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Radiological Health Risk from Gamma Radiation of Coastal Communities in Okrika Local Government Area of Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In-situ measurement of background ionization radiation was carried out in coastal communities of Okrika Local Government Area. This field work was achieved with the use of Digilert 200 to record the background ionization radiation and global positioning system in taking the coordinates of the sampled Locations. The exposure rate ranged from 0.010 mR/h to 0.017 mR/h with a mean value of 0.0122$\pm$ 0.03 mR/h, which is quite lower than the acceptable limit of 0.0133 $\mu R/h$. The absorbed dose varied from 85.70 nGy/h to 140.9 nGy/h with a mean value of 108.3+23.34 nGy/h. The mean value was a little higher than the world average of 89.0 nGy/h. The annual effective dose ranged from 0.13 mSv/y to 0.23 mSv/y with an overall mean of 0.1611$\pm$0.04 mSv/y. The overall mean value obtained was found to be lesser that the acceptable limit of 1.0 ms/y 10^{-3}. The excess life cancer risk ranged from 0.47 x 10^{-3} to 0.79 x 10^{-3} with overall mean of 0.57$\pm$ 0.12 which is higher than the world average of 0.29 x 10^{-3}. The study area is free from radiological hazards, even though there is no visible adverse effect on the populace, it is strongly recommended that companies and oil activities within the study area should be properly monitored to ensure that the populace and environment are free from radiological hazards, by ensuring that all forms of radiation exposure to both man and the environment should be kept as low as reasonably achievable.

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Keywords: Background ionizing radiation; absorbed dose; annual effective dose equivalent; excess life cancer risk; coastal communities.

1. INTRODUCTION

Man and the environment is constantly being exposed to radiation. This means that radiation is unavoidable as are continually exposed daily to varying doses of ionizing radiation from difference sources. background ionizing radiation (BIR) could emanate from both natural and anthropogenic sources. The natural sources of radiation are mainly due to cosmic rays and naturally occurring long – lived radioactive nuclides that originated from the earth's crust and are present everywhere in the environment, including the human body itself [1]. It is well known fact that naturally occurring radionuclides have contributed significantly to the level of exposures of humans to background ionizing radiation [2,3].

In addition to the natural sources, anthropogenic activities also contribute to the radiation level of the environment. For instance, the use of radionuclides and radioactive substances in nuclear reactors and power plants, industries, research institutions, medicine, quarrying activities, minerals processing, phosphate fertilizer processing, and fossil fuel combustion are usually accompanied with the release of radiation into the environment. It has been estimated that the global average dose of background ionizing radiation received by humans is approximated to 0.274 μSv/hr, of which 80% comes from nature, while the remaining 20% are from anthropogenic radiation sources [1].

The assessment of the radiation level and its impact on the environment has made a tremendous impact worldwide. This is as a result of the health issues resulting from the exposure of ionizing radiation on biological tissues. When highly energetic ionizing radiation interacts with biological tissues, it causes ionization with subsequent release of charged particle and free radicals resulting to the alteration in cell structure and damage to deoxyribonucleic acid (DNA). When the DNA is affected, it could result in gene mutation, chromosomal aberration and breakages or cell death [3]. Some of the hazardous effects of long-term exposure to radiation and the inhalation/ingestion of radionuclides are lung disease, erythema, cataract, redness of skin and leukemia [4].

A study on Terrestrial Radiation Around Oil and Gas Facilities in Ughelli Nigeria, this study was archived with the used of digilert nuclear radiation monitor and a Geographical Positioning System (GPS) [5]. The calculated average values in the fields ranged from 12.00±0.1 μR h^{-1} to 22.00±21 μR h^{-1} For the host communities it ranged from 09.00±1.0 μR h^{-1} to 11.00±0.5 μR h^{-1}. Among the fields Eriemu field has maximum peak deviation value of 88.9%. The computed average dose equivalent obtained are below the permissible limit of 0.02 mSv/week as recommended by UNSCEAR. The background ionizing radiation exposure rate from these facilities were all higher than the permissible limit 0.013 mR h^{-1} [1].

A study on the Assessment of Natural Radiation Dose Rates in and Around Ukhrul Town of Manipur India, was successfully caried out using a portable Micro-R survey meter [6]. The results from the research show that show that the average radiation levels for outdoors range from 5.50 ± 0.58 to 10.00 ± 0.84 with a mean value of 7.13 ± 0.77 μR/hr respectively. The annual effective dose to the populace due to the exposure of the natural background gamma radiation was calculated as 0.78 ± 0.08 μGy/year. The observations based on their findings revealed that the average natural background gamma radiation levels in Manipur were below the national average.

In 2020, research on Indoor and Outdoor Background Ionizing Radiation (BIR) of Sheda Science and Technology Complex in Abuja. Was successfully carried out with the use of a handheld radiation meter Radiagem 2000 series to measure the radiation level [7]. The results from the study indicates that the total Dose Rate are 0.113±0.022 μSv/h (indoor), and 0.071±0.016 μSv/h (outdoor), Sum of Annual Equivalent Dose are 0.794±0.155 mSv/y (indoor) and 0.124±0.074 mSv/y (outdoor), total Annual Effective Dose Equivalent are 0.556±0.109 mSv/y (indoor) and 0.087±0.020 mSv/y (outdoor), and the total Excess Lifetime Cancer Risk are 1.945±0.379 (indoor) and 0.304±0.104 (outdoor). The Annual Effective Dose rate lesser than the permissible limits of 1 mSv/y as recommended by ICRP. Therefore, the study area is radiological free.

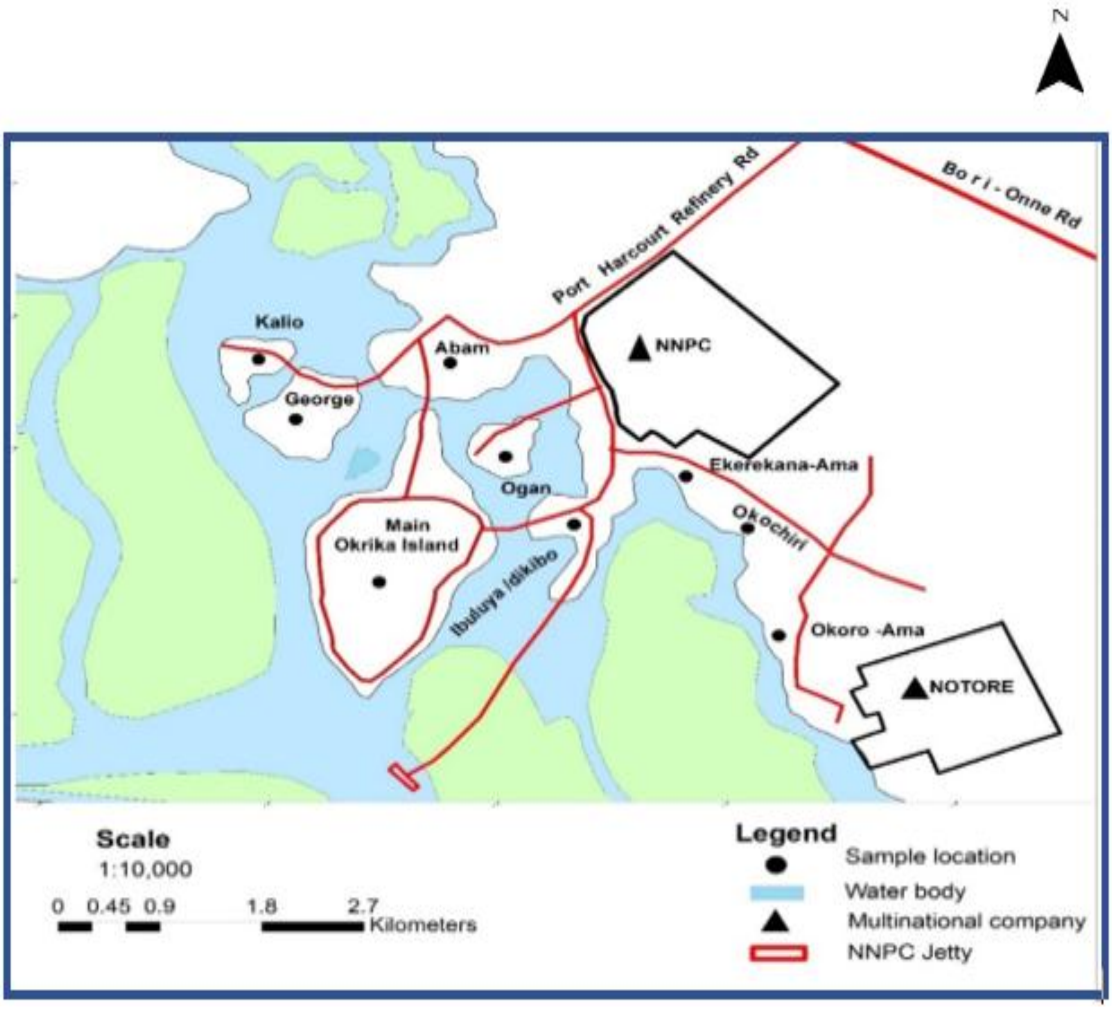
The list of review of other researchers who have carried similar work BIR is tabulated in Table 11.

Since the Background Ionization Radiation (BIR) level of the coastal communities in Okrika is completely lacking in any existing literature. It is imperative to carry out a detailed research work on the Coastal communities of Okrika. The aim of this study therefore is to measure the Background ionization radiation level in the coastal communities of Okrika and to determine its radiological risk to ascertain if the populace stands a risk to radiation hazards or not.

2. MATERIALS AND METHODS

2.1 Study Area

Okirika town is one of the island communities in Rivers State Nigeria, it is situated in the southern part of the state capital city (Port Harcourt). Being a coastal community, its major source of occupation is fishing. However, there are other forms of commercial activities like farming, boat transportation with smaller business outfits that operates within the study area. The Okrika town lies within 40.43'44" to 40.45'57" N latitude and 70.3'20" E to 70.6'42" E longitude [8]. It has an estimated population of 222,285 with land mass of 223.487 km^2 (National Population Commission [9]. Okrika Local Government Area is bounded to the north by Port Harcourt City, to the east by Ogu-Bolo and Eleme, to the south by Bonny and to the west by Degema L.G.A. respectively. The town plays a host to the Port Harcourt Refining Company (PHRC), a subsidiary of Nigerian National Petroleum Corporation (NNPC) and other minor oil and gas companies operating within and around its environs. In addition, it has a jetty and terminal for loading and off-loading crude oil products. The map of Okrika town showing the sampled coastal communities are which are; Ogan, Kalio, Ibuluya/dikibo, Okochiri, Abam, George, Okoro, Ekerekana-Ama and Main Okrika Island are shown in Fig. 1.



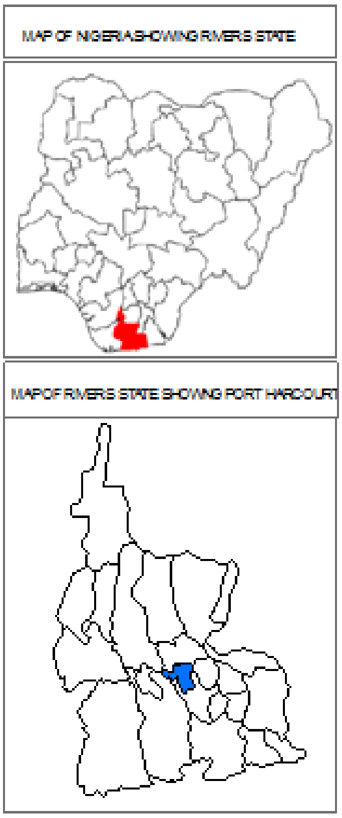


Fig. 1. Modified Map from google earth showing the sampled Locations

2.2 Methods

A well calibrated radiation meters Digilert Tm-200 Survey meter (S.E. International Inc, Summer Town, USA) containing a Geiger-Muller tube for the detection of alpha, beta, gamma and X-rays within the temperature range of - 10°C and 50°C was used to measure radiation levels and Geographical Positioning System (GPS) was used to measure the precise location of the sample location.The readings were taken within the most suitable hours of 13:00 and 16:00 hours because the meter has a maximum sensitivity to environmental radiation within these hours [10]. The tube of the radiation meter was raised to a height of 1.0m above the earth surface with its window facing first the earth surface and then vertically downwards (Ajayi and Laogun, 2006) [5,11]. The Geiger-Muller tube generates a pulse current each time radiation passes through the tube and causes ionization [12]. Each pulse is electronically detected and registered as a count visually shown on a highly accurate digital display with readings that can be displayed in terms of (counts per minutes) CPM and milliroentgen per her (mR/hr) or millisievert per hour (μSv/h). The radiation Exposure rate reading obtained in the coastal communities Is converted to absorbed dose using the conversion factor shown in Equation 1 [13].

$$1\mu R/h = 8.7\ nGy/h = 8.7 \times 10\ \mu Gy/\left(\frac{1}{8760y}\right) \quad (1)$$

2.2.1 Absorbed dose

It is defined as the measure of the amount of energy (radionuclides) deposited by ionization radiation in the human body for a given period [14]. The exposure rates were converted to absorbed dose rate using the conversion factor [15].

$$1\mu R/h = 876.212\ \mu Gy/y \quad (2)$$

2.2.2 Annual Effective Dose Equivalent (AEDE)

The computed absorbed dose rates were used to analyse the annual effective dose equivalent (AEDE) received by the populace living in coastal areas of Okrika. Dose conversion factor of 0.7

Sv/Gy as recommended by UNSCEAR for the conversion coefficient from the absorbed dose in air to the effective dose received by adults [16] and an occupancy factor of 0.25 for outdoor exposure was used [13]. The annual effective dose equivalent was estimated using Equation 3.

$$\text{AEDE (outdoor)(mSv/y)} = \text{Absorbed dose(nGy/h)} \times 8760 \times 0.7\text{Sv/Gy} \times 0.25 \quad (3)$$

2.2.3 Excess Lifetime Cancer Risk (ELCR)

The excess lifetime cancer risk (ELCR) describes the potential Carcinogenic effects, from the calculation based on the probability of cancer induced incidence in a population. This is as a result of exposure to ionizing radiation or the intakes of harmful chemical substances for a lifetime. In other words, the ELCR indicates chances of contracting cancer resulting to the exposure of radiation or toxic chemical substances for a specific period. The probabilities of contacting cancer by the populace of the coastal communities of Okrika who will spend all their lifetime in the study area can be estimated using the Excess Lifetime Cancer Risk (ELCR) which is determined using Equation 4.

$$\text{ELCR} = \text{AEDE} \times (\text{DL}) \times (\text{RF}) \quad (4)$$

Where AEDE, DL and RF is the annual effective dose equivalent, duration of life (70 years) and the risk factor (Sv/y), fatal cancer risk per Sievert. For low dose background radiations which are considered to produce stochastic effects, ICRP 60 uses 0.05 for the public [17].

3. RESULTS AND DISCUSSIONS

The results of *In-situ* measurement of the background ionization radiation and its radiological parameters are presented in Tables 1 to 9. The summary of the mean values of the exposure rate and its radiological parameters in all communities are shown in Table 10. The contour maps of the background ionizing radiation with good spatial distributions are presented in Figs. 2 to 7 The comparison of exposure rates absorbed dose, annual effective dose and excess life cancer risk with world average are presented in Figs. 7 to 11. And the comparison of average natural radioactivity levels in air with other researchers, who carried out similar radiological findings is presented in Table 11.

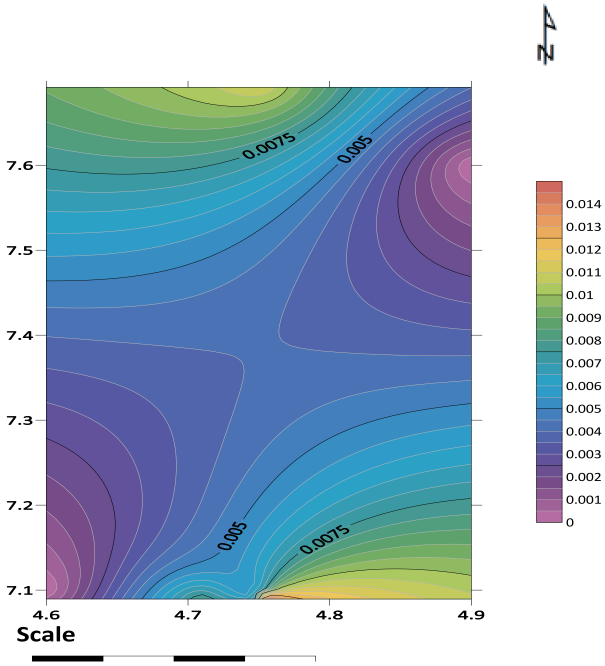


Fig. 2. Contour map of Ogan Island

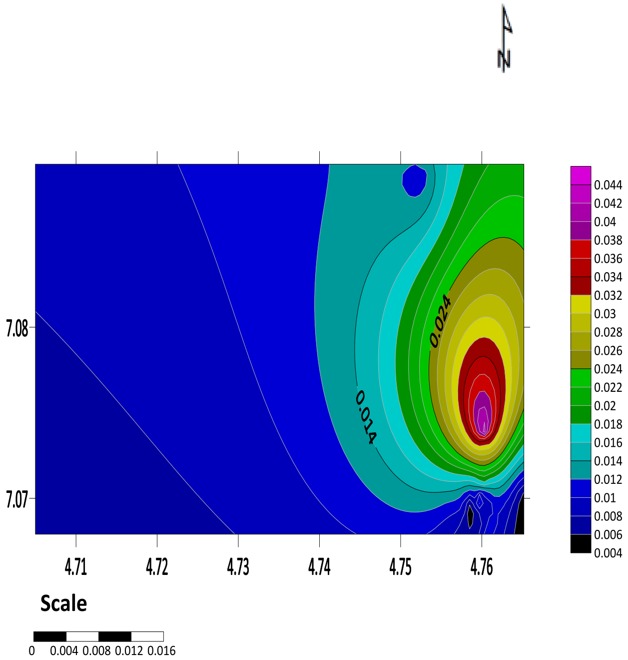


Fig. 3. Contour map of Kalio Island

Table 1. BIR level at Ogan-Ama

S/N	Sample Points	Geographical Coordinates	Average Radiation level (mR/h)	Absorbed dose (nGy/hr)	AEDR (mSv/y)	ELCR x 10^{-3}
1	Ogan Bridge pt 1	N4° 45' 5.43660" E7° 5' 28.764000"	0.008	66.7	0.10	0.36
2	Ogan Bridgept 2	N4° 45' 5.44260" E7° 5' 28.755000"	0.008	69.6	0.10	0.36
3	Joel compound	N 4° 45' 5.44260" E 7° 5' 28.83120"	0.008	69.6	0.11	0.37
4	Sand fill area-1	N 4° 45' 3.08820" E 7° 5' 28.83120"	0.016	139.2	0.21	0.75
5	Sand fill area-2	N 4° 44' 58.9740" E 7° 5' 26.98800"	0.009	81.2	0.12	0.44
6	Sand fill area-3	N 4° 44' 58.5054" E 7° 5' 27.88080"	0.010	87.0	0.13	0.47
7	Sand fill area-4	N 4° 44' 57.6882" E 7° 5' 29.10420"	0.007	63.8	0.10	0.34
8	Sestinity water-front bar	N 4° 42' 32.7018" E 7° 5' 27.03420"	0.008	69.6	0.11	0.37
9	Anglican church	N 4° 45' 4.22940" E 7° 5' 29.01480"	0.012	107.3	0.16	0.58
10	Angilcan ube pri school	N 4° 45' 8.17200" E 7° 5' 30.76080"	0.012	101.5	0.16	0.54
11	Ogan primary shool field	N 4° 45' 9.39900" E 7° 5' 31.94520"	0.015	130.5	0.20	0.70
12	State school ogan Ama	N 4° 45' 9.79920" E 7° 5' 30.54060"	0.014	124.7	0.19	0.67
13	Craft Center Ogan-Ama	N 4° 45' 10.374" E7° 5' 30.24540"	0.010	84.1	0.13	0.45
14	Town Hall Ogan-Ama	N 4° 45' 11.7000" E 7° 41' 29.5548"	0.011	95.7	0.15	0.51
15	Model Primary Health care	N 4° 45' 14.1546" E 7° 5' 31.95540"	0.015	130.5	0.20	0.70
16	Water tank Ogan	N 4° 45' 14.7954" E 7° 5' 33.34560"	0.011	98.6	0.15	0.53
17	Ogan Secondary School	N 4° 45' 16.4088" E 7° 5' 32.79480"	0.016	136.3	0.21	0.73
18	State School lumama	N 4° 45' 6.78900" E 7° 5' 26.40420"	0.012	104.4	0.16	0.56
19	Water tank lumama	N 4° 45' 5.95800" E 7° 5' 26.10180"	0.014	121.8	0.19	0.65
20	Town Hall Ogan-Ama	N 4° 45' 4.56780" E 7° 5' 24.47820"	0.014	124.7	0.19	0.67
21	Telecommunication Stand	N 4° 45' 3.43800" E 7° 5' 30.75720"	0.013	113.1	0.17	0.61
22	Late king SP ogan House	N4° 45' 2.980800"E 7° 5' 29.90340"	0.013	113.1	0.17	0.61
23	Brown Compound	N 4° 45' 4.50300" E 7° 5' 22.25700"	0.012	104.4	0.16	0.56
24	Late Robinson compound	N 4° 45' 8.44560" E 7° 5' 22.16700"	0.013	113.1	0.17	0.61
25	Derefaka Compound	N 4° 45' 8.44664" E 7° 5' 22.25000"	0.022	188.5	0.29	1.01
		Mean Value	**0.012±0.003**	**104.40 ±3.33**	**0.16±0.04**	**0.56±0.15**

Table 2. Bir level at Kalio

S/n	Sample points	Geographical coordinates	Average radiation level (mr/h)	Absorbed dose (ngy/hr)	Aedr (msv/y)	Elcr X 10^{-3}
1	Fuama kiri road	N 4° 45' 54.6834" E 7° 4' 12.2268"	0.005	40.6	0.06	0.22
2	Christ bible church	N 4° 45' 35.7768" E 7° 4' 12.1902"	0.005	40.6	0.06	0.22
3	Deeper life church	N 4° 45' 35.7156" E 7° 4' 14.1594"	0.018	153.7	0.24	0.82
4	Ibiokwein street	N 4° 45' 33.3210" E 7° 4' 10.7466"	0.012	101.5	0.16	0.54
5	Sand fill area-1	N 4° 45' 32.0760" E 7° 4' 10.6680"	0.005	40.6	0.06	0.22
6	Sand fill area-2	N 4° 45' 30.9348" E 7° 4' 9.08340"	0.004	33.6	0.05	0.18
7	Sand fill area-4	N 4° 45' 20.7108" E 7° 4' 9.37200"	0.011	92.8	0.14	0.50
8	Kalio state sec. sch.	N 4° 45' 27.9360" E 7° 4' 9.44340"	0.009	81.2	0.12	0.44
9	Milla compound	N 4° 45' 8.80920" E 7° 5' 22.1850"	0.009	81.2	0.12	0.44
10	Okona compound	N 4° 45' 8.80920" E 7° 5' 22.2786"	0.014	124.7	0.19	0.67
11	Obed compound	N 4° 45' 35.7906" E 7° 4' 9.77880"	0.008	69.6	0.11	0.37
12	Logos ministries	N 4° 45' 35.8092" E 7° 4' 10.1244"	0.018	159.5	0.24	0.86
13	Fyneman compound	N 4° 45' 38.3286" E 7° 4' 5.94120"	0.009	78.3	0.12	0.42
14	Kalio water-side 1	N 4° 45' 38.3358" E 7° 4' 5.95140"	0.009	78.3	0.12	0.42
15	Kalio water-side 2	N 4° 42' 18.0000" E 7° 4' 6.13920"	0.007	58.0	0.09	0.31
16	Kalio water-side 3	N 4° 45' 38.4300" E 7° 4' 5.14860"	0.012	101.5	0.16	0.54
17	Kalio water-side 4	N 4° 45' 36.9390" E 7° 4' 4.46460"	0.010	87.0	0.13	0.47
18	Kalio jetty	N 4° 45' 40.5498" E 7° 4' 8.65140"	0.010	87.0	0.13	0.47
19	Sika compound	N 4° 45' 40.5498" E 7° 4' 8.65140"	0.010	87.0	0.13	0.47
20	Kalio compound	N 4° 45' 39.6972" E 7° 4' 7.51080"	0.010	89.9	0.14	0.48
21	Abiye sika compound	N 4° 45' 39.9240" E 7° 4' 6.75480"	0.012	104.4	0.16	0.56
22	Community sec. sch. kalio	N 4° 45' 37.6812" E 7° 4' 11.4594"	0.008	66.7	0.10	0.36
23	State primary school	N 4° 45' 36.3132" E 7° 4' 14.6748"	0.015	131.7	0.20	0.71
24	Kalio bridge pt 1	N 4° 45' 36.6101" E 7° 4' 25.5121"	0.008	69.6	0.11	0.37
25	Kalio bridge pt 2	N 4° 45' 36.2312" E 7° 4' 25.8501"	0.010	84.1	0.13	0.45
		Mean value	**0.010±0.04**	**87.00±32.43**	**0.13±0.03**	**0.47±0.17**

Table 3. Bir level at Ibuluya/dikibo

S/N	Sample points	Geographical coordinates	Average radiation level (MR/H)	Absorbed dose (NGY/HR)	AEDR (MSV/Y)	ELCR X 10^{-3}
1	Lilly sea-side Hotel	N 4° 44' 37.8132" E 7° 5'37.8240"	0.014	118.9	0.18	0.64
2	Ayo Compound	N 4° 44' 43.2306" E 7° 5' 37.2474"	0.086	751.1	0.18	0.64
3	Water Side-1	N 4° 44' 42.8562" E 7° 5' 38.2884"	0.005	40.6	0.06	0.22
4	Water Side-2	N 4° 44' 42.8928" E 7° 5' 37.2474"	0.011	98.6	0.15	0.53
5	Block industry 1	N 4° 44' 39.1920" E 7° 5' 38.2986"	0.008	72.5	0.11	0.39
6	Block industry 2	N 4° 44' 41.0388" E 7° 5' 38.0898"	0.008	72.5	0.11	0.39
7	Waterside Sand Dump-1	N 4° 44' 41.0994" E 7° 5' 36.4740"	0.013	110.2	0.17	0.59
8	Waterside Sand Dump-2	N 4° 44' 41.3160" E 7° 5' 37.0314"	0.006	49.3	0.08	0.26
9	Waterside Sand Dump-3	N 4° 44' 38.9832" E 7° 5' 37.2222"	0.006	55.1	0.08	0.30
10	under the bridge	N 4° 44' 38.1006" E 7° 5' 36.4740"	0.013	110.2	0.17	0.59
11	Bridge area-1	N 4° 44' 38.5440" E 7° 5' 36.9270"	0.013	113.1	0.17	0.61
12	Bridge area-2	N 4° 44' 37.5246" E 7° 5' 37.0248"	0.005	46.4	0.07	0.25
13	Waterside Female Toilet	N 4° 44' 34.1808" E 7° 5' 37.6074"	0.007	58.0	0.09	0.31
14	Christ Army Church Ibuluya	N 4° 44' 44.0694" E 7° 0' 26.5314"	0.009	75.4	0.12	0.40
15	GE Tarrick Hotel	N 4° 44' 42.3888" E 7° 5' 48.8898"	0.006	55.1	0.08	0.30
16	State Primary Sch. Ibuluya	N 4° 44' 43.2168" E 7° 5' 46.7664"	0.012	107.3	0.16	0.58
17	State Pri. Sch. Playground	N 4° 44' 43.7640" E 7° 5' 45.9024"	0.018	153.7	0.24	0.82
18	Ibuluya Motor Park	N 4° 44' 43.9512" E 7° 5' 44.1852"	0.006	49.3	0.08	0.26
19	Okrika Grammar School	N 4° 44' 38.8032" E 7° 5' 49.6932"	0.028	243.6	0.37	1.31
20	St.Paul State Pri. Sch.	N 4° 44' 35.3754" E 7° 5' 46.4676"	0.036	316.1	0.48	1.70
21	St.Paul State Pri.Sch.field	N 4° 44' 36.6606" E 7° 5' 46.9356"	0.009	78.3	0.12	0.42
22	St. Paul Anglican Church	N 4° 44' 36.6354" E 7° 5' 44.0448"	0.005	46.4	0.07	0.25
23	Jetty Road -Pt.2	N 4° 44' 40.2216" E 7° 5' 47.5728"	0.012	101.5	0.16	0.54
24	Jetty Road-pt.2	N 4° 5' 47.34240" E 7° 5' 47.3424"	0.046	400.2	0.61	2.15
25	Dikibo male toilet	N 4° 44' 33.8022" E 7° 5' 45.1818"	0.061	533.6	0.82	2.86
26	Kelegbe Compound	N 4° 44' 38.4108" E 7° 5' 44.3574"	0.008	72.5	0.11	0.39
27	Adolphus Compound	N4° 44' 43.5474" E 7° 5' 51.5076"	0.013	116.0	0.18	0.62
		Mean value	**0.017±0.19**	**147.90±167.54**	**0.23±0.17**	**0.79±0.17**

Table 4. Bir level at Okochiri

S/N	Sample points	Geographical coordinates	Average radiation level (MR/H)	Absorbed dose (NGY/HR)	AEDR (MSV/Y)	ELCR X 10^{-3}
1	Tamunokuro Sokari compound	N 4° 44' 34.5912" E 7° 7' 6.12840"	0.011	92.8	0.14	0.50
2	George compound	N 4° 44' 35.9628" E 7° 6' 47.3754"	0.008	69.6	0.14	0.50
3	Felix compound	N 4° 44' 37.2660" E 7° 6' 47.4552"	0.010	84.1	0.13	0.45
4	Nonju Ama	N 4° 44' 12.3210" E 7° 6' 43.7610"	0.015	130.5	0.20	0.70
5	Amagian Ama	N 4° 44' 8.42640" E 7° 6' 51.1596"	0.027	232.0	0.36	1.24
6	Sandy Street	N 4° 44' 14.2002" E 7° 6' 48.4452"	0.010	87.0	0.13	0.47
7	Nepa office	N 4° 44' 13.9230" E 7° 6' 53.6796"	0.007	60.9	0.09	0.33
8	Primary Health Center	N 4° 44' 14.9388" E 7° 6' 53.5314"	0.009	75.4	0.12	0.40
9	Primary Health Center Junction	N 4° 44' 16.0224" E 7° 6' 53.6292"	0.016	142.1	0.22	0.76
10	Logoni Ama playground	N 4° 44' 26.5848" E 7° 7' 4.66320"	0.009	75.4	0.12	0.40
11	Lagoni/NNTORE boundary-1	N 4° 44' 15.8280" E 7° 7' 27.6672"	0.008	66.7	0.10	0.36
12	Lagoni/NNTORE boundary-2	N 4° 44' 11.6082" E 7° 7' 12.9432"	0.007	63.8	0.10	0.34
13	St John Catholic Galilee	N 4° 44' 33.7668" E 7° 7' 4.55460"	0.010	89.9	0.14	0.48
14	Ama Ibibo Dappa House pt 1	N 4° 44' 54.0882" E 7° 7' 13.8072"	0.007	60.9	0.09	0.33
15	Ama Ibibo Dappa House pt 2	N 4° 44' 54.0842" E 7° 7' 13.8053"	0.012	101.5	0.16	0.54
16	Alaye Eremie Ama	N 4° 44' 57.7710" E 7° 7' 13.8072"	0.014	118.9	0.18	0.64
17	Sunday Adokiye Alatoru Ama	N 4° 44' 48.5586" E 7° 7' 13.8642"	0.014	118.9	0.18	0.64
18	Promise Ikpuku Ama-1	N 4° 44' 48.2598" E 7° 7' 12.8064"	0.006	49.3	0.08	0.26
19	Promise Ikpuku Ama-2	N 4° 44' 43.9326" E 7° 7' 6.39060"	0.014	118.9	0.18	0.64
20	Sir Wokoma Ama	N 4° 44' 48.2598" E 7° 7' 12.8064"	0.005	46.4	0.07	0.25
21	Sokike Avenuw	N 4° 44' 40.1100" E 7° 7' 3.87840"	0.007	60.9	0.09	0.33
22	King Nemi Oputubeya Ama	N 4° 44' 42.3492" E 7° 6' 58.0752"	0.018	159.5	0.24	0.86
23	Chief Kalada kiri Ama	N 4° 44' 42.9612" E 7° 6' 57.3660"	0.011	95.7	0.15	0.51
24	De Specialist Diagnostic Center	N 4° 44' 43.1736" E 7° 6' 55.5006"	0.010	89.9	0.14	0.48
25	Mesaiah Road	N 4° 44' 39.0804" E 7° 6' 52.7574"	0.012	101.5	0.16	0.54
26	Okochiri Field	N 4° 44' 57.5124" E 7° 6' 18.7374"	0.007	60.9	0.09	0.33
27	Community Sec Sch	N 4° 44' 54.9240" E 7° 6' 20.9880"	0.007	60.9	0.09	0.33
28	Community Sec Sch waterside	N 4° 44' 55.8342" E 7° 6' 15.4512"	0.009	81.2	0.12	0.44
29	IPCO pipeline water side-1	N 4° 44' 45.1674" E 7° 6' 21.9996"	0.011	95.7	0.15	0.51
30	IPCO pipeline water side-2	N 4° 44' 45.0276" E 7° 6' 22.1112"	0.011	92.8	0.14	0.50
31	Kings Sec Sch Okochiri	N 4° 44' 59.1108" E 7° 6' 22.4706"	0.011	92.8	0.14	0.50
32	Former SDP House	N 4° 44' 57.7392" E 7° 6' 26.0640"	0.005	46.4	0.07	0.25
33	All Saints Anglican Church	N 4° 44' 50.8776" E 7° 6' 36.7272"	0.009	75.4	0.12	0.40

S/N	Sample points	Geographical coordinates	Average radiation level (MR/H)	Absorbed dose (NGY/HR)	AEDR (MSV/Y)	ELCR X 10^{-3}
34	Okochiri Round About	N 4° 44' 42.2808" E 7° 6' 45.1512"	0.008	72.5	0.11	0.39
35	NNPC/Okochiri bandary Rd-1	N 4° 45' 24.2670" E 7° 7' 3.52500"	0.010	89.9	0.14	0.48
36	NNPC/Okochiri bandary Rd-2	N 4° 45' 8.93460" E 7° 6' 48.5022"	0.007	60.9	0.09	0.33
37	NNPC/Okochiri bandary Rd-3	N 4° 45' 0.75600" E 7° 6' 38.4330"	0.009	75.4	0.12	0.40
38	NNPC/Okochiri bandary Rd-4	N 4° 45' 4.51740" E 7° 6' 30.6468"	0.007	60.9	0.09	0.33
39	Okochiri Town Hall	N 4° 44' 48.0330" E 7° 6' 39.3876"	0.011	92.8	0.14	0.50
40	Okochiri Beach	N 4° 44' 35.7360" E 7° 6' 37.0044"	0.013	116.0	0.18	0.62
		Mean value	**0.010±0.004**	**89.00±34.78**	**0.13±0.05**	**0.47±0.19**

Table 5. Bir level at Abam

S/N	Sample points	Geographical coordinates	Average radiation level (MR/H)	Absorbed dose (NGY/HR)	AEDR (MSV/Y)	ELCR X 10^{-3}
1	Seminary Street	N 4° 45' 36.4680" E 7° 5' 11.1654"	0.018	153.7	0.24	0.82
2	believe Abam Compound	N 4° 45' 35.5206" E 7° 5' 9.43020"	0.015	130.5	0.24	0.82
3	National Ministry Revival	N 4° 45' 34.9914" E 7° 5' 7.41420"	0.013	113.1	0.17	0.61
4	OPM free school	N 4° 45' 30.3942" E 7° 5' 5.23620"	0.008	66.7	0.10	0.36
5	OPM church	N 4° 45' 30.3726" E 7° 5' 5.61840"	0.013	110.2	0.17	0.59
6	DEAWOO Company	N 4° 45' 25.3512" E 7° 5' 4.94880"	0.018	153.7	0.24	0.82
7	Abam Bridge-1	N 4° 45' 20.2284" E 7° 5' 8.33640"	0.010	87.0	0.13	0.47
8	Abam Bridge-2	N 4° 45' 20.2350" E 7° 5' 8.38320"	0.006	53.1	0.08	0.28
9	Abam Sand Field--1	N 4° 45' 20.9046" E 7° 4' 51.5496"	0.007	63.8	0.10	0.34
10	Abam Sand Field--2	N 4° 45' 22.3056" E 7° 5' 21.6564"	0.007	60.9	0.09	0.33
11	Abam Sand Field-l-3	N 4° 45' 30.6396" E 7° 5' 32.3190"	0.006	55.1	0.08	0.30
12	Abam Sand Field--4	N 4° 42' 33.1590" E 7° 5' 31.5918"	0.009	78.3	0.12	0.42
13	Stae Primary Sch Abam-Ama	N 4° 45' 40.4598" E 7° 4' 54.4614"	0.019	168.2	0.26	0.90
14	State Pri. Sch. Field Abam-Ama	N 4° 45' 40.4712" E 7° 4' 54.4686"	0.003	23.2	0.04	0.12
15	Deawo watersides-1	N 4° 45' 22.1646" E 7° 5' 2.23080"	0.016	139.2	0.21	0.75
16	Deawo watersides-2	N 4° 45' 23.6010" E 7° 5' 0.67920"	0.016	136.3	0.21	0.73
17	Deawo watersides-3	N 4° 45' 26.3124" E 7° 4' 50.8620"	0.008	66.7	0.10	0.36
18	Abam bridge-1	N 4° 45' 30.3438" E 7° 4' 50.8620"	0.008	66.7	0.10	0.36
19	Abam bridge-2	N 4° 45' 33.5046" E 7° 4' 56.7840"	0.007	63.8	0.10	0.34
20	Amatel Hotel	N 4° 45' 35.1000" E 7° 5' 3.80340"	0.012	107.3	0.16	0.58
21	PDP Secretariate Okrika Chapter	N 4° 45' 40.4316" E 7° 5' 3.31080"	0.008	72.5	0.11	0.39
22	St. Lukes Anglican Church	N 4° 45' 41.5980" E 7° 5' 0.81240"	0.005	46.4	0.07	0.25

S/N	Sample points	Geographical coordinates	Average radiation level (MR/H)	Absorbed dose (NGY/HR)	AEDR (MSV/Y)	ELCR X 10^{-3}
23	Event Center	N 4° 42' 30.3042" E7° 5' 3.03000"	0.017	145.0	0.22	0.78
24	Community Sec sch Abam	N 4° 45' 37.3710" E 7° 4' 55.2246"	0.018	153.7	0.24	0.82
25	Community Sec sch Field Abam	N 4° 45' 37.1592" E 7° 4' 53.6910"	0.002	20.3	0.03	0.11
26	Abam Community watersides-1	N 4° 45' 46.7058" E 7° 4' 49.9794"	0.005	46.4	0.07	0.25
27	Abam Community watersides-2	N 4° 45' 42.6888" E 7° 4' 49.2636"	0.012	107.3	0.16	0.58
28	Abam Community watersides-3	N 4° 45' 51.1344" E 7° 4' 59.5056"	0.004	37.7	0.06	0.20
29	Abam Community watersides-4	N 4° 45' 53.2254" E 7° 5' 0.45240"	0.011	98.6	0.15	0.53
30	Abam Community watersides-5	N 4° 45' 51.0294" E 7° 5' 7.8210"	0.010	87.0	0.13	0.47
31	Abam Town Hall	N 4° 45' 51.0474" E 7° 5' 7.8498"	0.010	87.0	0.13	0.47
32	Fuby Paradise Resort	N 4° 45' 55.7886" E 7° 5' 6.1542"	0.010	89.9	0.14	0.48
		Mean value	**0.010±0.005**	**87.00±40.91**	**0.13±0.06**	**0.47±0.22**

Table 6. Bir level at George-Ama

S/N	Sample points	Geographical coordinates	Average radiation level (MR/H)	Absorbed dose (NGY/HR)	AEDR (MSV/Y)	ELCR X 10^{-3}
1	George Park Area-1	N 4° 45' 15.1776" E 7° 4' 37.0236"	0.017	147.9	0.23	0.79
2	George Park Area-2	N 4° 45' 14.7882" E 7° 4' 37.3476"	0.009	75.4	0.23	0.79
3	George Park Area-3	N 4° 45' 14.5800" E 7° 4' 37.4010"	0.014	121.8	0.19	0.65
4	Water Front-1	N 4° 45' 10.5552" E 7° 4' 40.6050"	0.011	92.8	0.14	0.50
5	Water Front-2	N 4° 45' 10.7022" E 7° 4' 42.8874"	0.007	60.9	0.09	0.33
6	Jetty	N 4° 45' 11.8398" E 7° 4' 40.9722"	0.014	124.7	0.19	0.67
7	Aka Compound	N 4° 45' 9.98940" E 7° 4' 39.9036"	0.009	81.2	0.12	0.44
8	Chief Rufus Ada George Drive	N 4° 45' 10.2594" E 7° 4' 37.5810"	0.012	101.5	0.16	0.54
9	Sand Filled Area-1	N 4° 45' 8.71920" E 7° 4' 37.6680"	0.013	113.1	0.17	0.61
10	Sand Filled Area-2	N 4° 45' 8.65440" E 7° 4' 36.6312"	0.008	66.7	0.10	0.36
11	Belema peace Compound	N 4° 45' 9.69420" E 7° 4' 35.9142"	0.011	92.8	0.14	0.50
12	C&C Construction Company-1	N 4° 45' 13.0500" E 7° 4' 1.97760"	0.007	60.9	0.09	0.33
13	C&C Construction Company-2	N 4° 45' 16.0668" E 7° 4' 20.7222"	0.011	98.6	0.15	0.53
14	Water Front-1	N 4° 45' 10.0146" E 7° 4' 17.0544"	0.006	55.1	0.08	0.30
15	Water Front-2	N 4° 45' 8.27220" E 7° 4' 18.7032"	0.010	89.9	0.14	0.48
16	Engr Gabriel Avenue	N 4° 45' 12.4662" E 7° 4' 27.9762"	0.008	69.6	0.11	0.37
17	Engr Aron close	N 4° 45' 7.72500" E 7° 4' 38.0202"	0.008	69.9	0.11	0.37
18	Uriel Compound	N 4° 45' 16.2900" E 7° 4' 32.5632"	0.010	89.9	0.14	0.48
19	Jackson Compound	N 4° 45' 16.2354" E 7° 4' 34.6578"	0.005	40.6	0.06	0.22

S/N	Sample points	Geographical coordinates	Average radiation level (MR/H)	Absorbed dose (NGY/HR)	AEDR (MSV/Y)	ELCR X 10^{-3}
20	Ang. Church George pt.1	N 4° 45' 16.8042" E 7° 4' 36.8934"	0.007	60.9	0.09	0.33
21	Ang. Church George pt-2	N 4° 45' 27.4536" E 7° 4' 30.3420"	0.012	104.4	0.16	0.56
22	Ang. Church primary School	N 4° 45' 16.6536" E 7° 4' 36.4080"	0.019	168.2	0.26	0.90
23	Engr Julius Compound	N 4° 45' 27.5826" E 7° 4' 30.3420"	0.012	104.4	0.16	0.56
24	Engr Enoch Compound	N 4° 45' 0.51120" E 7° 4' 39.2664"	0.008	66.7	0.10	0.36
25	NDDC Water Tank	N 4° 45' 22.1106" E 7° 4' 39.2664"	0.005	43.5	0.07	0.23
		Mean value	**0.010±0.04**	**87.00±31.17**	**0.13±0.05**	**0.47±0.18**

Table 7. Bir level at Okoro-Ama

S/N	Sample points	Geographical coordinates	Average radiation level (MR/H)	Absorbed dose (NGY/HR)	AEDR (MSV/Y)	ELCR X 10^{-3}
1	Ibiene Okoro Compound	N4° 43' 44.4570" E7° 6' 50.4756"	0.018	159.5	0.24	0.86
2	Apostolic Church	N4° 43' 44.2668" E7° 6' 51.6306"	0.009	81.2	0.24	0.86
3	Okoro Waterside-1	N4° 43' 40.3602" E7° 6' 50.7960"	0.009	75.4	0.12	0.40
4	Luci Compound	N4° 43' 40.3752" E7° 6' 50.9400"	0.005	46.4	0.07	0.25
5	Resting Hall	N4° 43' 43.5072" E7° 6' 49.3992"	0.012	104.4	0.16	0.56
6	Okoro jetty 2 pt 1	N4° 43' 42.9888" E7° 6' 48.4014"	0.012	101.5	0.16	0.54
7	Okoro jetty 2 pt 2	N4° 43' 43.1724" E7° 6' 48.2148"	0.019	168.2	0.26	0.90
8	Okoro jetty 2 pt 3	N4° 43' 43.5108" E7° 6' 47.9196"	0.021	182.7	0.28	0.98
9	One man country compound	N4° 43' 50.0268" E7° 6' 48.7074"	0.015	127.6	0.20	0.68
10	Israel Imama Compound	N4° 43' 51.6756" E7° 6' 50.0034"	0.019	168.2	0.26	0.90
11	Tamuno Compound	N4° 43' 44.8494" E7° 6' 48.0810"	0.012	101.5	0.16	0.54
12	Ibitanumo Compound	N4° 43' 44.5656" E7° 6' 48.4482"	0.006	55.1	0.08	0.30
13	Gods power House	N4° 43' 43.9746" E7° 6' 48.9024"	0.018	153.7	0.24	0.82
14	Lekerigbo House	N4° 43' 45.7386" E7° 6' 49.6296"	0.008	72.5	0.11	0.39
15	Gift Okoro Compound	N4° 43' 45.4506" E7° 6' 51.7458"	0.006	55.1	0.08	0.30
16	Love Okoro compound	N4° 43' 45.4434" E7° 6' 51.7062"	0.006	55.1	0.08	0.30
17	Orubie Primary School	N4° 43' 42.5598" E7° 6' 54.8964"	0.020	174.0	0.27	0.93
18	Orubie Primary Sch field	N4° 43' 42.9204" E7° 6' 54.9360"	0.014	121.8	0.19	0.65
19	NOTERE bandary pt-1	N4° 43' 41.6136" E7° 6' 53.7366"	0.011	95.7	0.15	0.51
20	NOTERE bandary pt-2	N4° 43' 22.1622" E7° 6' 53.7366"	0.011	98.6	0.15	0.53
21	NOTERE bandary pt-3	N4° 43' 46.2036" E7° 6' 56.6382"	0.013	110.2	0.17	0.59
22	NOTERE bandary pt-4	N4° 43' 53.6802" E7° 6' 57.5094"	0.002	20.3	0.03	0.11
23	Jama Compound	N4° 43' 48.0216" E7° 6' 41.2092"	0.008	72.5	0.11	0.39

S/N	Sample points	Geographical coordinates	Average radiation level (MR/H)	Absorbed dose (NGY/HR)	AEDR (MSV/Y)	ELCR X 10^{-3}
24	Tamunokombia Compound	N4° 43' 51.7362" E7° 6' 49.9284"	0.022	194.3	0.30	1.04
25	Oku Waterside-1	N4° 43' 48.7194" E7° 6' 46.9182"	0.010	84.1	0.13	0.45
26	Oku Waterside-2	N4° 43' 50.5698" E7° 6' 46.8396"	0.009	78.3	0.12	0.42
		Mean value	**0.012±0.005**	**104.40±47.25**	**0.16±0.074**	**0.56±0.26**

Table 8. Bir level at Ekerekana-Ama

S/N	Sample points	Geographical coordinates	Average radiation level (MR/H)	Absorbed dose (NGY/HR)	AEDR (MSV/Y)	ELCR X 10^{-3}
1	Ekerekana Market	N 4° 45' 1.72740" E 7° 6' 11.9658"	0.046	403.1	0.62	2.16
2	Akinabie Sokari Compound	N 4° 45' 4.78800" E 7° 6' 1.71000"	0.040	350.9	0.62	2.16
3	Akuruma Compound	N 4° 45' 3.96000" E 7° 6' 4.55340"	0.021	182.7	0.28	0.98
4	Ekerekana Male Toilet	N 4° 44' 58.8294" E 7° 6' 8.94540"	0.019	168.2	0.26	0.90
5	Ekerekana Waterside 1	N 4° 44' 57.1410" E 7° 6' 6.75300"	0.006	55.1	0.08	0.30
6	Ekerekana Waterside 2	N 4° 44' 58.0482" E 7° 6' 12.9990"	0.010	87.0	0.13	0.47
7	Ekerekana Waterside 3	N 4° 44' 54.4200" E 7° 6' 4.32660"	0.003	26.7	0.04	0.14
8	Ekerekana Town Hall	N 4° 45' 2.13480" E 7° 6' 3.29700"	0.019	168.2	0.26	0.90
9	Welding Section	N 4° 45' 2.42640" E 7° 6' 15.1950"	0.021	185.6	0.28	1.00
10	Refinary Waste Channel	N 4° 45' 3.69360" E 7° 6' 6.47940"	0.013	116.0	0.18	0.62
11	Ekerekana Small Bridge	N 4° 45' 5.00340" E 7° 6' 6.05160"	0.018	156.6	0.24	0.84
12	Ekerekana Main Bridge	N 4° 45' 2.61360" E 7° 6' 7.39380"	0.014	118.9	0.18	0.64
13	Ekerekana Bakery Road	N 4° 45' 4.30560" E 7° 6' 2.56260"	0.010	89.9	0.14	0.48
14	Ekerekana Play Ground	N 4° 45' 0.99660" E 7° 6' 2.63460"	0.012	107.3	0.16	0.58
15	Ekerekana - PPMC Staff Quarters Boundary	N 4° 45' 5.84940" E 7° 6' 5.21280"	0.008	72.5	0.11	0.39
16	Back of Green Hospital	N 4° 44' 59.6112" E 7° 6' 0.67320"	0.007	58.3	0.09	0.31
17	Jubilee Superstores	N 4° 45' 4.97520" E 7° 5' 59.6610"	0.014	124.7	0.19	0.67
18	Old Navy Quarters/Road	N 4° 45' 4.98180" E 7° 6' 4.42800"	0.009	75.7	0.12	0.41
19	Ekerekana Bakery	N 4° 45' 5.54400" E 7° 6' 8.37300"	0.008	72.5	0.11	0.39
20	Somifemeka Compound	N 4° 45' 6.24960" E 7° 6' 10.1448"	0.012	107.3	0.16	0.58
21	Kalada Kiri Compound	N 4° 45' 2.93040" E 7° 6' 5.77020"	0.019	162.4	0.25	0.87
22	Chief Promise Ipuku Cpompound	N 4° 45' 1.86120" E 7° 6' 0.36360"	0.021	179.8	0.28	0.96
23	Abel Compound	N 4° 45' 8.01720" E 7° 6' 0.31980"	0.020	171.1	0.26	0.92

S/N	Sample points	Geographical coordinates	Average radiation level (MR/H)	Absorbed dose (NGY/HR)	AEDR (MSV/Y)	ELCR X 10^{-3}
24	Big Alabo Compound	N 4° 45' 4.01040" E 7° 6' 4.92420"	0.020	174.0	0.27	0.93
25	UBE Board Okrika	N 4° 45' 4.68660" E 7° 6' 11.7468"	0.016	139.2	0.21	0.75
26	Provide Compound	N 4° 45' 8.61120" E 7° 6' 1.29240"	0.012	107.3	0.16	0.58
		Mean value	**0.016±0.10**	**139.20±83.29**	**0.21±0.13**	**0.75±0.10**

Table 9. Bir level at Main Okrika Island

S/N	Sample points	Geographical coordinates	Average radiation level (MR/H)	Absorbed dose (NGY/HR)	AEDR (MSV/Y)	ELCR X 10^{-3}
1	Owoi Polo	N4° 44' 16.4544" E7° 5' 7.28520"	0.016	139.2	0.21	0.75
2	Ogoloma School field	N4° 44' 38.4540" E7° 5' 38.7486"	0.012	107.3	0.21	0.75
3	Saint Peter's Secondary	N4° 44' 24.4242" E7° 4' 56.2074"	0.006	55.1	0.08	0.30
4	St. Paul's First African Church	N4° 44' 31.9662" E7° 4' 58.4934"	0.020	171.1	0.26	0.92
5	Comprehensive School Ibaka	N4° 44' 32.5968" E7° 4' 39.2046"	0.004	37.7	0.06	0.20
6	Ibaka Sand Field	N4° 44' 31.8228" E7° 4' 37.4514"	0.011	95.7	0.15	0.51
7	ATC Pavallion	N4° 44' 33.6906" E7° 0' 25.4946"	0.014	124.7	0.19	0.67
8	Ibaka Toilet	N4° 44' 42.2988" E7° 4' 43.5648"	0.019	168.2	0.26	0.90
9	Ibaka Sand field	N4° 44' 40.7184" E7° 4' 45.2454"	0.005	43.5	0.07	0.23
10	St. Augustine Ang. Church Ebaba	N4° 4' 28.49160" E7° 4' 49.8462"	0.011	95.7	0.15	0.51
11	Maxwell Compound	N4° 44' 43.7892" E7° 4' 50.2680"	0.019	162.4	0.25	0.87
12	Ogbobo Sec School	N4° 45' 26.7114" E7° 4' 56.4492"	0.006	55.1	0.08	0.30
13	Ogbobo Market	N4° 45' 26.7114" E7° 4' 56.3340"	0.007	60.9	0.09	0.33
14	Sea Side Estate	N4° 44' 45.7512" E7° 4' 56.4492"	0.021	182.7	0.28	0.98
15	King Koli Drive	N4° 44' 48.7752" E7° 4' 55.8480"	0.015	127.6	0.20	0.68
16	Tomobi Sand field	N4° 44' 26.3682" E7° 4' 52.6182"	0.016	142.1	0.22	0.76
17	Christ the King Ang. Church	N4° 45' 0.42780" E7° 4' 48.4608"	0.021	185.6	0.28	1.00
18	Ademebin Sand field	N4° 42' 29.2278" E7° 4' 59.5842"	0.014	124.7	0.19	0.67
19	Chief Engr Roland Compound	N4° 44' 41.1894" E7° 3' 32.1870"	0.018	159.5	0.24	0.86
20	Owoleme Bin Sand Field	N4° 44' 40.9122" E7° 5' 21.9084"	0.017	145.0	0.22	0.78
21	Awoleme Bin Toilet	N4° 44' 40.0266" E7° 5' 21.1740"	0.014	121.8	0.19	0.65
22	Romijo Town Hall	N4° 42' 15.9366" E7° 4' 52.3590"	0.015	130.5	0.20	0.70
23	Ngene Bin	N4° 44' 31.0374" E7° 5' 25.1226"	0.014	124.7	0.19	0.67
24	Anyungu Bin Health Centre	N4° 44' 20.7960" E7° 5' 14.9784"	0.007	58.0	0.09	0.31
25	Anyungu Bin Sand field	N4° 44' 19.6548" E7° 5' 15.6840"	0.013	110.2	0.17	0.59

S/N	Sample points	Geographical coordinates	Average radiation level (MR/H)	Absorbed dose (NGY/HR)	AEDR (MSV/Y)	ELCR X 10^{-3}
26	Gream-Ama Sand field	N4° 44' 19.6764" E7° 5' 15.8994"	0.015	130.5	0.20	0.70
27	Gream-Ama St. Luke's Christ Army Church	N4° 44' 19.6548" E7° 5' 15.6840"	0.020	176.9	0.27	0.95
28	Ogoloma sand Dump	N4° 44' 19.9968" E7.087945000"	0.005	43.5	0.07	0.23
29	St. Stephen's Anglican Church	N4° 44' 20.3820" E7° 5' 15.2766"	0.015	127.6	0.20	0.68
30	Ogoloma Sand Field Market	N4° 43' 57.2262" E7° 3' 15.9552"	0.008	66.7	0.10	0.36
31	Chief Awa white Compound	N4° 43' 57.9900" E7° 5' 3.08400"	0.016	139.2	0.21	0.75
32	Ogoloma Bridge	N4° 43' 55.0986" E7° 4' 49.2636"	0.013	116.0	0.18	0.62
33	Ogoloma Palace	N4° 43' 55.5240" E7° 4' 50.1564"	0.020	174.0	0.27	0.93
34	Ogolo Health Centre	N4° 44' 8.53800" E7° 4' 43.6620"	0.010	89.9	0.14	0.48
35	Galaxy Studio	N4° 44' 8.09880" E7° 4' 42.5670"	0.009	75.4	0.12	0.40
36	Ogoloma Bakery	N4° 44' 8.12760" E7° 4' 42.5490"	0.018	156.6	0.24	0.84
37	Okungba Girls Sec. Sch.	N4° 44' 6.67260" E7° 4' 40.8468"	0.031	272.6	0.42	1.46
38	Ogungba field	N4° 44' 17.9442" E7° 4' 41.3754"	0.016	142.1	0.22	0.76
39	Okrika Borikin Filling Station	N4° 42' 1.92600" E7° 4' 38.8092"	0.020	171.1	0.26	0.92
40	Okrika Borikin Bush	N4° 44' 25.2414" E7° 4' 39.7770"	0.015	130.5	0.20	0.70
41	Plaza atc	N4° 44' 31.3872" E7° 4' 38.5968"	0.016	139.2	0.21	0.75
42	Olumba Obu Church	N4° 4' 39.12960" E7° 4' 39.1296"	0.007	63.8	0.10	0.34
43	Cherubim & Seraphin Church	N4° 44' 30.0372" E7° 4' 39.1728"	0.021	185.6	0.28	1.00
44	Assemblies of God Church	N4° 44' 31.1136" E7° 4' 42.5388"	0.014	118.9	0.18	0.64
45	Our Saviour Christ Army Church	N4° 4' 27.19500" E7° 4' 43.9140"	0.016	142.1	0.22	0.76
46	St. Peter's church	N4° 44' 34.2672" E7° 5' 2.95020"	0.005	46.4	0.07	0.25
47	Fiberesima	N4° 44' 34.2240" E7° 5' 3.27420"	0.004	34.8	0.05	0.19
48	Market Square pt-1	N4° 44' 32.4636" E7° 5' 16.1160"	0.012	101.5	0.16	0.54
49	Market Square pt-2	N4° 43' 25.7160" E7° 5' 15.0354"	0.008	69.6	0.11	0.37
50	Ngemeberi	N4° 44' 32.4636" E7° 5' 16.1160"	0.013	116.0	0.18	0.62
		Mean value	**0.013±0.004**	**113.10±34.78**	**0.17±0.05**	**0.61±0.19**

Table 10. Mean exposure rate measured and their radiological parameters in Okrika

S/N	Communities sampled	Exposure rate(MR/H)	Absorbed dose(NGY/HR)	AEDR (MSV/Y)	ELCR X 10^{-3}
1	OGAN	0.012	104.40	0.16	0.56
2	KALIO	0.010	87.00	0.13	0.47
3	IBULUYA/DIKIBO	0.017	147.90	0.23	0.79
4	OKOCHIRI	0.010	87.00	0.13	0.47
5	ABAM	0.010	87.00	0.13	0.47
6	GEORGE-AMA	0.010	87.00	0.13	0.47
7	OKORO-AMA	0.012	104.40	0.16	0.56
8	EKEREKANA-AMA	0.016	139.20	0.21	0.75
9	MAIN OKRIKA ISLAND	0.013	113.10	0.17	0.61
	MEAN	0.0122±0.03	108.3±23.34	0.1611±0.04	0.57±0.12
	WORLD AVERAGE	0.0133	89.0	1.0	0.29

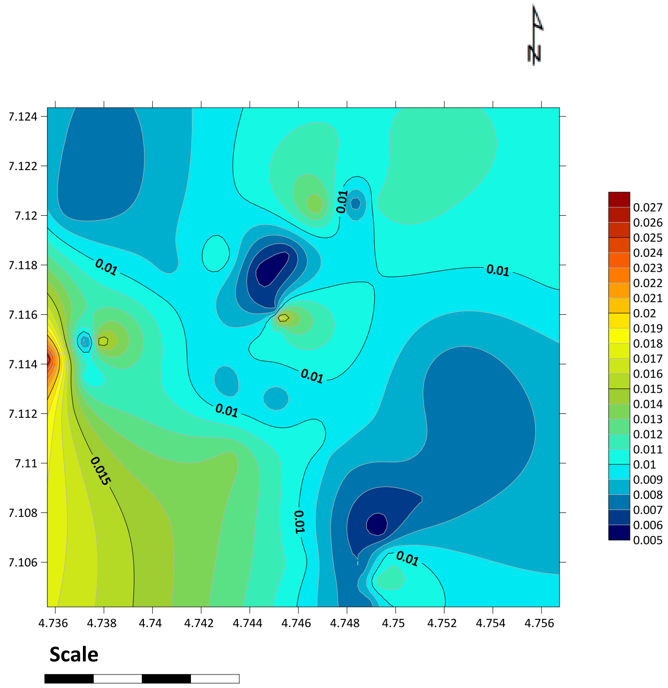


Fig. 4. Contour map of Okochiri

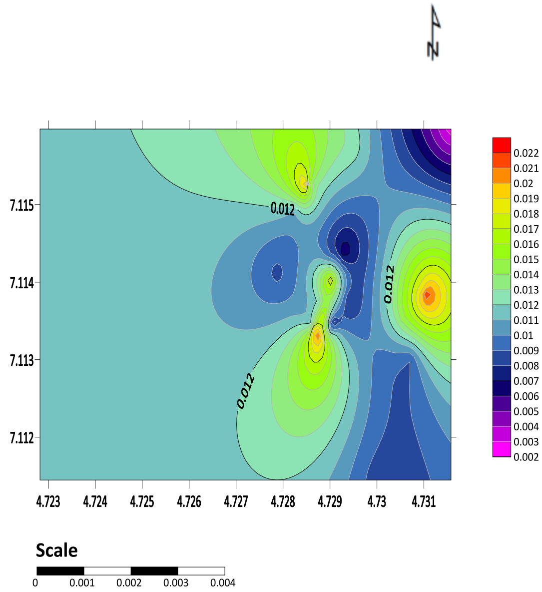


Fig. 5. Contour map of Okoro-ama community

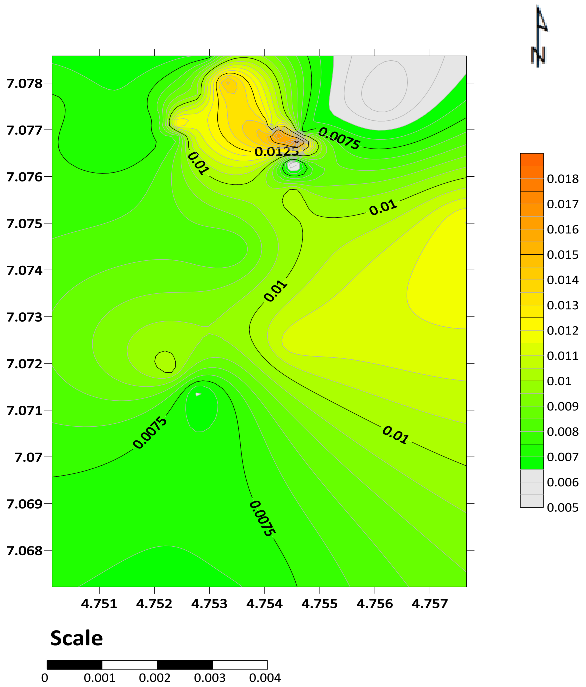


Fig. 6. Contour map of George-ama community

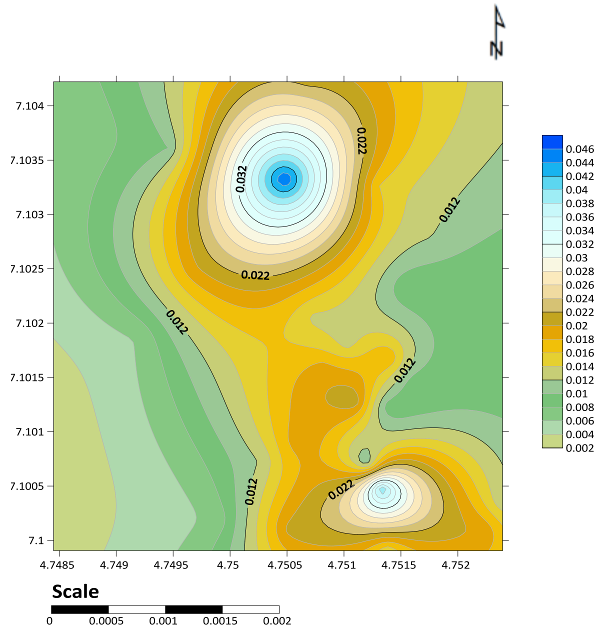


Fig. 7. Contour map of Ekerekana-ama community

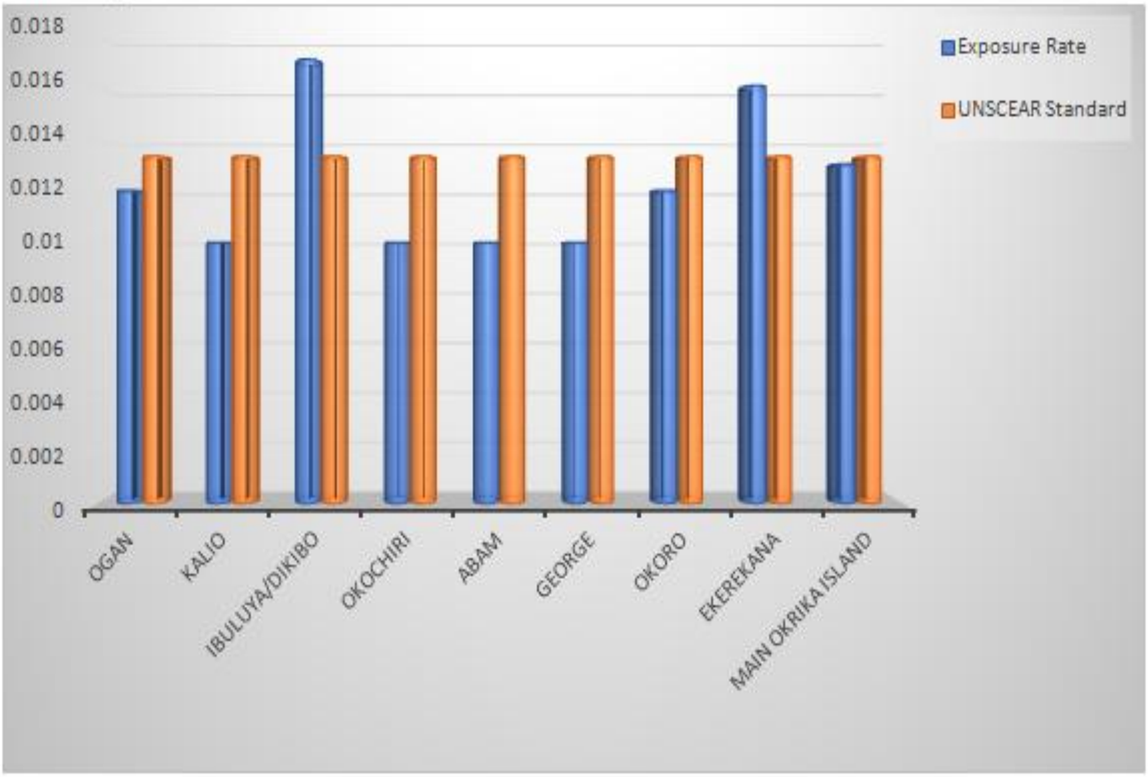


Fig. 8. Comparison of exposure rate with UNSEAR, 2000

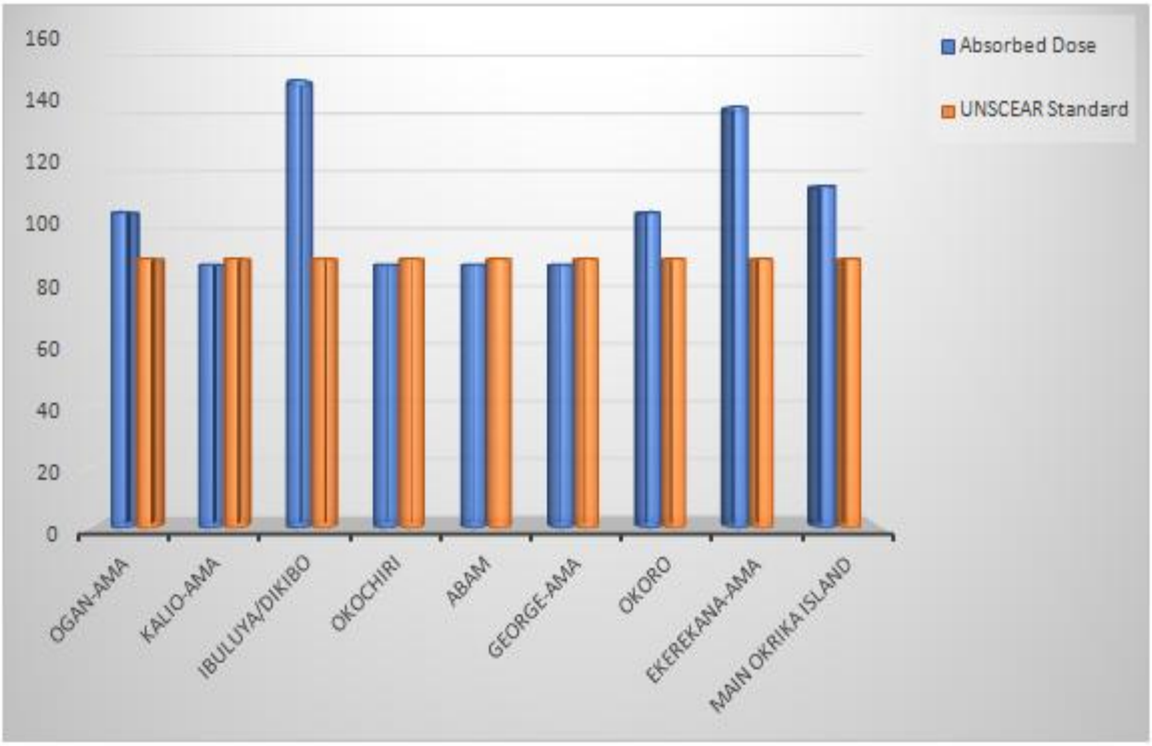


Fig. 9. Comparison of absorbed dose rate with UNSCEAR, 2008

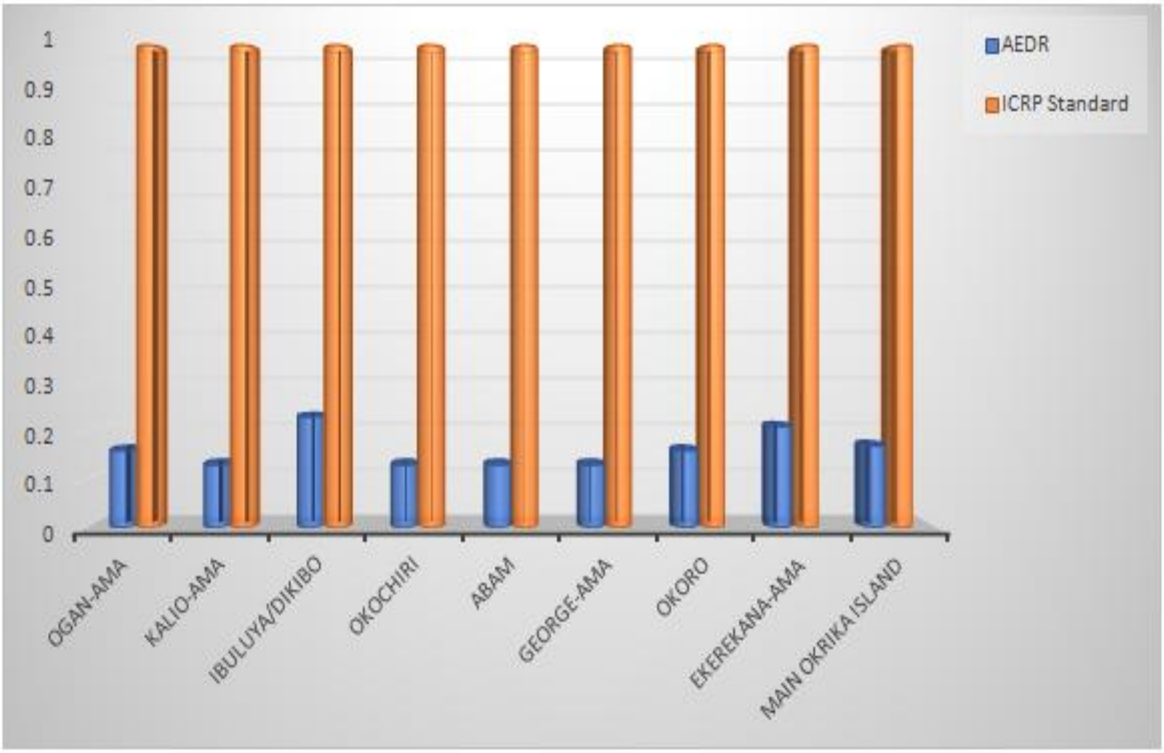


Fig. 10. Comparison of annual effective dose equivalent with ICRP, 2003

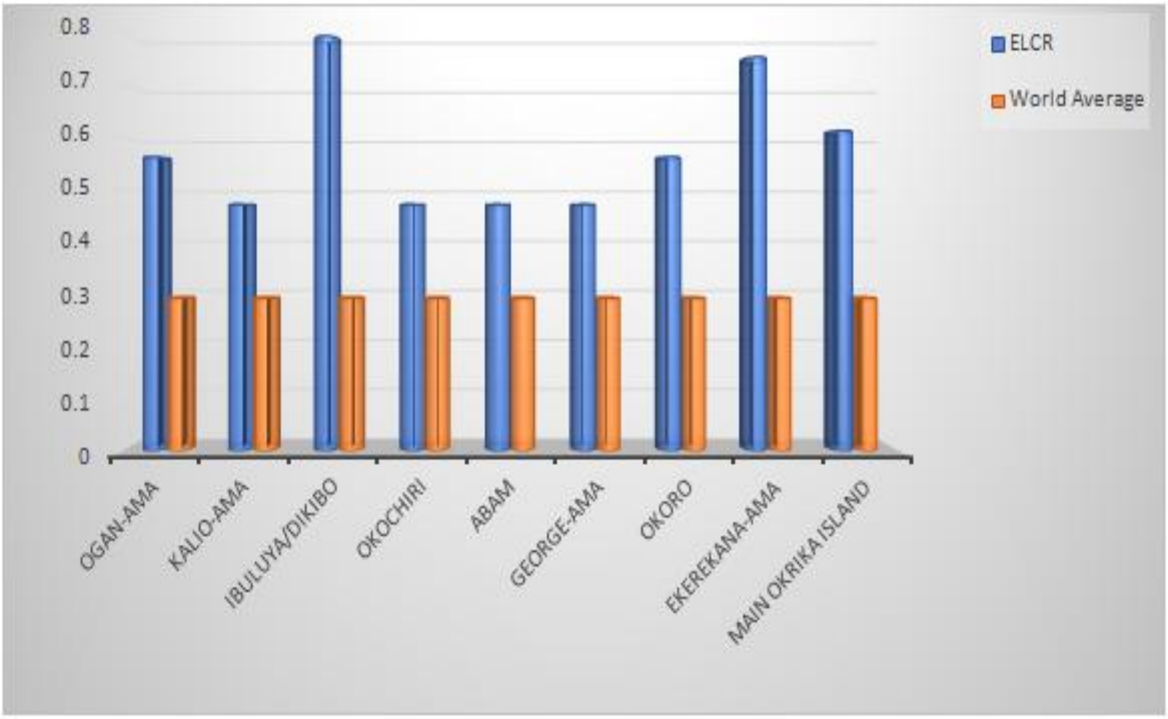


Fig. 11. Comparison of ELCR with world average. UNSCEAR, 2008

Table 11. Comparison of average natural radioactivity levels in air with other authors

Location	Absorbed dose (NGY/H)	Annual effective dose equivalent (MSY/Y)	Excess lifetime cancer risk	Reference
Ponnaiyar River, India	112.66	0.14	0.20	Ramasamy et al., [18]
Ghana	77.0	0.090		Amekudzie et al. [19]
Delta, Nigeria	167.04 - 154.86	0.240	0.018 – 0.90	Nwanne et al., [20]
Iran	113.0	0.720		Gholami et al., [21]
Northern Pakistan	87.47	0.920	3.21	Aziz et al., [22]
Imo River, Rivers State	150.95	0.240	0.81	Ononugbo et al., [4]
Bayelsa State	238.06 - 204.45	0.290 - 0.250	1.02 - 0.88	Anyalebechi et al., [23]
Okrika, Nigeria	108.3	0.161	0.57	This work

The minimum value of the exposure rate of 0.010$\mu R/h$ was found in Kalio Ama, and Abam while the maximum value of 0.017 mR/h was obtained at Ibuluya/dikibo Ama, with an overall mean of 0.0122$\pm$ 0.03 mR/h. The mean value obtained from all the communities is found to be lower when compared with the acceptable exposure limit of 0.0133 mR/h [1]. The maximum value of the exposure rate could have been influenced by the activities of oil and gas company, as well as unauthorized petroleum activities carried by group of individuals within the study area. This result obtained is comparable to a study carried out in oil spillage site at Obodo Creek in Gokana Local Government Area of Rivers State [24].

The absorbed dose ranged from 87.00 to 147.90 nGy/h with a mean value of 108.3± 23.34 nGy/h. The mean value was a little higher than the world average of 89 nGy/h. The minimum value was found in Kalio-Ama and the maximum at Ibuluya/dikibo community.

Ibuluya/dikibo has an outlet pathway to rivers, the study area is a host to a multinational companies, these companies use this pathway to discharge all sorts of effluents and waste substances into the river. Whenever these companies are in operation, their waste products if not properly treated affects the immediate neighbouring environment and creeks. This might have contributed to the high level of radiation recorded within the community.

The annual effective dose ranged from 0.13 to 0.23 mSv/y with and overall mean of 0.1611$\pm$0.04 mSv/y. The lowest value was found at Kalio-Ama and maximum value at Ibuluya/dikibo-Ama community. The overall mean value is found to be lesser that the acceptable limit of 1.0 ms/y [17,25]. This result obtained is similar to the work done in indoor and outdoor background ionization in Abuja [7].

The excess life cancer risk ranged from 0.47 x10^{-3} to 0.79 x10^{-3} with an overall mean value of 0.57$\pm$0.12 x10^{-3}. The values of individual communities and the overall mean are higher than the world average of 0.29 x 10^{-3}. This result indicate that the background ionization radiation might has been influenced due to man-man activities particularly oil activities within the study areas. This work is similar to the work carried out in Emeolugu village in Rivers State [26]. Also, the chances of developing cancer health related issue in this area are significant subject to long term exposure. This calls out for further findings to be carried within the environment in order to ascertain this fact, this calls out for research to be carried out to be carried out in areas of, crops, tubers, vegetable etc. within the study areas to ascertain this fact.

Figs. 2 to 7 show the contour of background ionization radiation of selected communities with good spatial distribution. The vertical colour code on the right gives the density of background ionization radiation indicating areas of higher to lower concentration in descending order.

4. CONCLUSION

The average value of AED is 0.1611±0.04 mSv/y is below the standard limit of 1 mSv/y [25] as recommended by ICRP. The excess lifetime cancer risk is above the recommended limit of (UNSCEAR). This indicates that even though there is no visible adverse effect on the populace it is recommended that companies and oil activities within the study area should be properly monitored in order to keep the populace and environment free from the hazards of radiation to as low as reasonably achievable, hence chances of developing cancer related issues in the selected areas are significant.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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