undesirable energy to human tissue should therefore be avoided at all cost hence the need to assess radiological health risk in Elebele community as a result of terrestrial gamma radiation. The objective of this study was to obtain *in-situ* measurement of background ionizing radiation (BIR) level of Elebele community in Bayelsa State, Nigeria.

STUDY AREA

Elebele community is one of the numerous autonomous communities in Ogbia Local Government Area of Bayelsa State in the Niger Delta region of Nigeria. There was ongoing oil exploration activity in the community with crisscrossing of existing oil pipelines. The native residents are mainly farmers and fishermen. Elebele is located between latitude 4.76143N and longitude 6. 2915E and for the purpose of this research the study area was arbitrary categorized into zones (Fig. 1).

The major soil types in the area are known to be as young, shallow, poorly drained and acidic sulphate. Several soil units were identified within the area based on physiographic differences. Since the study area has the same geological features and is located in the same Bayelsa State previously described by Anekwe and Ibe 2017, the soil types are of the high-lying levees. They are made up of sandy loam, loamy sandy, silt loamy soils which include the moderately fine texture, red silt or clay loamy soils. The bed of the dead creeks and streams contain silted river belt soils. The basin soils which include silky clay loam or sandy loam are occupied by flood for most of the year. The transition zone soils such as silt and sandy silt are under the influence of fresh water and tidal floods. However there are pockets of potash deficiency especially in the sandy soils and the texture of majority of the soils ranges from medium to fine grains (Anekwe and Ibe, 2017). Generally, the Niger Delta region which is a low land area and a low-lying relief is characterized by flood plains, tidal flats and coastal beaches and beach ridge barriers with cliffs and lagoons being the dominant relief features. The study area Elebele in Ogbia Local Government Area is indicated with black color on the map.

MATERIALS AND METHODS

Materials

The instrument used in carrying the *in-situ* measurement of the outdoor BIR exposure level was Radalert 200 radiation meter. The Nuclear radiation monitoring meter contains a Geiger-Muller tube which is capable of detecting alpha, beta and gamma radiation. The radiation meter was well calibrated for accurate results. Global Positioning System (GPS) was used to determine the geographical coordinates of the selected sample points within the study area. The values of background ionizing radiation obtained were used in mathematical equations to compute the risk indices.

Methods

The study area was sectioned into four zones for convenience. An *in-situ* measurement was carried out in forty (40) sampling points which were arbitrarily selected within the four zones (Z) Zone A to Zone D.

The radiation meter was set to measure the exposure rate in milli-Roetgen per hour. Readings were taken at each point by holding the meter 1m above the ground level and at each point reading was recorded after a beep. In order to obtained accurate outdoor radiation measurement three different readings were taken at each sampled point leading to one hundred and twenty (120) readings and the average recorded which gave forty (40) recorded background ionizing radiation values. The standard deviations were calculated to account for the errors in the measurement. A standard geographical positioning system (GPS) was used to take the precise positions were readings were taken.

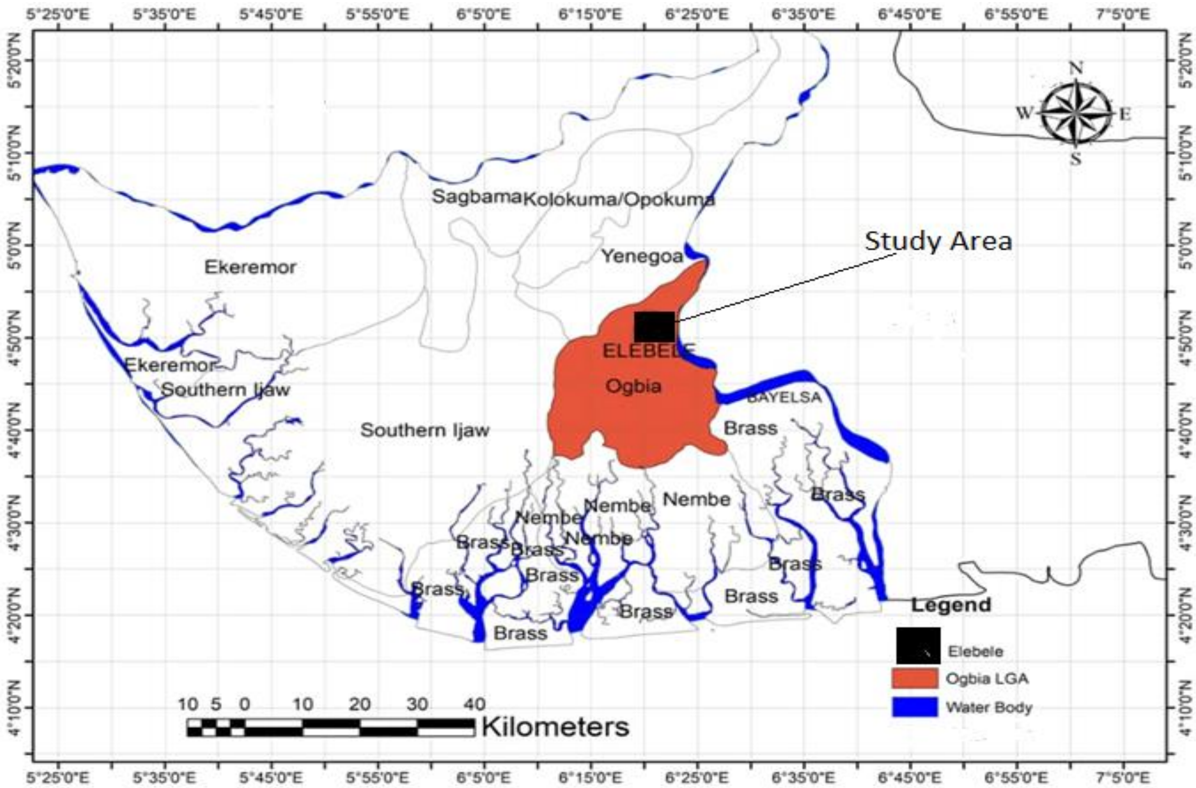

Fig. 1. Map of the study Area.

Absorbed dose

The absorbed dose rate was obtained from the exposure dose rate in (mR/h) using the conversion factor. The absorbed dose is donated with D.

D = Exposure dose rate x 8.7 (nGy/hr) 1

1μR/hr =8.7 nGy/hr

Equivalent Dose

Equivalent Dose is the product of the obtained average value of absorbed dose of radiation on a tissue and its radiation weighting factor(WR).

$$1\text{mR/hr} = \frac{0.96x24x365}{100}(\text{mSv/yr}) \qquad 2$$

Excess Lifetime Cancer Risk (ELCR)

Excess Lifetime Cancer Risk (ELCR) is a carcinogenic potential effect characterized by assessing the probability of cancer occurrence in a population of individuals for a specific lifetime from projected intakes (and exposures) and chemical specific dose-response data (i.e. slope factors).

The excess lifetime cancer risk was calculated using the following equation

ELCR=AEDExAverage duration of life (DL) x Risk Factor (RF) 3

where, AEDE, DL and RF are the annual effective dose equivalent, duration of life (50yrs) and the risk factor (Sv^{-1}) fatal risk per Sievert. For low dose background radiations which are considered to produce stochastic effects, ICRP 60 uses values of 0.05 for the public (Taskin *et al.*,2009).

Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent (AEDE) received by the residence within the study area was calculated using the absorb dose. Dose conversion factor of 0.7Sv/Gy and the occupancy factor for outdoor is 0.2(6/24), it was assumed that the people spend 6 hours outdoors. The annual effective dose was determined using the following equations (Muhmoud *et al.*, 2014).

AEDE (outdoor) (mSv/yr) =Dose rate (nGy/h)x8760hx0.75Sv/Gy x 0.25 4

RESULTS AND DISCUSSION

The results of the background ionizing radiation, radiological parameter and some hazard indices were presented in Tables 1 to 4. The hazard indices include the computed absorbed dose, annual effective dose equivalent(AEDE) and excessive life cancer risk (ELCR). Table 5 showed the mean values of the total outdoor radiological parameters of the community. Figures 2 to 12 compare the background ionizing radiation and hazard indices with their respective permissible levels.

Table 1. Exposure rate and radiological parameters of Zone A.

S/N	Sampling Points	Exposure dose rate ($mRhr^{-1}$)	Coord. (degree)	ED (mSv/yr)	ABS'D (nGy/hr)	AEDE (mSv/yr)	ELCR ($\times 10^{-3}$)
1	ZA_1	0.013±0.001	N04°50´52" E06°20´56"	1.009	104.4	0.17	0.60
2	ZA_2	0.009±0.001	N04°50´55" E06°20´55"	1.093	113.1	0.19	0.67
3	ZA_3	0.025±0.002	N04°50´59" 06°20´53"	2.210	216.7	0.41	1.18
4	ZA_4	0.025±0.003	04°51´ 3" 06°20´51"	2.210	216.7	0.41	1.18
5	ZA_5	0.019±0.002	04°51´2" 06°20´48"	1.598	165.3	0.27	0.85
6	ZA_6	0.029±0.001	04°51´5" 06°20´55"	4.23	425.5	0.93	1.37
7	ZA_7	0.014±0.002	04°51´10" 06°20´50"	1.177	121.8	0.20	0.70
8	ZA_8	0.019±0.003	06°20´48" 06°20´48"	1.598	165.3	0.27	0.85
9	ZA_9	0.025±0.002	04°51´15" 06°20´48"	2.210	216.7	0.41	1.18
10	ZA_{10}	0.027±0.001	04°51´18" 06°20´45"	3.22	322.7	0.67	1.567
	Mean	0.021±0.002		2.06±0.001	206.82±0.003	0.39±0.001	1.01±0.001

Table 2. Exposure rate and radiological parameters of Zone B.

S/N	Sampling Points	Exposure dose rate ($mRhr^{-1}$)	Coord. (degree)	ED (mSv/yr)	ABS'D (nGy/hr)	AEDE (mSv/yr)	ELCR ($\times 10^{-3}$)
1	ZB_1	0.031±0.002	N04°51´18" E06°20´42"	5.24	531.5	1.19	1.75
2	ZB_2	0.029±0.001	N04°51´24" E06°20´40"	4.23	425.5	0.93	1.37
3	ZB_3	0.025±0.003	N04°51´23" E06°20´43"	2.210	216.7	0.41	1.18
4	ZB_4	0.014±0.002	N04°51´36" E06°20´75"	1.177	121.8	0.20	0.70
5	ZB_5	0.015±0.002	N04°51´35" E06°20´79"	1.682	174.0	0.33	0.89
6	ZB_6	0.014±0.001	N04°51´27" E06°20´42"	1.177	121.8	0.20	0.70
7	ZB_7	0.023±0.002	N04°51´28" E06°20´45"	2.78	288.3	0.70	1.32
8	ZB_8	0.035±0.003	N04°51´23" E06°20´38"	7.26	743.5	1.71	2.51
9	ZB_9	0.014±0.002	N04°51´23" E06°20´35"	1.177	121.8	0.20	0.70
10	ZB_{10}	0.017±0.002	N04°51´22" E06°20´36"	1.429	147.9	0.23	0.81
	Mean	0.022±0.002		2.8362±0.002	289.28±0.001	0.61±0.001	1.193±0.003

Table 3. Exposure rate and radiological parameters of Zone C.

S/N	Sampling Points	Exposure dose rate($mRhr^{-1}$)	Coord.(degree)	ED (mSv/yr)	ABS'D (nGy/hr)	AEDE (mSv/yr)	ELCR ($\times 10^{-3}$)
1	ZC_1	0.025±0.003	04°51´21"06°20´34"	2.210	216.7	0.41	1.18
2	ZC_2	0.019±0.002	04°51´19"06°20´36"	1.598	165.3	0.27	0.85
3	ZC_3	0.025±0.003	04°51´17"06°20´37"	2.210	216.7	0.41	1.18
4	ZC_4	0.029±0.002	04°51´ 16"06°20´36"	4.23	425.5	0.93	1.37
5	ZC_5	0.025±0.003	04°51´17"06°20´34"	2.210	216.7	0.41	1.18
6	ZC_6	0.014±0.001	04°51´19"06°20´32"	1.177	121.8	0.20	0.70
7	ZC_7	0.019±0.002	04°51´20"06°20´32"	1.598	165.3	0.27	0.85
8	ZC_8	0.025±0.002	04°51´21"06°20´34"	2.210	216.7	0.41	1.18
9	ZC_9	0.014±0.001	04°51´23"06°20´38"	1.177	121.8	0.20	0.70
10	ZC_{10}	0.025±0.003	04°51´26"06°20´35"	2.210	216.7	0.41	1.18
	Mean	0.022±0.002		2.08±0.001	208.32±0.002	0.39±0.001	1.04±0.002

Table 4. Exposure rate and radiological parameters of Zone D.

S/N	Sampling Points	Exposure dose rate($mRhr^{-1}$)	Coord.(degree)	ED (mSv/yr)	ABS'D (nGy/hr)	AEDE (mSv/yr)	ELCR ($\times 10^{-3}$)
1	$Z D_1$	0.018±0.001	N04°51´28"E06°20´36"	1.09	1122.3	0.14	0.66
2	ZD_2	0.023±0.002	N04°51´27"E06°20´40"	2.78	288.3	0.70	1.32
3	ZD_3	0.029±0.003	N04°51´26"E06°20´41"	4.23	425.5	0.93	1.37
4	ZD_4	0.031±0.001	N04°51´30"E06°20´33"	5.24	531.5	1.19	1.75
5	ZD_5	0.015±0.001	N04°51´26"E06°20´29"	1.682	174.0	0.33	0.89
6	ZD_6	0.022±0.002	N04°51´20"E06°20´28"	2.28	235.7	0.48	1.13
7	ZD_7	0.028±0.003	N04°51´31"E06°20´38"	3.73	372.5	0.80	1.18
8	ZD_8	0.018±0.001	N04°51´48"E06°20´30"	1.09	1122.3	0.14	0.66
9	ZD_9	0.019±0.001	N04°51´42"E06°20´16"	1.598	165.3	0.27	0.85
10	ZD_{10}	0.021±0.002	N04°51´52"E06°20´52"	1.766	182.7	0.35	0.94
	Mean	0.022±0.002		2.55±0.002	462.01±0.001	0.53±0.002	1.08±0.002

Table 5. Mean of Radiological Parameters of the four Zones.

s/n	Sampling Points	Exposure dose rate(mRhr^{-1})	EQUIVALENT DOSE(mSv/yr)	ABSORBED DOSE(nGy/hr)	AEDEOUTDOOR(mSv/yr)	ELCR (x 10^{-3})
1	Zone A	0.021	2.06	206.82	0.39	1.01
2	Zone B	0.022	2.84	289.28	0.611	1.19
3	Zone C	0.022	2.08	208.32	0.39	1.04
4	Zone D	0.022	2.55	462.01	0.53	1.08
	Standard values	0.013		84.00	1.00	0.29

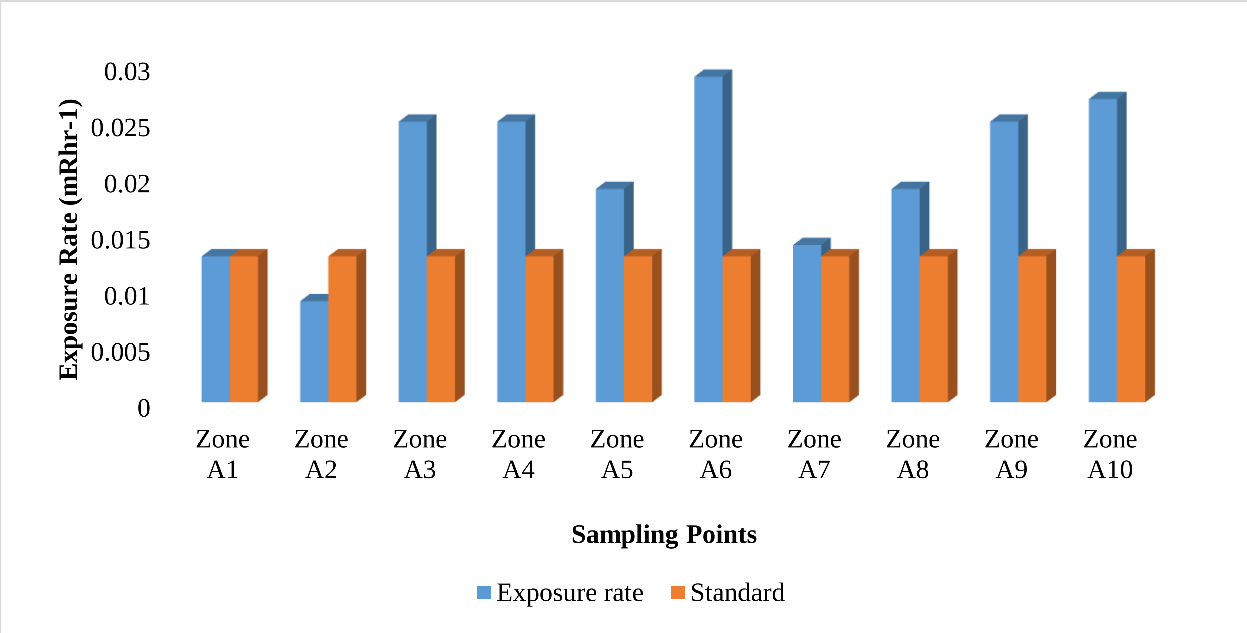

Fig. 2. Comparison of background ionizing radiation of Zone A with Standard.

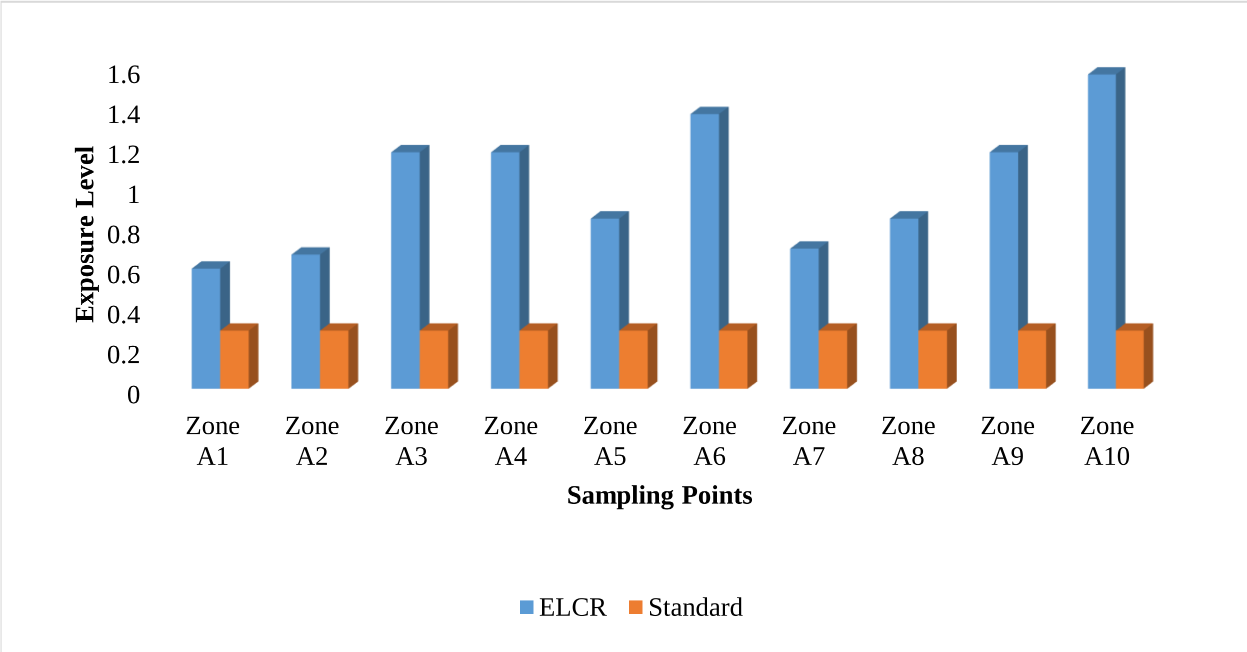

Fig. 3. Comparison of ELCR of Zone A with Standard.

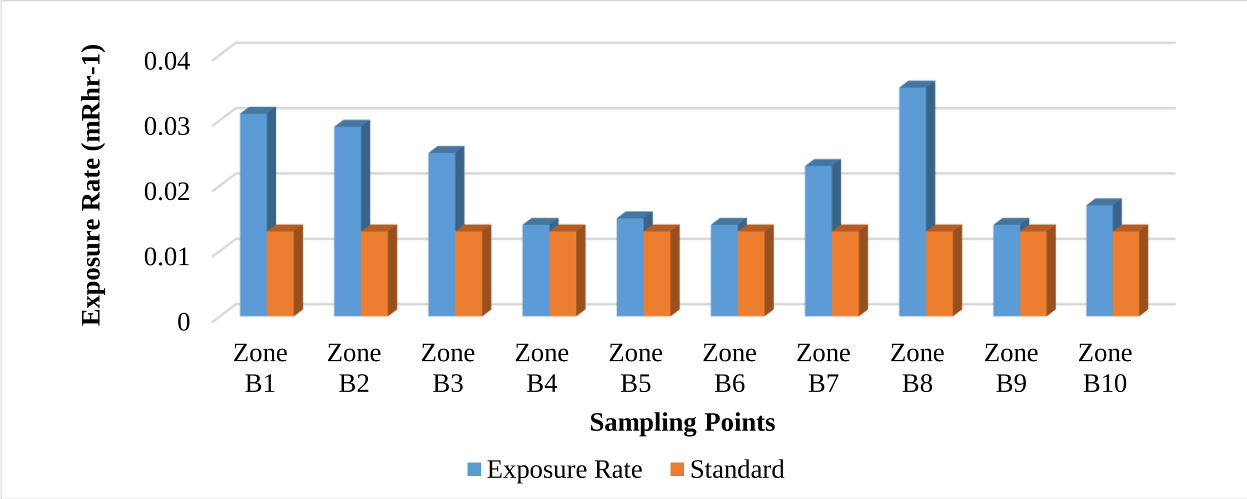

Fig. 4. Comparison of background ionizing radiation of Zone B with Standard.

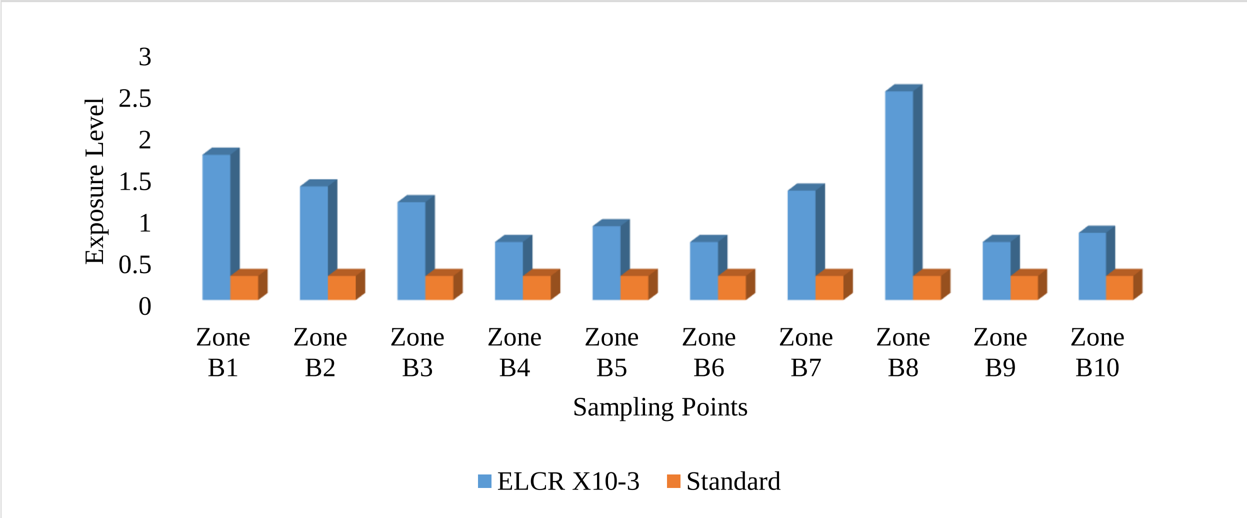

Fig. 5. Comparison ELCR of Zone B with Standard.

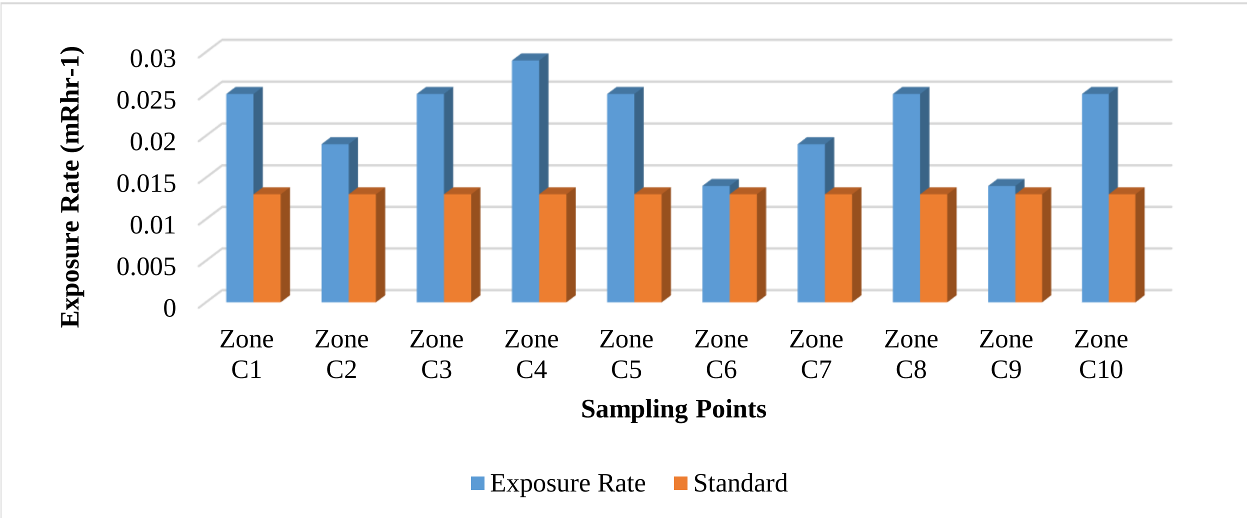

Fig. 6. Comparison of background ionizing radiation of Zone C with Standard.

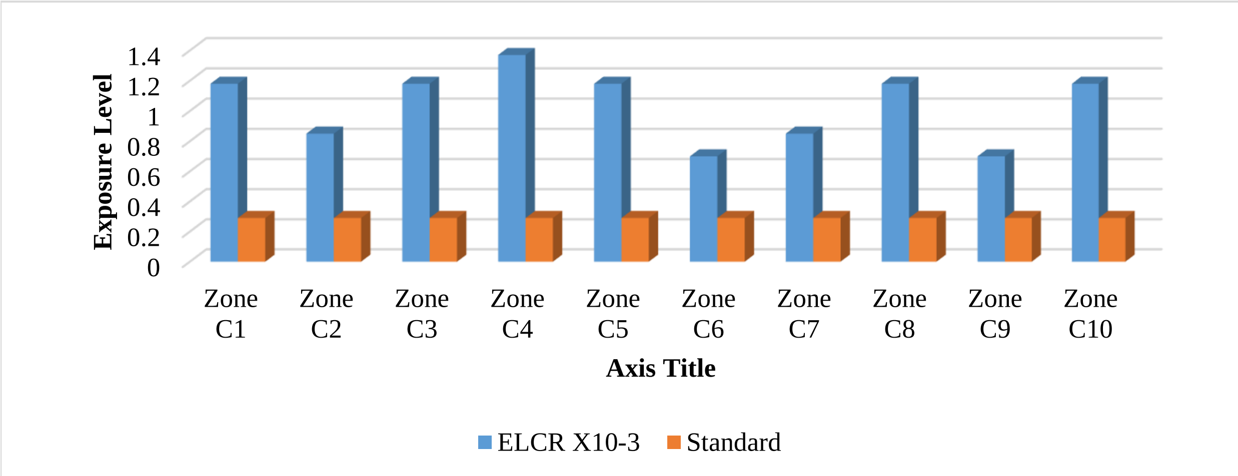

Fig. 7. Comparison ELCR of Zone C with Standard.

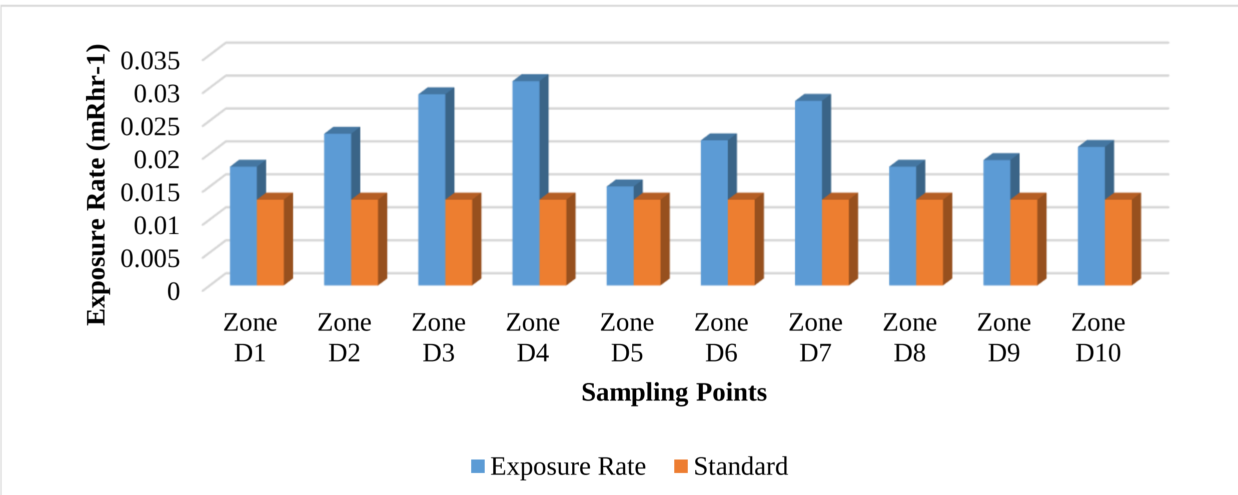

Fig. 8. Comparison of background ionizing radiation of Zone D with Standard.

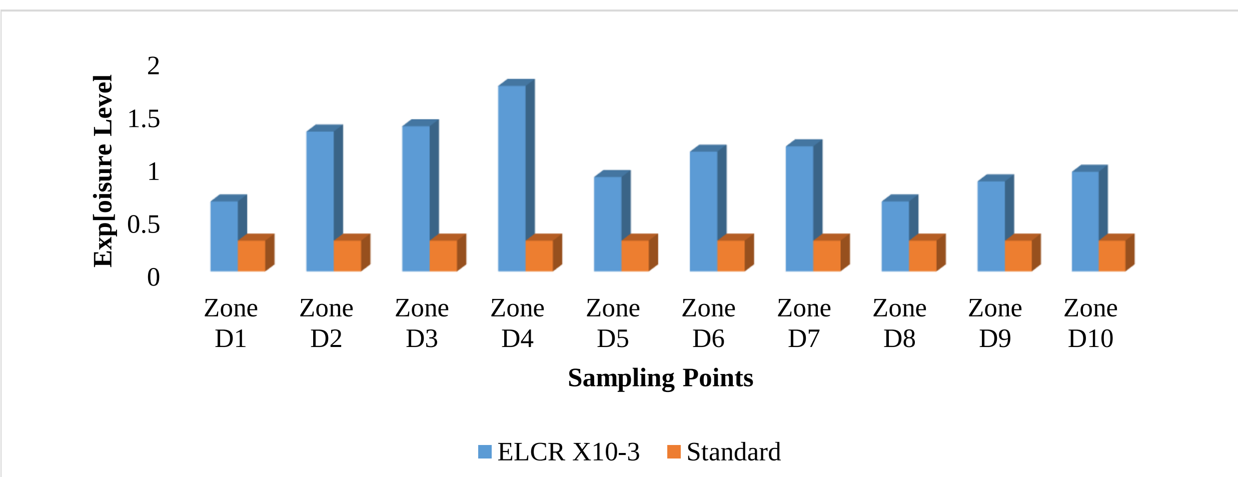

Fig. 9. Comparison of ELCR of Zone D with Standard.

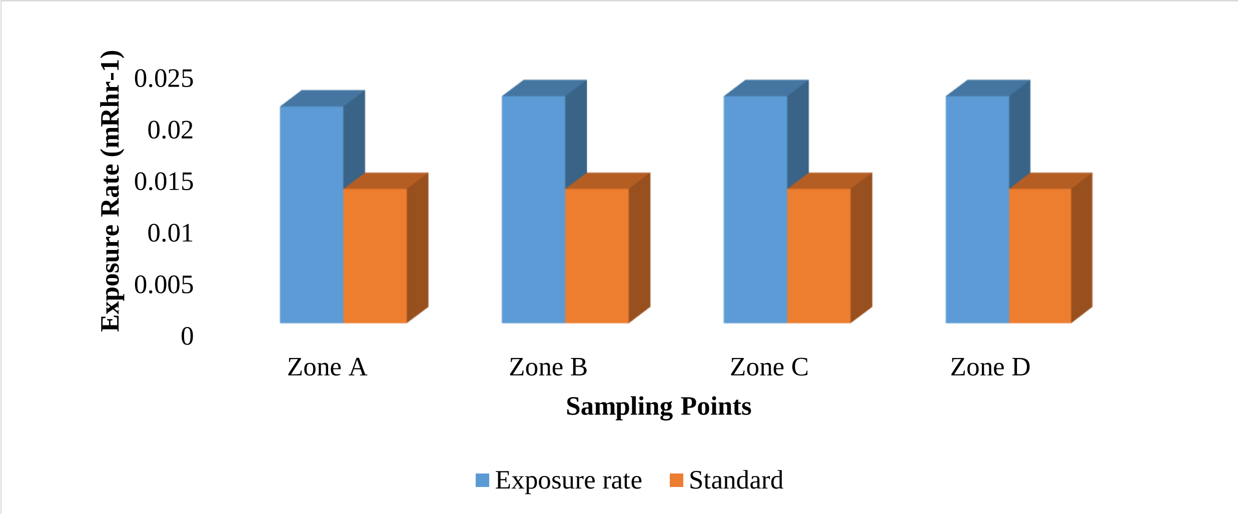

Fig. 10. Comparison of BIR Mean of the four Zones with Standard.

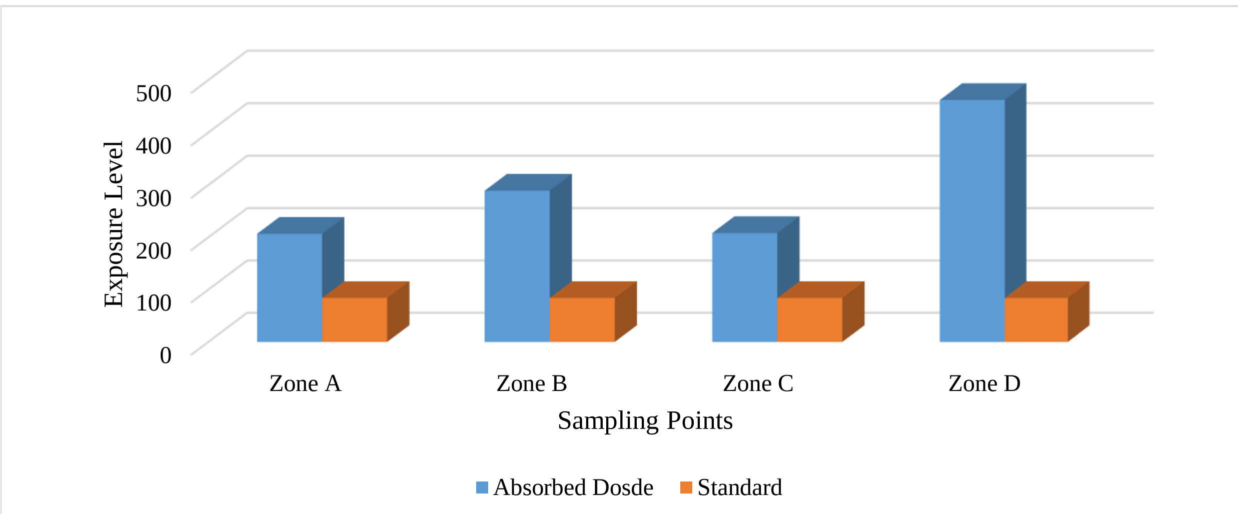

Fig. 11. Comparison of Absorbed Mean of the four Zone with Standard.

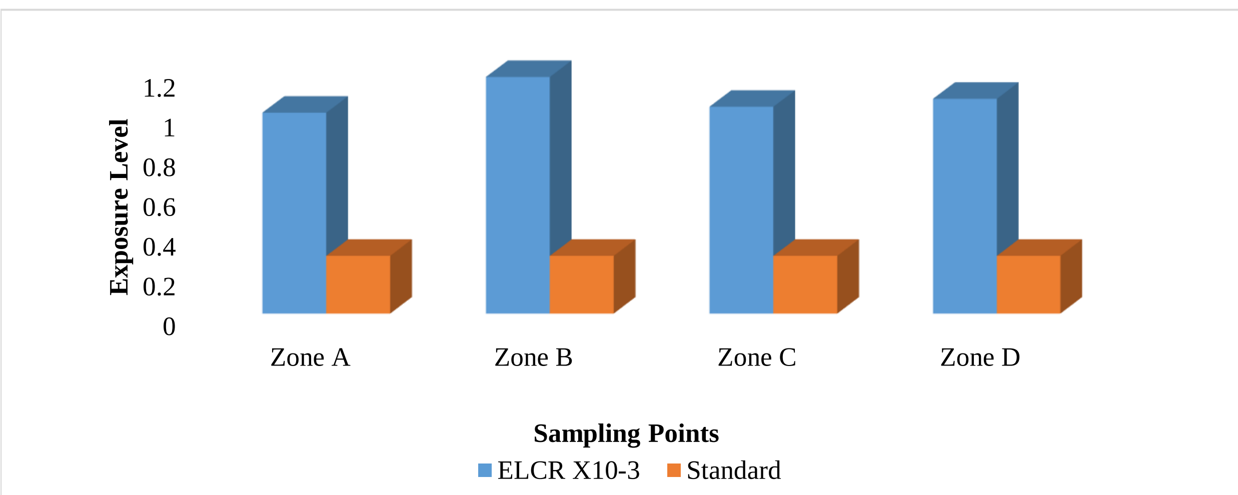

Fig. 12. Comparison of the ELCR Mean of the four Zone with Standard.

The *in-situ* measurement of background ionizing radiation of Elebele community in Ogbia Local Government Area of Bayelsa state of Nigeria has been carried out and the results are presented in Tables 1 to 4. The BIR results of Zone A, Zone B, Zone C and Zone D ranged as follows; 0.009-0.25, 0.014-0.35, 0.014-0.25 and 0.015-0.031 $mRhr^{-1}$ with mean values of 0.021, 0.022, 0.022 and 0.022 $mRhr^{-1}$ respectively. The evaluation of radioisotopes of natural origin becomes very important in order to achieve specific objective to quantifying the radiological parameters and their respective health implications (Anekwe and Odezuligbo, 2022). So in this study, the obtained results from the four Zones were as shown in Tables 1 to 4 with some values above the standard value of 0.013$mRhr^{-1}$. The higher BIR value was recorded in Zone D with a mean value of 0.022 $mRhr^{-1}$. The average results were higher than the reported work of Ugbede and Benson(2018). This higher radiation value within the zones might be due to the current oil exploration activities ongoing in the area and the points with lower radiation value may be due to the distance from the actual point of radiation impact. The average absorbed doses obtained in the four zones were slightly higher than the recommended safe limit of 84.0$nGyhr^{-1}$ and they were also higher than the reported work of Anekwe and Ibe (2017) of similar environment. The annual effective dose equivalent (AEDE) of the study area were above the standard value of 1.0 $mSvyr^{-1}$and also higher than the reported work of Anekwe and Ibe (2017). Excess life time cancer risk (ELCR) at the Zones varies as follows 0.60 -1.57, 0.70-2.51, 0.70-1.18 and 0.66-1.75 with mean of 1.01 ± 0.001, 1.19 ± 0.003, 1.04 ± 0.002 and $1.08\pm0.002x10^{-3}$ respectively. The results of the Excess life time cancer risk of the study area are all higher than the standard value of $0.29x10^{-3}$ as recommended by ICRP (2007) and the reported work of Taskin et *al.* (2009). Figures 2 to 12 compared BIR, absorbed dose and ELCR with normal and each had a slight increase above corresponding permissible limit.

CONCLUSION

The *in-situ* measurement of outdoor background ionizing radiation of Elebele community was successfully carried out with the corresponding computed radiological hazard levels. Some of the measured values in the four Zones were slightly higher than the standard value of 0.013$mRhr^{-1}$ as recommended by International Commission on Radiation Protection. There were slight increases above the standard values of the radiological hazard indices. These slight elevations are unlikely to pose any short-term health effect on Elebele populace, hence the data will serve as base line radiation information.

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