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Measurement of Outdoor Ambient Radiation and Evaluation of Radiological Risks of Coastal Communities in Ndokwa East, Delta State, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author CPO designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the analyses of the study. Author FUN managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: The aim of this study is to measure the outdoor ambient radiation and evaluate its associated radiological risk parameters of the coastal communities of Ndokwa East.
Study Design: The design of this study is purely experimental work.
Place and Duration: This study was carried out in five coastal communities of Ndokwa East.
Methodology: Measurement of outdoor ambient radiation of the five coastal communities was done using a Radalert-200 nuclear radiation monitor (S.E international, inc. Summer town, USA), containing a Geiger Muller tube capable of detecting α, β, γ and X-rays within the temperature range of -10° to 50℃, and a geographical positionin g system (GPS) were used to measure the precise location of sampling. Measurements were repeated six times at each site on different days within the 1 months to take care of any fluctuation in the environmental temperature, and this was repeated for 6 months in which the monitoring was carried out.
Results: The values of radiation exposure obtained range from 7.00 ± 0.05 μRh^{-1} (3.12 ± 0.45 µSv/week) in $Asemuku_{08}$ and $Okpai_{01}$ communities to 29.00 ± 0.021 μRh^{-1} (8.46 ± 2.05 µSv/ week)

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in Okpai $_{07}$ near oil and gas drilling company site. The estimated mean outdoor absorbed dose rate for the five coastal communities ranges from 77.20 to 113.07 $nGyh^{-1}$.The mean annual effective dose equivalent estimated for the five coastal communities ranges from 0.143 to 0.173 $mSvy^{-1}$while the mean estimated excess lifetime cancer risk ranges from 0.495×10^{-3} to 0.607×10^{-3} which were higher than the world level of 0.29×10^{-3}.

Conclusion: The result of this studies clearly show that those coastal communities have been radio logically polluted by the oil and gas activities and farming practices in the area. Though these values obtained may not cause immediate health problems there is a probability of long term health risk on the residents of these communities.

Keywords: Radalert; excess lifetime cancer risk; absorbed dose; Ndokwa; annual effective dose.

1. INTRODUCTION

Natural radiation is the major source of human exposure to ionizing radiation and its largest contributing component to effective dose arises from inhalation of radon gas and its radioactive progeny [1]. Background ionizing radiation comes from three major sources, namely terrestrial radiation, cosmic and man-made radiation. Natural background radiation that originate from the terrestrial environments varies tremendously worldwide. Natural radioactivity has great contribution to ionizing radiation to the world population due to its presence in the natural environment [2]. The primary radioactive elements in the earth's crust are potassium, uranium, thorium and their radioactive decay products. According to UNSCEAR [3], about 87% of the radiation dose received by mankind is due to natural radiation sources. Cosmic rays from space include energetic protons, gamma ray, electrons and so [4,5]. The exposure to cosmic radiation depends mostly on altitude, latitude and solar activity [6]. Human external exposure to radiation from all source types is mainly due to gamma rays because of its penetrative ability [7]. Chemical and physical changes which require the direct adsorption of energy from the incident radiation by the target represents the initial physical perturbations from which subsequent radiation effects evolve [8]. These effects starts with the initial changes at the molecular ,cellular, tissue and whole body levels that may lead to a wide range of health effects ranging from irritation, radiation-induced cancer, hereditary disorders to immediate death [9].

Exposure to natural radiation can come through inhalation, ingestion or otherwise enters the blood stream through wounds and also from irradiation from external sources such as linear accelerators. Radiation damage to tissues or organs of the body depends on the dose of radiation received or the absorbed dose which is expressed in a unit called gray (Gy). The potential damage from an absorbed dose depends on the type of radiation and sensitivity of different tissues and organs. The effective dose is used to measure ionizing radiation in terms of the potential for causing harm. Sievert, the unit of effective dose takes into account the type of radiation and sensitivity of tissues and organs [10].

Radiation studies have shown that radionuclides are known to be associated with organic materials in nature. Therefore, oil, gas and oil field brines contains natural radioactive materials. Hydrocarbon exploration and exploitation activities have the potential to increase the concentration of radionuclides and risk of radiation exposure to the environment and humans [11]. Many researchers have conducted different studies for monitoring and risk assessment of radiation exposure. Farai and Jibiri [12] reported the outdoor gamma radiation exposure dose rate for eastern zone of Nigeria showing values between 0.025 and 0.08 l $Gyh^{-1.}$ Akpabio et al. [13] also studied the environmental radioactive levels in Ikot–Ekpene and reported that the radioactivity levels in the area is generally low ranging.

Human beings are exposed outdoors to the natural terrestrial radiation that originates predominantly from the upper 30 cm of the soil [14]. Radionuclides with half-lives comparable with the age of the earth or their corresponding decay products existing in terrestrial material such as ^{238}U, ^{232}Th and ^{40}K are of a great interest. More specifically, natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on the geological and geographical conditions and appear at different levels in the soils of each region in the world [15]. Naturally occurring radioactive materials (NORMs) found in the earth's crust is brought to the surface during oil and gas production processes.

During the last few decades, the river Niger coastal areas of Ndokwa East, Delta State have experienced intense influx of effluents from operational oil and gas industries, aquaculture practices, transportation and boat construction activities, dredging and so on. Coastal communities of Ndokwa East are mostly peasant farmers that rely so much on fishing and farming for their daily living. Their outdoor activities are basically higher than indoor activities. Measurement of external gamma dose due to terrestrial sources is necessary not only due its contribution to the collective dose but also due to variations of the individual dose related to the pathways. These doses strongly depends on the concentration of ^{238}U, ^{232}Th, their progenies and ^{40}K present in rocks and soil which also is dependent on the geology of the area [2]. The aim of this study therefore is to measure the background ionizing radiation of the coastal communities of Ndokwa East and assess the radiation dose in order to control possible health effects from such natural sources. The result of this work serves as baseline radiological data of those communities for future studies.

2. MATERIALS AND METHODS

2.1 Study Area

This study was conducted between March and June, 2015–2016 which represent the season's transit (dry to wet) period, while measurement was made in strategic coastal communities of Ndokwa East, Delta state. The study area comprises of five communities (Aboh, Abalagada, Agwe-Etiti, Asemuku and Okpai) in Ndokwa east local government area which lies between latitude 5°45' N to 6°01'N and longitude 6°06'E to 6°20'E, it is bounded by the River Niger on the east, Isoko North Local Government Area in the south, Ughelli North, Ethiope West, Ika North and South, Aniocha South and Oshimili South Local Government Areas to the North. The study area is part of Niger Delta and it is underlain by sedimentary rocks, which consists mainly of yellow and white sand with pebbles, clay and sandy clay occur in lenses [13]. Three geological formation of Benin, Agbada and Akata formations occur in the area and they overlay one another, which has made the area viable for hydrocarbon exploration and development.

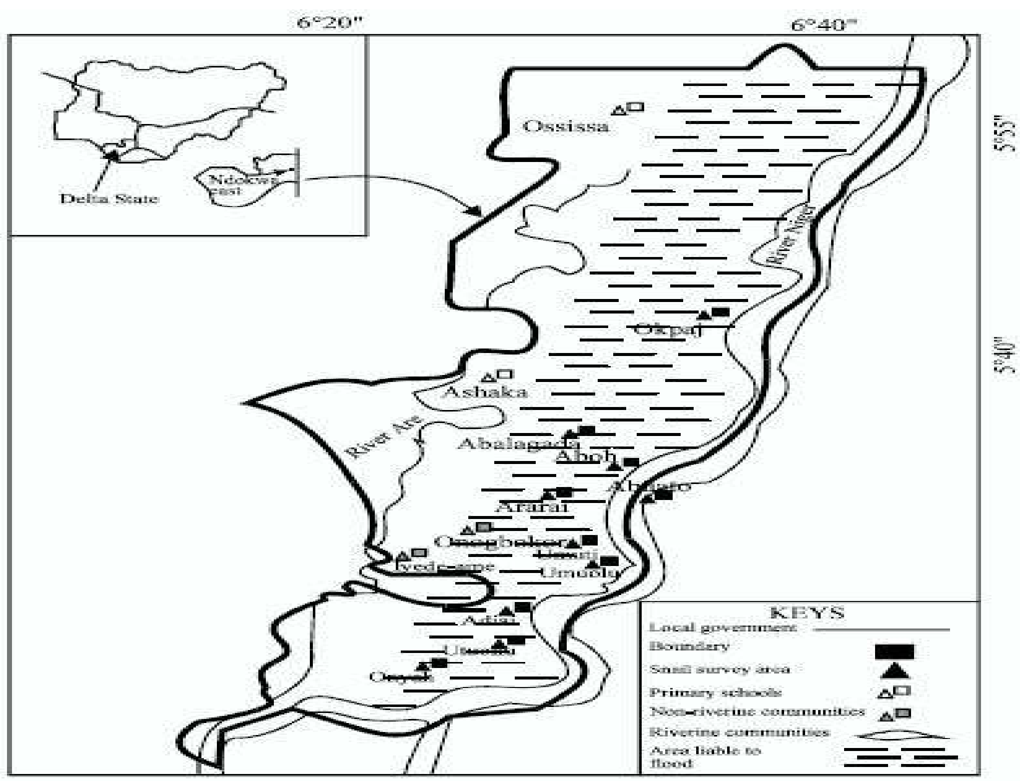

Fig. 1. Map of the study area

2.2 Sampling Method

An in situ approach of background ionizing radiation measurement was adopted and preferred to enable samples maintain their original environmental characteristics. A Radalert-200 nuclear radiation monitor (S.E international, inc. Summer town, USA), containing a Geiger Muller tube capable of detecting a, b, c and X-rays within the temperature range of -10°to 50°C, and a geographical positioning system (GPS) were used to measure the precise location of sampling. During measurement, the tube of the radiation monitoring meter was raised to a standard height of 1.0 m above the ground [16,17], with its window first facing vertically upward or the suspected source and then vertically downward while the GPS readings taken at that spot.

Measurements were repeated six times at each site on different days within the 1 months to take care of any fluctuation in the environmental temperature, and this was repeated for 6 months in which the monitoring was carried out. Readings were taken between the hours of 1300 and 1600 h, since the radiation meter has the maximum response to environmental radiation within these hours as recommend by NCRP [18]. The meter was set to read in milli-Roetgen per hour. The equivalent dose rate in micro-Sievert per week was obtained using the relation [19].

$$1Rh^{-1} = 0.445 \text{ Sv/week} \quad (1)$$

3. RESULTS AND DISCUSSION

3.1 Equivalent Dose Rate

To estimate the whole body equivalent dose rate over a period of 1 year, we use the National Council on Radiation Protection and Measurement [18,17] NCRP recommendation:

$$1 \text{ mRh}^{-1} = \frac{0.96\times24\times365}{100} \text{ mSvy}^{-1} \quad (2)$$

The results of the measured background ionizing radiation (BIR) levels and calculated equivalent dose, absorbed dose rate, the annual equivalent dose rate and the excess lifetime cancer risk obtained in this study are presented in Tables 1. Table 1 shows the average exposure rate determined for the fifty sampled locations within coastal communities. The values obtained range from 7.00 ± 0.05 µRh^{-1} (3.12 ± 0.45 µS/week) in Asemuku$_{08}$ and Okpai$_1$ communities to 19.00 ± 0.021 µRh^{-1} (8.46 ± 2.05 µSv/week) in Okpai$_{07}$ near oil and gas drilling company site. The corresponding equivalent dose rate over 1 year ranged from 0.59 ± 0.08 mSvy^{-1} to 1.60 ± 0.39 mSvy^{-1}.The lowest radiation exposure value was recorded at the Asemuku$_8$ and Okpai$_{01}$ and the highest value was recorded at Okpai Coastal community near oil and gas drilling site that was drilling during the sampling period. This high radiation measured may be due to effluents from the drilling company and radon gas emanating from the oil and gas gathering center.

The average exposure rate and equivalent dose rate value obtained in the five coastal communities exceeded the recommended ambient background level of 13.00 µRh^{-1} and 1.00 mSvy^{-1}, respectively by ICRP, [20] for the general public. The result indicates that 68% of the sampled location exceeded the ambient permissible levels for the general public. The high radiation recorded in Okpai community may be due to its proximity to the flow and flare stations and other oil and gas related activity in the area that emits radon gas [21]. Fig. 2 shows the comparison of the equivalent doses at different sampling points with the world acceptable standard while Fig. 3 gives the distribution pattern of radiations within the communities sampled. Figs. 2 and 3 clearly show that some sampling points recorded higher radiation exposure as well as the associated equivalent doses while some sampling points recorded lower doses and radiation levels compared to their standards. These values obtained are in agreement with works done in similar environments in other countries and some part of Nigeria.

3.2 Absorbed Dose Rate

The radiation dose to an organism is the total quantity of energy absorbed from ionizing radiation per unit mass of the tissue and the dose rate refers to the energy absorbed over time. The exposure dose rate measured in µRh^{-1} were converted unto absorbed dose rate using the conversion factor [22].

$$1\mu Rh^{-1} = 8.7 \text{ nGyh}^{-1} = \frac{8.7\times10^{-3}}{\frac{1}{8760\,y}} \mu Gyy^{-1} = 76.212 \mu Gyy^{-1} \quad (3)$$

The result of the outdoor absorbed dose rate for the five communities are presented in Tables 1–5. The estimated minimum and maximum outdoor absorbed gamma dose rates of 87.0 and 130.5 $nGyh^{-1}$ respectively recorded at Agwe-Etiti community, 69.60 $nGyh^{-1}$ and 174.0 $nGyh^{-1}$ respectively recorded at Abalagada community, 60.9 $nGyh^{-1}$ and 121.8 $nGyh^{-1}$ respectively at Asemuku, 87.0 $nGyh^{-1}$ and 139.2 $nGyh^{-1}$ at Aboh and 60.9 $nGyh^{-1}$ and 165 $nGyh^{-1}$ respectively recorded at Okpai community. The mean gamma absorbed dose rates obtained in the five communities were higher than the world population weighted average gamma dose rate value of 59.0 $nGyh^{-1}$ [3].

Table 1. Background radiation level at Agwe-Etiti coastal communities of Ndokwa East

S/N	Sample area	GPS	Average exposure rate μRh^{-1}	Equivalent dose rate (μSv/week	Equivalent dose rate (μSvy^{-1})	D ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR $\times 10^{-3}$
1	$ETITI_{01}$	N05°36.445' E006°36.743'	12.0±0.01	5.34	1.01	104.40	0.160	0.560
2	$ETITI_{02}$	N05°37.024' E006^{0}36.918'	10.0±0.011	4.45	0.84	87.00	0.133	0.467
3	$ETITI_{03}$	N05°37.199' E006°37.115'	15.0±0.04	6.68	1.26	130.5	0.200	0.700
4	$ETITI_{04}$	N05°37.759' E006°37.177'	11.0±0.03	4.90	0.93	95.7	0.147	0.513
5	$ETITI_{05}$	N05°37.891' E006°37.211'	10±0.10	4.45	0.84	87.0	0.133	0.467
6	$ETITI_{06}$	N05°38.278' E006°37.120'	10.0±0.03	4.45	0.84	87.00	0.133	0.467
7	$ETITI_{07}$	N05°38.625. E006°36.966	11.0±0.02	4.90	0.93	95.70	0.147	0.513
8	$ETITI_{08}$	N05°38.946' E006°36.768'	12.0±0.03	5.34	1.01	104.4	0.160	0.560
9	$ETITI_{09}$	N05°39.060' E006°36.724'	15.0±0.07	6.68	1.26	130.5	0.200	0.700
10	$ETITI_{10}$	N05°39.184' E006°36.619'	10.0±0.01	4.45	0.84	87.00	0.133	0.467
		Mean	**10.0±0.01**	**5.16**	**0.98**	**92.22**	**0.155**	**0.495**

Table 2. Background radiation level at Abalagada coastal communities of Ndokwa East

S/N	Sample area	GPS	Average exposure rate μRh^{-1}	Equivalent dose rate (μSv/week	Equivalent dose rate (μSvy^{-1})	D ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR $\times 10^{-3}$
11	ABAL(01)	N05°34.345' E006°35.113'	20.0±0.003	8.9	1.68	174.0	0.267	0.935
12	ABAL(02)	N05°34.964' E006°35.115'	10.0±0.001	4.45	0.84	87.0	0.133	0.463
13	ABAL(03)	N05°35.225' E006°34.161'	12.0±0.002	5.34	1.01	104.40	0.160	0.560
14	ABAL(04)	N05°35.445' E006°35.142'	10.0±0.005	4.45	0.84	87.0	0.133	0.463
15	ABAL(05)	N05°35.941' E006°35.126'	8.0±0.001	3.56	0.67	69.60	0.107	0.375
16	ABAL(06)	N05°36.770' E006°35.210'	8.0±0.002	3.56	0.67	69.60	0.107	0.375
17	ABAL(07)	N05°37.034' E006°35.322'	16.0±0.001	7.12	1.35	139.20	0.213	0.746
18	ABAL(08)	N05°37.073' E006°.35.397	12.0±0.001	5.34	1.01	104.4	0.160	0.560
19	ABAL(09)	N05°37.013' E006°35.515'	14.0±0.005	6.23	1.18	121.80	0.187	0.654
20	ABAL(10)	N05°37.931' E006°35.587'	14.0±0.003	6.26	1.18	121.80	0.187	0.654
		Mean	**12.0±0.001**	**5.52**	**1.04**	**107.88**	**0.165**	**0.580**

Table 3. Background radiation level at Asemuku coastal community of Ndokwa East

S/N	Sample area	GPS	Average exposure rate μRh^{-1}	Equivalent dose rate (μSv/week)	Equivalent dose rate (μSvy^{-1})	D (nGyh^{-1})	AEDE (mSvy^{-1})	ELCR ×10^{-3}
21	ASEM(01)	N05°39.381' E006°36.419'	14.0±0.002	6.23	1.18	121.8	0.187	0.654
22	ASEM(02)	N05°39.426' E006°36.391'	9.0±0.001	4.01	0.76	78.30	0.120	0.420
23	ASEM(03)	N05°39.526' E006°36.27'	9.0±0.001	4.01	0.76	78.3	0.120	0.420
24	ASEM(04)	N05°39.614' E006^{0}36.219'	10.0±0.002	4.45	0.84	87.0	0.133	0.463
25	ASEM(05)	N05°39.697' E006°36.156'	11.0±0.001	4.90	0.93	95.7	0.147	0.513
26	ASEM(06)	N05°39.779' E006°36,109'	13.0±0.001	5.79	1.09	113.1	0.173	0.617
27	ASEM(07)	N05°40.003' E006°36.997'	12.0±0.002	5.34	1.01	104.4	0.160	0.560
28	ASEM(08)	N05°40.130' E006°35.965'	7.0±0.001	3.12	0.59	60.9	0.095	0.331
29	ASEM(09)	N05°40.398' E006°35.939'	11.0±0.001	4.90	0.93	95.7	0.147	0.513
30	ASEM(10)	N05°40.636' E006°35.882	12.0±0.001	5.34	1.01	104.4	0.160	0.560
		Mean	**11.0±0.001**	**4.81**	**0.91**	**93.96**	**0.143**	**0.505**

Table 4. Background radiation level at Aboh coastal community of Ndokwa East

S/N	Sample area	GPS	Average exposure rate μRh^{-1}	Equivalent dose rate (μSv/week)	Equivalent dose rate (μSvy^{-1})	D (nGyh^{-1})	AEDE (mSvy^{-1})	ELCR ×10^{-3}
31	ABOH(01)	N05°32.069' E006°31.554'	14.0±0.001	5.34	1.18	121.80	0.187	0.655
32	ABOH(02)	N05°32.196' E006°31603'	10.0±0.001	4.45	0.84	87.00	0.133	0.466
33	ABOH(03)	N05°32.576' E006°31.745'	15.0±0.002	6.68	1.26	130.50	0.200	0.700
34	ABOH(04)	N05°32.756' E006°31.806'	13.0±0.002	5.79	1.09	113.10	0.173	0.606
35	ABOH(05)	N05°32.559' E006°31.878'	9.0 ±0.001	4.01	0.76	78.30	0.120	0.420
36	ABOH(06)	N05°32.971' E006°31.924'	12.0 ±0.001	5.34	1.01	104.40	0.160	0.560
37	ABOH(07)	N05°33.941' E006°32.016	16.0 ±0.004	7.12	1.35	139.20	0.213	0.746
38	ABOH(08)	N05°33.208' E006°32.268'	10.0±0.001	4.45	0.84	87.00	0.133	0.466
39	ABOH(09)	N05°33.096' E006°32.396	10.0 ±0.002	4.45	0.84	87.00	0.133	0.466
40	ABOH(10)	N05°33.106' E006°32.726	11.0 ±0.000	4.90	0.93	95.70	0.147	0.515
		Mean	**12.0 ±0.001**	**5.25**	**1.01**	**77.20**	**0.160**	**0.560**

3.3 Annual Effective Dose Equivalent (AEDE)

The values of the absorbed dose calculated were used to estimate the annual effective dose equivalent received by residents in those coastal communities. Dose conversion factor of 0.7 Sv/Gy recommended by UNSCEAR [23] for the conversion coefficient from absorbed dose in air to effective dose received by adults and occupancy factor of 0.2 for outdoor. The annual effective dose equivalent was calculated using the equation below:

$$AEDE\ (outdoor) = D\ (nGyh^{-1}) \times 8760\ h \times 0.7\ Sv/Gy \times 0.2 = D\ (nGyh^{-1}) \times 1.2264 \times 10\text{-}3\ Sv/Gy \quad (4)$$

The mean value of AEDE for outdoor exposure for Etiti, Abalagada, Asemuku, Aboh and Okpai community are 0.16, 0.17, 0.143, 0.16 and 0.173 $mSvy^{-1}$ respectively. These values of AEDE obtained in the five communities are similar to the values reported in Al-Rakkah in Saudi Arabia. The worldwide average value of AEDE is 0.41 mSv of which 0.07 $mSvy^{-1}$ from outdoor exposure and 0.34 $mSvy^{-1}$ from indoor exposure [3,21,19], and the values obtained in this study are well above the world average normal AEDE level for outdoor which is an indication of radiological contamination of the terrestrial environment of the sampled communities.

3.4 Excess Lifetime Cancer Risk (ELCR)

The estimated values of AEDE was used to calculate the excess lifetime cancer risk for the five communities using the equation:

$$ELCR = AEDE\ (mSvy^{-1}) \times \text{average Duration of life (DL) in years} \times \text{Risk factor } (RF\ Sv^{-1}) \quad (5)$$

Where AEDE, DL and RF are the annual effective dose equivalent, duration of life (70 years) and the risk factor (Sv^{-1}), the fatal cancer risk per Sievert. For low dose background radiationwhich are considered to produce stochastic effects, ICRP 60 uses value of 0.05 Sv^{-1} for the public exposure [24]. The mean excess lifetime cancer risk calculated are 0.50×10^{-3}, 0.58×10^{-3}, 0.51×10^{-3}, 0.56×10^{-3} and 0.61×10^{-3} for Abalagada, Etiti , Asemuku, Aboh and Okpai communities respectively. The overall average ELCR values obtained in this study is almost twice the world average value of 0.29×10^{-3} [24]. This implies that residents of these communities sampled who spend their lifetime there will suffer cancer risk.

Fig. 4 shows the radiation contour of the sampled communities. The contour reveals the BIR distribution and higher radiations levels were recorded in areas with oil and gas activities. The overall result of this study show relatively high radiation area compared to other parts of the world but the values obtained may not cause immediate health risk but long term exposure may lead to some radiation related health risk.

Table 5. Background radiation level at Okpai coastal community of Ndokwa East

S/N	Sample area	GPS	Average exposure rate μRh^{-1}	Equivalent dose rate (µSv/week	Equivalent dose rate (μSvy^{-1})	D ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR $\times 10^{-3}$
41	OKPAI(01)	N05°40.993’ E006°35.936’	7.0 ±0.001	3.12	0.59	60.90	0.093	0.331
42	OKPAI(02)	N05°41.179’ E006°35.391’	8.0 ±0.001	3.56	0.67	69.60	0.107	0.373
43	OKPAI(03)	N05°41.371’ E006°35.815’	18.0 ±0.01	8.01	1.51	156.60	0.240	0.840
44	OKPAI(04)	N05°41.460’ E006°35.834’	14.0 ±0.002	6.23	1.18	121.80	0.187	0.654
45	OKPAI(05)	N05°41.612’ E006°35.817’	15.0 ±0.001	6.68	1.26	130.50	0.200	0.700
46	OKPAI(06)	N05°41.722’ E006°35.825’	11.0 ±0.001	4.90	0.93	95.70	0.147	0.513
47	OKPAI(07)	N05°41.867’ E006°35.817’	19.0±0.005	8.46	1.60	165.00	0.253	0.885
48	OKPAI(08)	N05°41.930’ E006°35.873’	9.0 ±0.001	4.01	0.76	78.30	0.120	0.420
49	OKPAI(09)	N05°41.838’ E006°35.930’	15.0 ±0.003	6.68	1.26	130.50	0.200	0.700
50	OKPAI(10)	N05°41.627 E006°35.932	14.0 ±0.000	6.23	1.18	121.80	0.187	0.654
		Mean	**29.0 ±0.003**	**5.79**	**1.09**	**113.07**	**0.173**	**0.607**

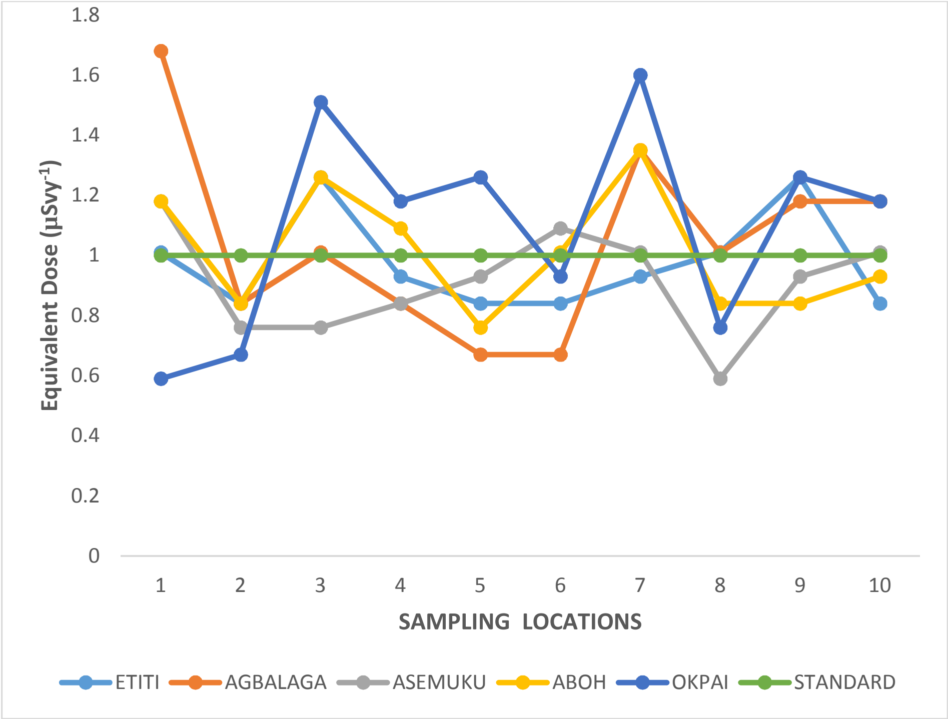

Fig. 2. Comparison of equivalent doses of the five coastal communities with the standard

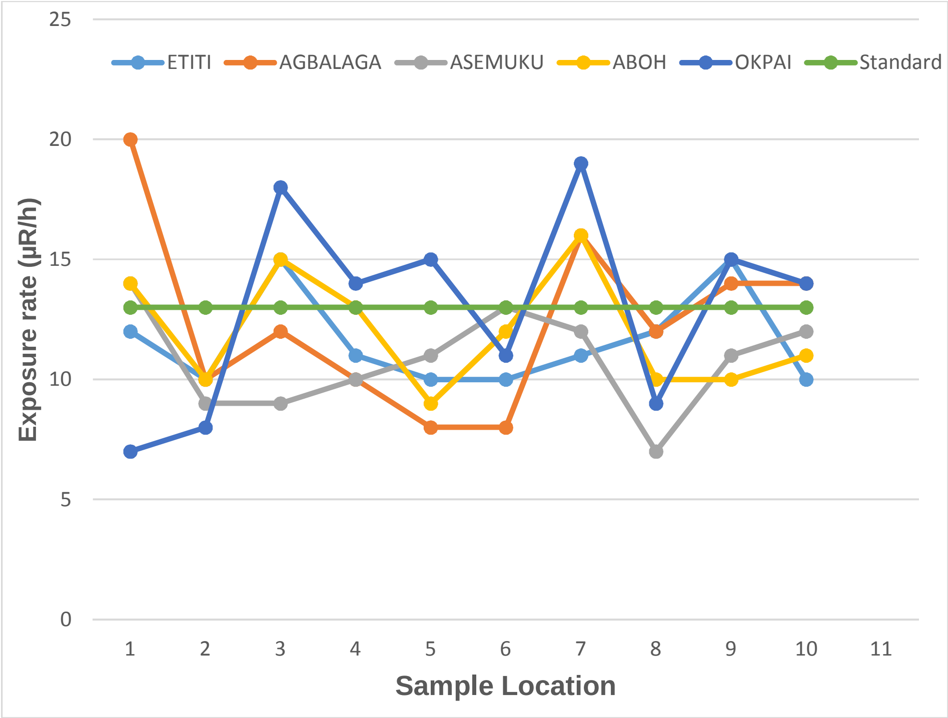

Fig. 3. Radiation distribution pattern within the five coastal communities

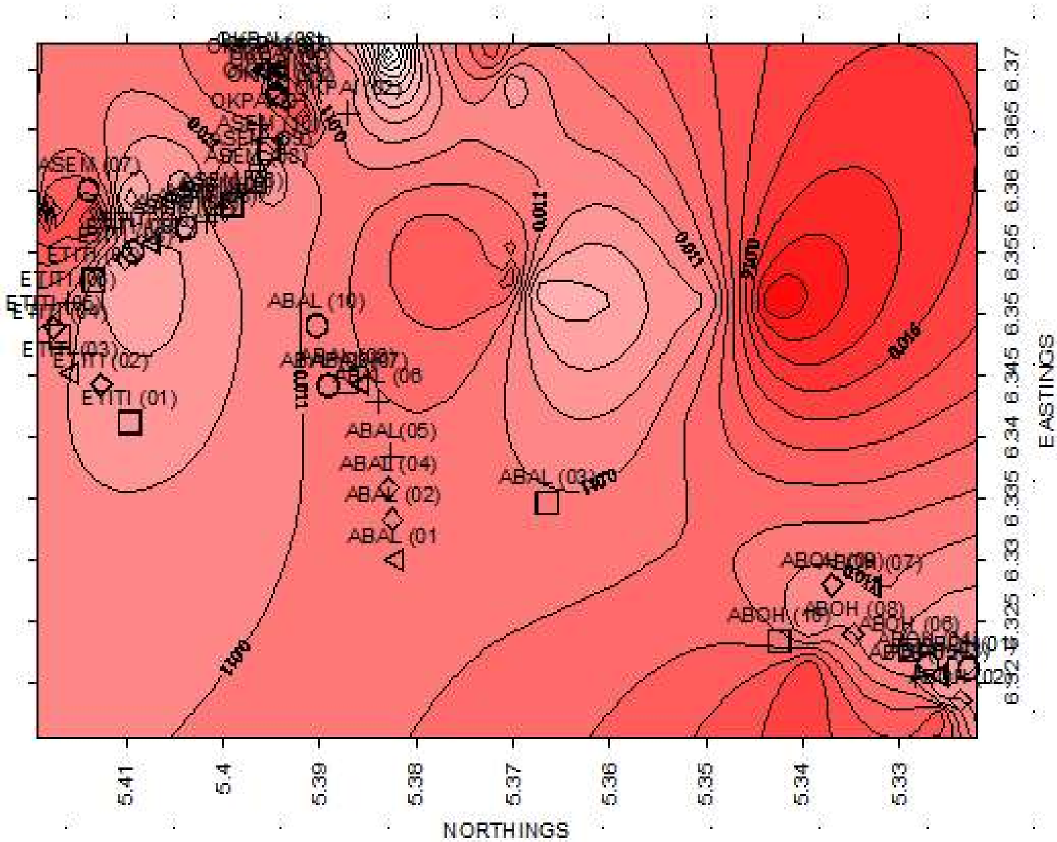

Fig. 4. Radiation Contour map of the area sampled

4. CONCLUSION

Measurement of background ionizing radiation of five coastal community in Ndokwa East Delta state has been carried out using well calibrated radiation meter (Radalert- 200) and a global positioning system (GPS). The radiation exposure rates obtained varied from location to location and from one community to another. Some locations recorded higher radiation while some recorded lower radiations than the normal background radiation level of 13.0 μRh^{-1}.

The absorbed dose rates and annual effective dose equivalent estimated for the five coastal communities were above their world safe values. The mean estimated excess lifetime cancer risk were also higher than the world level of 0.29×10^{-3}. This shows that there is a probability of developing cancer by the residents and farmers in these coastal areas at long term exposure. The result of this studies clearly show that those coastal communities have been radiologically polluted by the oil and gas activities and farming practices in the area. It is therefore important to recommend as follows:

- There should be regular monitoring of radiation levels by Government agencies responsible for environmental radiation safety.
- Further studies be carried out on the water, soil and sediment from those locations with high radiation exposure levels.
- Research on radionuclide dispersion and transportation in marine environment through development of radiation models be carried out in the area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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