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Estimation of Radiation Risk Due to Exposure to Terrestrial Radiation

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Authors' contributions

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

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ABSTRACT

An *in-situ* measurement of background radiation level of Ewoi community in Ogbia Local Government Area of Bayelsa State Nigeria was done using two radiation meters (Digilert-200 and Radalert-100). Exposure rate measured ranged from 0.010 to 0.028 mRh^{-1} with mean value of 0.016 mRh^{-1}. The mean value of absorbed dose was 128.67 $nGyh^{-1}$ while the mean indoor and outdoor annual effective dose equivalents were 0.40 $mSvy^{-1}$ and 0.13 $mSvy^{-1}$ respectively. The mean excess lifetime cancer risk estimated from both indoor and outdoor effective doses were 1.0×10^{-3} and 0.33×10^{-3} respectively. It was observed that all the radiological parameters estimated from the radiation exposure rate were higher than their world average values except the annual effective doses. The result of this study shows that Ewoi community recorded slightly high background radiation level and this may be attributed to oil and gas exploration activity in the area. The result of this work serves as radiological baseline data of the area for future studies.

Keywords: Exposure; absorbed dose; effective dose; cancer risk and digilert-200.

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1. INTRODUCTION

Background exposure from normal levels of the naturally occurring radioactive materials (NORMS) are present in all environmental materials and do vary remarkably from place to place. Where human activities have increased the relative concentration of the radionuclides, they are referred to as the technologically enhanced naturally occurring radioactive materials (TENORMs) [1]. Natural radioactivity has great ionizing radiation effect on the world population due to its presence in our surroundings at different amounts, thus man by the very nature of his environment is exposed to varying amount of radiation with or without his consent. The ambient radiation encompasses both the natural and artificial radioactivity in his environment [2]. Survey taken by the World Health Organization (WHO) and the international commission on radiological protection (ICRP) shows that residents of temperate climates spend only about 20% of their time outdoor and about 80% indoor(homes, schools offices or other buildings) [3].

Materials used for building (soil and rock) are major sources of radiation exposure to the population and also means of migration for the transfer 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 [4]. ^{222}Rn results from radioactivity of uranium - 238 which decays with a half-life of 3.82days. When it is inhaled it penetrates into the lungs. It's most dangerous daughters are the α- emitters (^{218}Po and ^{241}Po) which emit α-particles with high energy of 6.0 MeV and 7.69 MeV respectively. The continuous deposition and interaction of such high energy particles with the lung leads to its damage leading to lung cancer. It has been establish that chronic exposure to even low dose rate of nuclear radiation from an irradiated building has the potential to induce cytogenetic damage in human beings [4]. One of the radionuclides around man's environment that contributes high amount of potential lethal dose is radon; which causes the majority of deaths resulting from lung cancer [5].

Human beings are exposed outdoors to the natural terrestrial radiation that originates predominantly from the upper 30 cm of the soil. 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. Naturally occurring radioactive materials (NORMs) found in the earth's crust is brought to the surface during oil and gas production processes.

Of particular concern for indoor background ionizing radiation is the incidence of the invisible, odourless radioactive gas ^{222}Rn which is a member of the Uranium radioactive series. Estimation of radiation doses from the background shows 2.4mSvyr^{-1} annual exposure from all ionizing sources, 40% is contributed by internal exposure to radon alone [4]. A strong correlation between radon exposure (inhalation) and the prevalence of lungs cancer have also been reported [4,6]. Figures in the ICRP [7] statement imply that the risk of death from exposure to radon at work and at home could be greater than the one observed from travelling by car and the estimated risk of lung cancer from exposure to radon could be greater than the observed risk of lung cancer from all the remaining causes. In Malaysia, cancer (stomach, breast, lung, liver, leukaemia and thyroid) is one of the major health problems, it has been certified medically that cancer is the fourth leading cause of death [8]. Natural sources of radiation include; extraterrestrial cosmic radiation (consisting of 87% proton, 12% α-particles and 1% heavier nuclide) [9] and terrestrial radiation from primordial elements in the earth.

Radiation dose depend on the intensity and energy of radiation, type of radiation, exposure time, the area exposed and the depth of energy deposition. 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 [10]. It is however important to mention that the biological effect depend not only on the total dose the tissue is exposed to, but also on the rate at which the dose was received. The equivalent dose rate (EDR); the absorbed dose do not give an accurate indication of the harm that radiation can do since equal absorbed doses do not necessarily have the same biological effects. An absorbed dose of 0.1Gy of alpha radiation is more harmful than an absorbed dose of 0.1Gy of beta or gamma radiation. To reflect damage done in biological systems from different types of radiation, the equivalent dose is used. It is define in terms of the absorbed dose weighted by a factor which depends on the type of radiation. Its unit is Sievert (Sv).

When ionizing radiation interacts with any medium (air, tissue, water, plastic, etc.), energy is transferred from the radiation field to the medium. The quantity that describes this energy transfer is the absorbed dose and is measured by the concentration of absorbed energy [11]. Exposure to ionizing radiation poses a high risk and this risk may include cancer induction, radiation cataractogenesis, and indirect chromososal transformation. The practice is to keep ones exposure to ionizing radiation as low as reasonably possible and this is known as the ALARA principle [12]. However, Radon (^{222}Rn) finds its way indoor through building materials, diffusion, and convection and through the soil under the building. Some of the materials used in the construction of buildings are known to be radioactive [13]. Studies on health effects due to ionizing radiation have produced substantial evidence that exposure to high levels of radiation can cause illness or even death. It can also cause retardation in children of mothers exposed to radiation during pregnancy. Deterministic effects are characterized by the three qualities stated by the Swiss physician and scientist Paracelsus about 500 years ago when he wrote "the size of the dose determines the poison." (A corollary to this is the old adage that there are no harmful chemicals [or radiation], only harmful uses of chemicals [or radiation]):

1. A certain minimum dose must be exceeded before the particular effect is observed.
2. The magnitude of the effect increases with the size of the dose.
3. There is a clear, unambiguous causal relationship between exposure to the noxious agent and the observed effect [11].

Several studies have been carried out in Nigeria to measure the natural background radiation levels of high populated communities, hospitals and industrial areas [14,15,3]. The aim of this study is to measure the background ionizing radiation of Ewoi community and its surroundings in order to calculate the absorbed dose, annual effective dose equivalent and excess lifetime cancer risk on the populace of the study area. The result of this study will serve as baseline radiological data of the area for future environmental studies.

2. MATERIALS AND METHODS

2.1 Study Area

Ewoi community is a community in Ogbia Local Government Area of Bayelsa state and is made up of six electoral units with no oil wells but with ongoing oil exploration activity. It is located at latitude 4.76143N and longitude 6.2915E, bounded by Otuabula 1, Otuabula 2, Otuoke and Otuaba communities. Ewoi community comprises of five kindred: Zukewoi, Igbeligbe, Obarogu, Ayeleba and Otuobom kindred.

Ewoi community is located within the lower delta plain believed to have been formed during the Holocene of the quaternary period by the accumulation of sedimentary deposits. The major geological characteristic of the Bayelsa state is sedimentary alluvium. The entire state is formed of abandoned beach ridges and due to many tributaries of the River Niger in this plain, considerable geological changes still abound. The major soil types in the state are young, shallow, poorly drained soils (inceptisol Aquepts) and acid sulphate soils (Sulphaquepts). There are variations in the soils of Bayelsa State; some soil types occupy extensive areas whereas others are of limited extent. However, based on physiographic differences, several soil units could be identified in the state. These include: the soils of the high-lying levees e.g. sandy loam, loamy sandy, and silt loamy soils as well as sands; the soils of the low-lying levees e.g. the moderately fine texture, red silt or clay loamy soils; the meander belt soils which differ only slightly from the soils of the levees. The silted river belt soils e.g. peat for clay water bogged soils found mainly in the beds of dead creeks and streams. The basin soils e.g. silky clay loam or sandy loam which are inundated by water for most of the year; the transition zone soils e.g. silt and sandy silt which are known to be under the daily influence of tidal floods and fresh waters. There are pockets of potash deficiency especially in the sandy soils. The texture of majority of the soils ranges from medium to fine grains.

Generally, Bayelsa State is a lowland state characterized by tidal flats and coastal beaches, beach ridge barriers and flood plains. The net features such as cliffs and lagoons are the dominant relief features of the state. The fact that the state lies between the upper and lower Delta

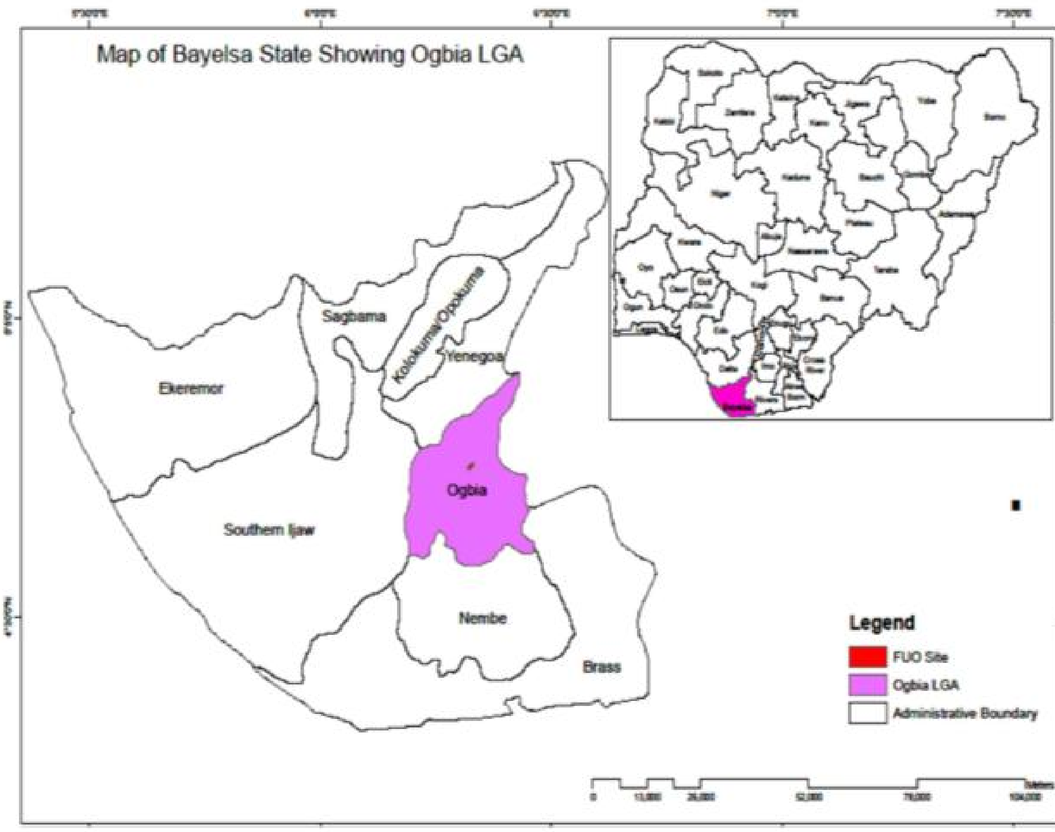

Fig. 1. Map of Bayelsa state showing Ogbia LGA

plain of the Niger Delta suggests a low-lying relief. The broad plain is gentle-sloping. The height or elevation decreases downstream. There are numerous streams of varying volumes and velocities in the state. These include Rivers Nun, Ekoli, Brass, Koluama, and so on.

An in-situ measurement of background ionizing radiation indoors and outdoors of the Ewoi community were measured using well calibrated Radalert-100 and Digilert-200 nuclear radiation meters (S.E. International INC. Summer Town, USA). The radiation meters contain a Geiger – Muller tube capable of detecting alpha, beta, gamma and X-rays within the temperature range of -10^{o}c and 50^{o}c. The radiation meters were set to measure the exposure rate in milli-Roetgen per hour. A geographical positioning system (GPS) was used to take the precise positions were readings were taken outdoor. Six readings were taken, three each using each of the radiation meters an average was taken and recorded. The mean exposure rates were calculated along with their standard deviations. The absorbed dose rate (nGy/h) was obtained from the external dose rate in (μR/h) using the conversion factor [16]:

$$1\mu R/h = 8.7 nGy/h = 8.7\times10^{-3}\mu Gy/(1/8760)y = 76.212\mu Gy/y \quad (1)$$

3. RESULTS

The in-situ results of the background ionizing radiation and the calculated values of the absorbed dose, annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR) of the Ewoi community are presented in Table1.

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 [17,18] recommendation:

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

Table 1. Exposure rate measured in Ewoi communities of Ogbia local government area of Bayelsa State, Nigeria and their radiological parameters

S/N	Sampling point	Latitude	Longitude	Average exposure mRh^{-1}	D ($nGyh^{-1}$)	Equivalent dose($mSvy^{-1}$)	AEDE (Indoor) $mSvy^{-1}$	AEDE (Outdoor) $mSvy^{-1}$	ELCR Indoor × 10^{-3}	ELCR Outdoor × 10^{-3}
1	Zukewoi 1	4.76241096	6.28892426	0.028	243.6	2.3548	1.12	0.37	2.8	0.93
2	Zukewoi 2	4.76207426	6.28932885	0.018	156.6	1.5138	0.72	0.24	1.8	0.6
3	Zukewoi 3	4.76142689	6.28882368	0.022	191.4	1.8502	0.88	0.29	2.2	0.73
4	Zukewoi 4	4.76114479	6.28861145	0.019	165.3	1.5979	0.76	0.25	1.9	0.63
5	Zukewoi 5	4.76085838	6.28839134	0.017	147.9	1.4297	0.68	0.23	1.7	0.58
6	Zukewoi 6	4.76057453	6.28830559	0.015	130.5	1.2615	0.60	0.20	1.5	0.50
7	Zukewoi 7	4.76166024	6.28971518	0.016	139.2	1.3456	0.64	0.21	1.6	0.53
8	Igbeligbe 1	4.76111047	6.28998055	0.017	147.9	1.4297	0.68	0.23	1.7	0.58
9	Igbeligbe 2	4.76073416	6.29016101	0.011	95.7	0.9251	0.44	0.15	1.1	0.38
10	Igbeligbe 3	4.76038711	6.29038774	0.013	113.1	1.0933	0.52	0.17	1.3	0.43
11	Igbeligbe 4	4.75926012	6.29064775	0.014	121.8	1.1774	0.56	0.19	1.4	0.48
12	Igbeligbe 5	4.75854653	6.29083820	0.011	95.7	0.9251	0.44	0.15	1.1	0.38
13	Igbeligbe 6	4.75818104	6.29113071	0.012	104.4	1.0092	0.48	0.16	1.2	0.40
14	Igbeligbe 7	4.75887334	6.29106273	0.011	95.7	0.9251	0.44	0.15	1.1	0.38
15	Obarogu 1	4.75900422	6.29151896	0.018	156.6	1.5138	0.48	0.16	1.2	0.40
16	Obarogu 2	4.7592359	6.29185969	0.020	174.0	1.682	0.44	0.15	1.1	0.38
17	Obarogu 3	4.75973973	6.29175139	0.015	130.5	1.2615	0.72	0.24	1.8	0.60
18	Obarogu 4	4.76028607	6.29156791	0.021	182.7	1.7661	0.80	0.27	2.0	0.68
19	Obarogu 5	4.760899887	6.29140420	0.013	113.1	1.0933	0.60	0.20	1.5	0.50
20	Obarogu 6	4.76177725	6.29117479	0.015	130.5	1.2615	0.84	0.28	2.1	0.70
21	Obarogu 7	4.761733620	6.29085754	0.017	147.9	1.4297	0.52	0.17	1.3	0.43
22	Ayeleba 1	4.761788860	6.29053501	0.016	139.2	1.3456	0.60	0.20	1.5	0.50
23	Ayeleba 2	4.76223423	6.29046779	0.020	174.0	1.682	0.68	0.23	1.7	0.58
24	Ayeleba 3	4.76271221	6.29063316	0.019	165.3	1.5979	0.64	0.21	1.6	0.53
25	Ayeleba 4	4.76271028	6.29043325	0.019	165.3	1.5979	0.80	0.27	2.0	0.68
26	Ayeleba 5	4.76256771	6.28971459	0.018	156.6	1.5138	0.76	0.25	1.9	0.63

S/N	Sampling point	Latitude	Longitude	Average exposure mRh^{-1}	D ($nGyh^{-1}$)	Equivalent dose($mSvy^{-1}$)	AEDE (Indoor) $mSvy^{-1}$	AEDE (Outdoor) $mSvy^{-1}$	ELCR Indoor × 10^{-3}	ELCR Outdoor × 10^{-3}
27	Ayeleba 6	4.76348506	6.28803226	0.018	156.6	1.5138	0.76	0.25	1.9	0.63
28	Ayeleba 7	4.76330946	6.28747142	0.016	139.2	1.3456	0.72	0.24	1.8	0.60
29	Otuobom 1	4.76331336	6.28696138	0.021	182.7	1.7661	0.82	0.26	1.8	0.60
30	Otuobom 2	4.76319144	6.28659326	0.016	139.2	1.3456	0.64	0.21	1.6	0.53
31	Otuobom 3	4.76437799	6.28777889	0.015	130.5	1.2615	0.84	0.28	2.1	0.70
32	Otuobom 4	4.76494628	6.28866452	0.014	121.8	1.1774	0.64	0.21	1.6	0.53
33	Otuobom 5	4.78580000	6.31173000	0.014	121.8	1.1774	0.60	0.21	1.6	0.50
34	Otuobom 6	4.77026841	6.29463233	0.010	87.0	0.841	0.56	0.19	1.4	0.48
35	Otuobom 7	4.78580000	6.31173000	0.013	113.1	1.0933	0.58	0.20	1.5	0.48
	Mean			**0.016**	**128.67**	2.3548	**0.40**	**0.13**	**1.0**	**0.33**

3.2 Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent received by individuals in the community were estimated from the absorbed dose rate , a dose conversion factor of 0.7 Sv/Gy and the occupancy factor indoor and outdoor was 0.75(18/24) and 0.25(6/24) respectively. It has been estimated that people spend approximately 18 hours indoors and 6 hours outdoors. The annual effective dose equivalent is determined using the equations [16]:

AEDE (indoor) (mSv/y) = Absorbed dose rate (nGy/h) x 8760 h x 0.7 Sv/Gy x 0.75 (3)

AEDE (outdoor) (mSv/y) = Absorbed dose rate (nGy/h) x 8760 h x 0.7Sv/Gy x 0.25 (4)

3.3 Excess Lifetime Cancer Risk (ELCR)

The excess lifetime cancer risk was calculated using the following equation

ELCR = AEDE x Average duration of life (DL) x Risk Factor (RF) (5)

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 [19].

4. DISCUSSION

Measurement of background ionizing radiation of Ewoi community in Ogbia local government Area of Bayesla State of Nigeria was done using two radiation meters (Radalert-200 and Digilert-100). Exposure rate measured in thirty –five locations ranges from 0.010 to 0.028 mRh^{-1} with mean value of 0.016 mRh^{-1}. Zukewoi recorded the highest exposure rate of 0.028 mRh^{-1} while Otuobom recorded the least radiation level of 0.010 mRh^{-1}. This high value recorded at Zukewoi could be due to oil exploration activities that are ongoing in the community. Otuobom recorded the least background radiation because there is no known industrial activity in the area that could release radiation to the environment. The mean exposure rate recorded was higher than the safe limit of 0.013 mRh^{-1} stipulated by International committee of Radiological Protection [20].

The exposure rate measured was converted to absorbed dose rate using the appropriate conversion factor as shown in equation 1. The absorbed dose of radiation ranges from 87.0 to 243.6 $nGyh^{-1}$ with an average value of 128.67 $nGyh^{-1}$. The average value of128.67 $nGyh^{-1}$ is higher than the world average value of 84.0 $nGyh^{-1}$ may be due to the radiation emissions from seismic operations in the area. The indoor annual effective dose equivalent estimated ranges from 0.56 to 1.12 $mSvy^{-1}$ with mean value of 0.40 $mSvy^{-1}$ while the outdoor annual effective dose ranges from 0.19 to 0.37 $mSvy^{-1}$ with an average value of 0.13 $mSvy^{-1}$. Excess lifetime cancer risk (ELCR) estimated from the indoor annual effective dose ranges from 1.4×10^{-3} to 2.8×10^{-3} with average value of 1.0×10^{-3} while ELCR estimated from the outdoor annual effective dose ranges from 0.48×10^{-3} to 0.93×10^{-3} with mean value of 0.33×10^{-3}.

Fig. 2 shows the 3-D radio-map of the study area while Fig. 3 shows the comparison of the measured radiation levels at the sampling points with the normal background level. The result of the computed mean effective equivalent dose rate for the locations are above the dose limit of 1 $mSvy^{-1}$ for the general public and far below the dose limit of 20 $mSvy^{-1}$ for radiological workers as recommended by the International Commission on Radiological Protection [20]. Also, the results show that the thirty (30) locations, representing 85.7% of the sampled area, exceed the accepted ICRP background level of 0.013 mRh^{-1}, the values also exceeded the range of values previously reported in the Niger Delta region [21,22,23,24]. The maximum exposure rate of 0.028 mRh^{-1} recorded at Zukewoi 1 could be because of the oil exploration activity involving dynamite sounding and industrial waste discharge released into the atmosphere. Ewoi community which comprises five kindred: Zukewoi, Igbeligbe, Obarogu, Ayeleba and Otuobom kindred recorded on average slightly high background radiation with no oil and gas facility except the oil exploration that is ongoing in the area due to the geological composition of the area in addition to radiations emission during the detonation of dynamite during shooting operations.

The high indoor annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR) recorded at all the sampling points are below the internationally permissible limit for radiological workers, but marginally above the limit for the general public. The calculated indoor annual effective doses may be due to the building materials and emissions from explosives. The implication is that the environment is gradually becoming unsafe for the general populace in the study area. At the present level, there is the danger of radionuclide build-up in the atmosphere and the precipitation of produced waters (that contain radioactive elements) which on condensation as rain may constitute radioactive pollution of rain water. Also, environmental pollution can arise from formation water entering as seepage and leakage from these source points (points where the dynamites are detonated) and carried to the sub-surface where they can make contact with the underground water and sea water. The associated radionuclide interacts with sulphates in the river and sea water where they partially precipitate and are consumed by aquatic animals, hence posing radiological risk to aquatic life and the final human consumer [24,25], result of this indirect radionuclide ingestion, the level of exposure of the community is greatly increased.

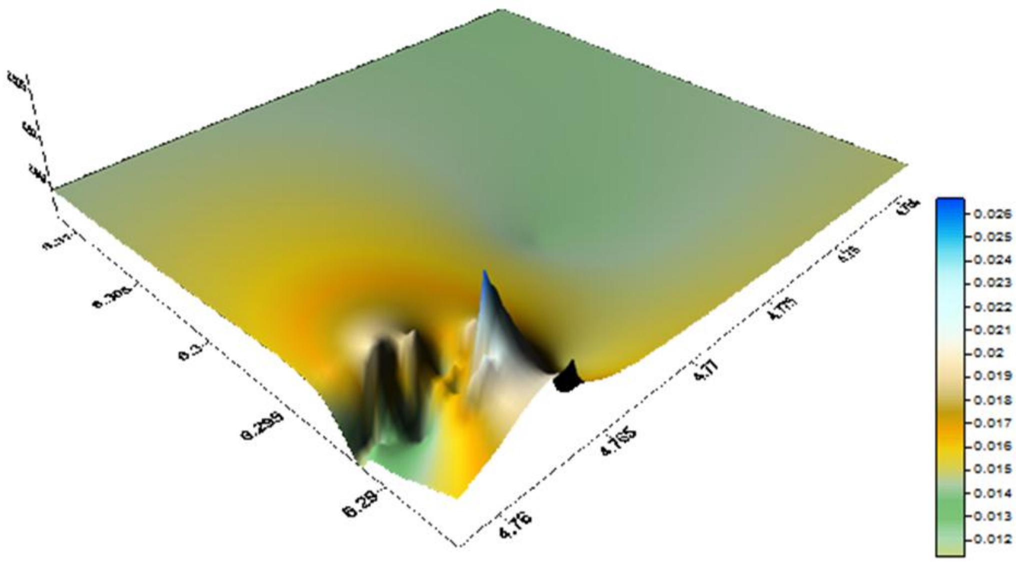

Fig. 2. 3-D radiological map of the study area

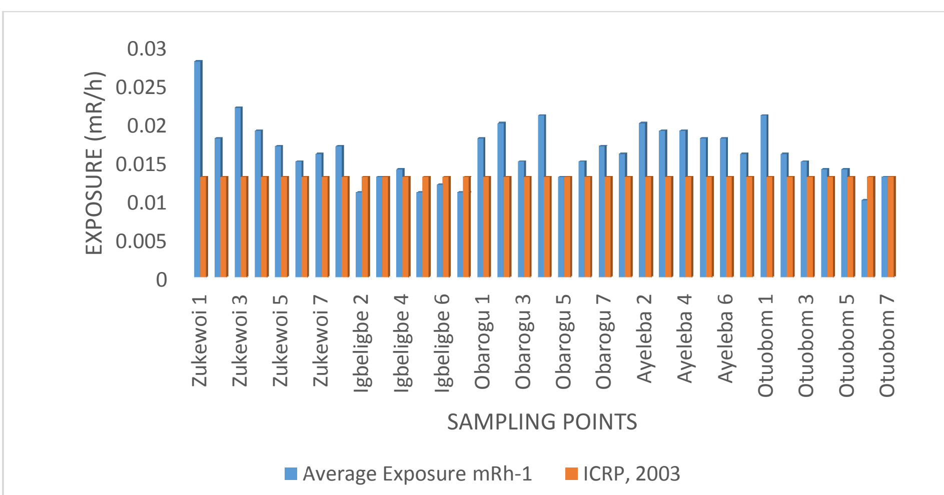

Fig. 3. Comparison of radiation exposure rate of various hamlet of Owai community with ICRP, 2003 standard

5. CONCLUSION

The environmental radioactivity profile of Ewoi community in Ogbia Local Government Area of Bayelsa State shows that the background radiation levels of the area may have been impacted by the activities of the oil and gas exploration company in this area. The impact may be due to input materials from seismic exploration activities emanating from dynamite explosions. It may also be attributed to geological composition of the area which contributed to the enhanced radiation level measured in that community. The absorbed dose and excess lifetime cancer risk estimated were far higher than the world safe value for the general public. Although our results indicate no immediate health hazards, there may be long term, future health effects on the general population of the studied community.

Considering the values obtained in this research work and the likely health impact, it is important that further studies be carried out on activity concentration of radionuclide on the soil, water (drinking water resources of the community), and food crops from Ewoi community for identification of radionuclides present and their concentrations in order to quantify their radiological health implications and ways to control it.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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