RADIOLOGICAL HEALTH RISK DUE TO GAMMA DOSE RATES AROUND OKPOSI OKWU AND UBURU SALT LAKES, EBONYI STATE

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ABSTRACT: *Human beings are always exposed to varying doses of terrestrial ionizing radiation which may pose immediate or long – term health risk at radiation doses higher than the suggested safe limit by radiation protection and measurement agencies. Therefore, it is important to quantitatively measure and evaluate the radiological health risk due to gamma dose rates around salt lake environments. In situ measurement of gamma dose level around Okposi Okwu and Uburu salt lakes in Ohaozara Local Government Area of Ebonyi State had been conducted using two well calibrated nuclear radiation metres (Radalert – 100 and Digilert – 50) and geographical position system (GPS). Readings were taking randomly in thirty one sampling geographical locations each around the salt lakes at the gonad level of about one metre above the ground to determine the absorbed dose rate (D) nGyh^{-1}, annual effective dose equivalent (AEDE) mSvy^{-1} and the excess lifetime cancer risk (ELCR). Comparatively, the D, AEDE and ELCR values obtained for Uburu salt lake were higher than Okposi Okwu salt lake. The D and ELCR values recorded for the two salt lakes exceeded the suggested safe limit 84 nGyh^{-1}and* 0.29×10^{-3} *for general public respectively, while the AEDE for the two lakes were found to be in good agreement with the 0.48 mSv prescribed standard safe limit for the general public. In general, the results showed that terrestrial background ionizing radiation due to radionuclides in soil within the salt lakes is high and chances of developing cancer by immediate populace over a long term exposure is very significant. Measurements have been taken as representing the baseline values for terrestrial outdoor gamma dose rate around the salt lakes. Length of time spent within the salt lakes and farming around the lakes should be minimized. There is also need to investigate the radionuclide content of food crop cultivated near the salt lakes.*

KEYWORDS: Radiation, Salt Lake, Excess Lifetime Cancer Risk, Dose Rate, Uburu, Okposi Okwu.

INTRODUCTION

Background ionizing radiations present in environment are mainly due to radiations from natural (cosmic ray and terrestrial) and human – made sources. Human populace is continuously and in most cases unconsciously exposed to varying doses in the terrestrial environment. Unlike non – ionizing radiation which include ultraviolet rays, visible light, infrared, microwaves and radio waves which may have only the thermal effects or no severe health effect, ionizing radiation include all particulate radiations (proton, neutron, alpha and beta particles) and the energetic x – rays and gamma rays [1] released during radioactive decay, have sufficient energy to knock off electrons from the atoms in the materials it interact with, hence are dangerous to health as it passes through human tissue and biological systems at higher doses. Exposure to ionizing radiation at elevated doses can initiate induction of cancer in organs and tissues of the body. New cases of cancer has been observed to be the major cause of mortality in recent times, therefore, it is essential to evaluate the radiological health risk associated with the exposure to background ionizing radiation in terrestrial environment.

The high energetic cosmic ray particles originates from the sun and interstellar spaces which interacts with the earth atmosphere producing radionuclides of ^{3}H, ^{23}Na, ^{14}C and ^{7}Be which during radioactive decay releases doses of ionizing radiation and particles in air; terrestrial radionuclides originate mostly from primordial radionuclides whose halve lives are comparable with the age of the earth, comprising of ^{238}U (Uranium - 238) and ^{232}Th (Thorium - 232) series and radioisotope of ^{40}K (potassium – 40) present in rock, soil and groundwater. The irradiation of human body by high cosmic rays and terrestrial gamma radiation doses from radionuclides of primordial origin is a major external source of ionizing radiation which contributes significantly to the absorbed dose rate (D) in air and annual effective dose equivalent (AEDE).

In addition to the natural sources, some of the man – made sources of ionizing radiation include ^{137}Cs, ^{134}Cs and ^{90}Sr usually released and dispersed from nuclear power plants at both normal and abnormal operations [2] and other artificial sources from medical, industrial, and commercial practices [3]. Commercial mining activities and the use of agrochemicals such as chemical fertilizers and organic manure have been identified to contain concentration of radionuclides [4, 5, 6, 7, and 8] and may redistribute radionuclide in environment.

Higher concentrations of natural background ionizing radiation are associated with igneous rock than the sedimentary rock areas of the world [9]. The amount of terrestrial gamma dose rate received by human beings from rocks and soil found in different locations varies due to geochemical and radionuclide characteristics of the materials. According to [10] the associated external exposure due to gamma radiation emitted by primordial radionuclides in the environment depends primarily on the geographical locations and the geological conditions. To avoid any epidemiological, somatic, and radiological side effect, International Commission on Radiation Protection [11] and United Nations Scientific Committee on Effects of Atomic Radiation [10] have recommended and consequently set average absorbed dose (D) and annual effective dose equivalent (AEDE) for general public as 84 $nGyh^{-1}$ and 0.48 $mSvy^{-1}$ while mean standard of 0.29×10^{-3} had been suggested as the excess life time cancer risk [10, 12].

Studies on external exposure to natural sources of ionizing radiation in different countries of the world using different measuring techniques have been conducted and reported worldwide [13,14,15,16,17,18,19,20 21]. Studies have shown that both natural and man-made nuclides have radiobiological implication because they significantly contribute to human external radiation dose and to the internal dose by inhalation and ingestion [22]. Studies on health effects due to ionizing radiations have produced substantial evidence that exposure to high level of radiations can cause illness such as cancer, cataract, mental disorder or even death. This study will set a baseline data for radiation levels of the two salt lakes and from the obtained data we shall estimate excess lifetime cancer risk and other health related parameters for the general populace that utilizes the salt lakes for their business.

MATERIALS AND METHOD

Study Area

Okposi Okwu (06^{0} 02′ 20″ N to 060 05′ 23″ N; 007^{0} 44′ 31″ E to 007^{0} 48′ 37″ E) and Uburu (06^{0} 04′ 04″ N to 06^{0} 07′ 00″ N; 007^{0} 45′ 30″ E to 0070 48′ 37″ E) town, found in the lower

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Benue Trough, are located in Ohaozara Local Government Area (LGA) in Ebonyi State, Southeastern Nigeria. The bedrock of the area is made up of sedimentry rocks belonging to the Asu – River group of Albian age [23,24,25,26]. According to [23], the lithology in the locality of the salt lakes varies with location; while Okposi is a mud filled depression surrounded by sandstone exposures, Uburu salt lake area (neighboring town) consist of sandstone beds with intercalation of fine grained bands of silts and shale. The fracture system within the bedrock is responsible for the occurrence of brine in the region [27]. The small scaled salt production in the locality has been for about 400 years [28] and elevated concentration of heavy metals had been reported from the samples of salt water from the lakes [29, 24]. The maps Okposi Okwu and Uburu salt lakes respectively are shown in **Figures 1 and 2**.

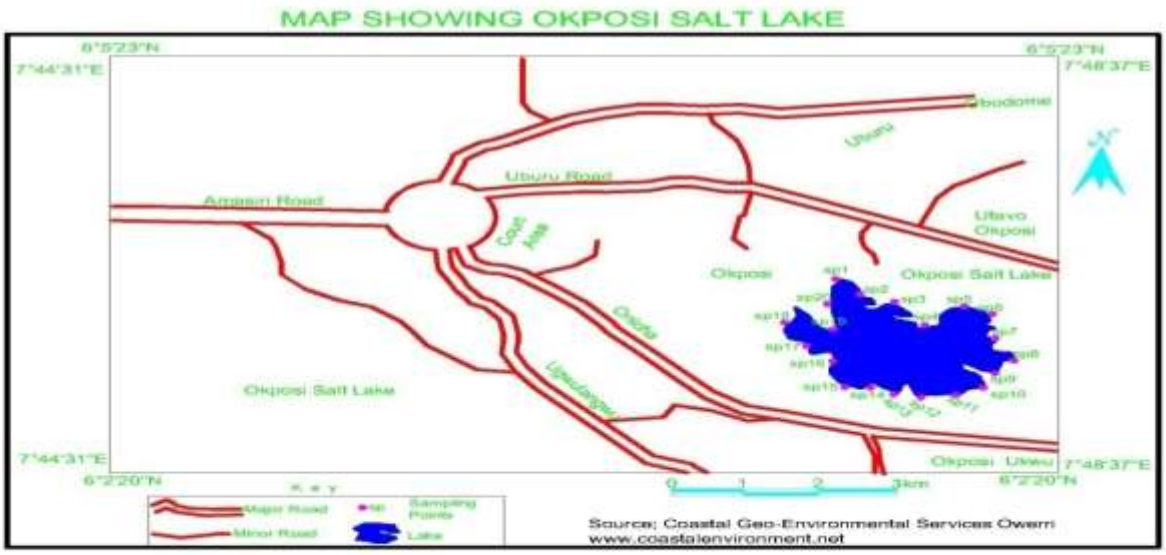

Figure 1. Map showing Okposi Okwu salt lake in Ohaozara LGA

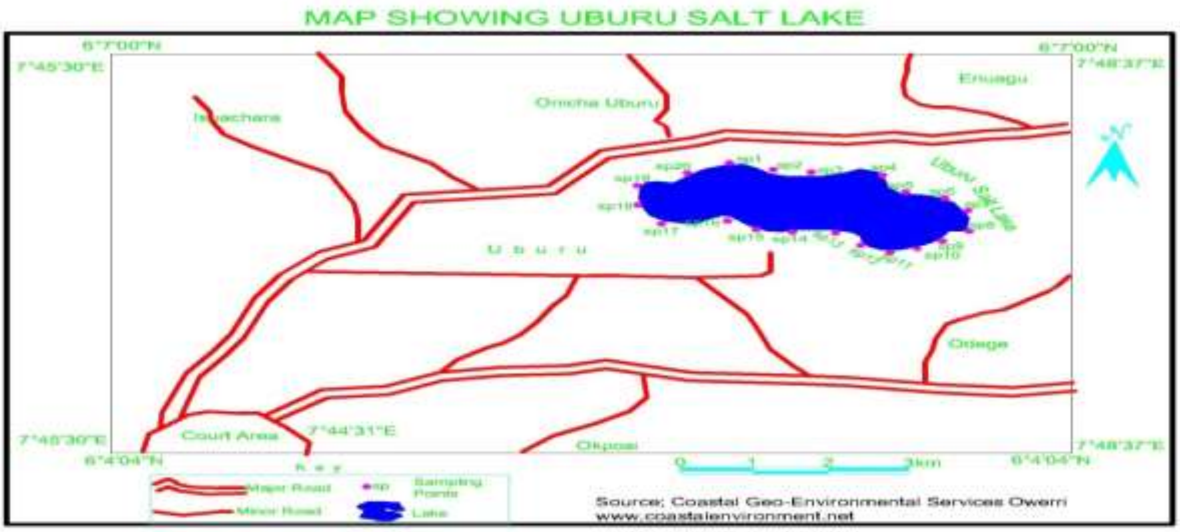

Figure. 2 Map showing Uburu salt lake in Ohaozara LGA

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Field Measurement

An *in situ* approach of background ionization radiation measurement was preferred and adopted to enable sample maintain their original environmental statistics [20] (Avwiri *et al.*, 2013). Measurements were carried out using two well calibrated nuclear radiation monitoring metre (Radarlert – 100 and Digilert – 50) (S.E International Inc. Summer Town, USA) containing a Geiger Muller Tube (GMT) capable of detecting alpha, beta, gamma and X – rays within the temperature range of $-10°C$ to $50°C$. The range of hours between 1200 and 1600 were considered since the exposure rate metre has a maximum response to environmental radiation within these hours.

The meters were held with its window facing the salt lake to be measured and then vertically downward. Each time radiation passes through the GMT and causes ionization, a pulse of electrical current is generates and each pulse is electronically detected and registered as a count. For each location two measurements spanning over 2 minutes were carried out and these measurements were then averaged to single value. Data obtained for outdoor exposure rate in mR/h was converted into absorbed dose rate nGy/h using the conversion factor [30]:

$$1\mu R/h = 8.7 \ nGy/h = 8.7 \times 10^{-3} \mu Gy/(1/8760)yr = 76.212\mu Gyy^{-1} \quad (1)$$

RESULTS

Table 1 shows the exposure rate measured at Okposi Okwu salt lake and the associated radiation parameters. The absorbed dose rate (D), ranged from 139.2 $nGyh^{-1}$ to 269.7 $nGyh^{-1}$ with mean and standard deviation of 187.8±37.40 $nGyh^{-1}$. While **Table 2** shows the exposure rate measured at Uburu salt lake and the associated radiation parameters. The absorbed dose rate in air ranged from 130.5 $nGyh^{-1}$ to 356.7 nGy^{-1} with mean and standard deviation of 214.1±58.90 $nGyh^{-1}$. The absorbed dose measured in the two salt lakes exceeded the world accepted values of 84 $nGyh^{-1}$ [10].

The Annual Equivalent Dose Equivalent (AEDE)

Measured absorbed gamma dose rates were used to calculate the annual effective dose equivalent (AEDE) received by people of surveyed area. For calculating AEDE we have used dose conversion factor of 0.7 Sv/Gy and the occupancy factor for indoor and outdoor was 0.75 (18/24), and 0.25 (6/24) respectively. Occupancy factor for indoor and outdoor situations were calculated based upon interviews with peoples of the study area. Peoples of study area spent almost 6 h in outdoor and 18 h in indoor environment. The annual effective dose is determined using the following equations [30].

$$AEDE_{(outdoor)} (mSv/y) = \text{Absorbed dose rate } (nGy/h) \times 8760h \times 0.7Sv/Gy \times 0.25 \times 10^{-6} \quad (2)$$

In the [31] report the Committee used 0.7 Sv/Gy for the conversion coefficient from absorbed dose in air to effective dose received by adults. From **Table 1**, the annual effective dose ranges from 0.213 to 0.413 $mSvy^{-1}$ with a mean and standard deviation of 0.288±0.045 $mSvy^{-1}$ for Okposi Okwu salt lake which is lower than the 0.48 $mSvy^{-1}$ recommended by [10] report.

While from **Table 2** , the annual effective dose equivalent for Uburu salt lake ranged from 0.200 to 0.547 mSvy^{-1} with a mean and standard deviation of 0.335$\pm$0.084 mSvy^{-1} .

3.2. Excess Lifetime Cancer Risk (ELCR)

Based upon calculated values of AEDE, Excess Lifetime Cancer Risk (ELCR) is calculated using Equation (3).

Excess lifetime cancer risk (ELCR) = AEDE x Average duration of life (DL) x Risk factor (RF) (3)

where AEDE, DL and RF is the annual effective dose equivalent, duration of life (70 years) and Risk factor (http://en.worldstat.info/Asia/ Pakistan) and risk factor (Sv^{-1}), fatal cancer 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 exposure. The excess lifetime cancer risk for Okposi Okwu ranged from 0.746 × 10^{-3} to 1.446× 10^{-3} with the mean of 1.007±0.155 while for Uburu lake, it ranged from 0.700 × 10^{-3} to 1.915 × 10^{-3} with the mean value of 1.173 × 10^{-3}.

Table 1. Excess lifetime cancer risk due to gamma dose rates at Okposi Okwu salt lake area.

Serial number	Geographical location	Average exposure rate $(mR\ h^{-1})$	D $(nGy\ h^{-1})$	AEDE $(mSv\ y^{-1})$	ELCR × 10^{-3}
1	N06° 02′ 13.3″ E007° 48′ 21.0″	0.027±0.002	234.9	0.360	1.260
2	N06° 02′ 13.4″ E007° 48′ 20.8″	0.020±0.002	174.0	0.267	0.935
3	N06° 02′ 13.5″ E007° 48′ 21.3″	0.027±0.001	234.9	0.360	1.260
4	N06° 02′ 13.7″ E007° 48′ 20.1″	0.022±0.004	191.4	0.293	1.026
5	N06° 02′ 13.9″ E007° 48′ 20.2″	0.019±0.001	165.3	0.253	0.886
6	N06° 02′ 14.3″ E007° 48′ 19.9″	0.023±0.004	200.1	0.307	1.075
7	N06° 02′ 14.7″ E007° 48′ 19.9″	0.018±0.001	156.6	0.240	0.840
8	N06° 02′ 15.0″ E007° 48′ 20.2″	0.021±0.002	182.7	0.280	0.980
9	N06° 02′ 15.2″ E007° 48′ 20.4″	0.024±0.005	208.8	0.320	1.120
10	N06° 02′ 15.0″ E007° 48′ 20.4″	0,021±0.004	182.7	0.280	0.980
11	N06° 02′ 15.1″ E007° 48′ 20.8″	0.019±0.001	165.3	0.253	0.886
12	N06° 02′ 15.2″ E007° 48′ 20.9″	0.016±0.003	139.2	0.213	0.746
13	N06° 02′ 15.3″	0.021±0.003	182.7	0.280	0.980

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	E007° 48′ 21.1″				
14	N06° 02′ 14.9″ E007° 48′ 21.3″	0.024±0.004	208.8	0.320	1.120
15	N06° 02′ 14.8″ E007° 48′ 21.4″	0.020±0.002	174.0	0.267	0.935
16	N06° 02′ 14.7″ E007° 48′ 21.5″	0.017±0.001	147.9	0.227	0.795
17	N06° 02′ 14.6″ E007° 48′ 21.6″	0.025±0.001	217.5	0.333	1.166
18	N06° 02′ 15.0″ E007° 48′ 21.7″	0.023±0.001	200.1	0.307	1.075
19	N06° 02′ 15.4″ E007° 48′ 21.8″	0.023±0.002	200.1	0.307	1.075
20	N06° 02′ 15.5″ E007° 48′ 20.3″	0.031±0.002	269.7	0.413	1.446
21	N06° 02′ 16.0″ E007° 48′ 20.4″	0.018±0.002	156.6	0.240	0.840
22	N06° 02′ 16.3″ E007° 48′ 20.4″	0.020±0.002	174.0	0.267	0.935
23	N06° 02′ 16.4″ E007° 48′ 20.2″	0.016±0.003	139.2	0.213	0.746
24	N06° 02′ 13.3″ E007° 48′ 21.0″	0.021±0.001	182.7	0.280	0.980
25	N06° 02′ 16.7″ E007° 48′ 21.3″	0.021±0.003	182.7	0.280	0.980
26	N06° 02′ 16.9″ E007° 48′ 19.9″	0.022±0.002	191.4	0.293	1.026
27	N06° 02′ 17.2″ E007° 48′ 19.9″	0.024±0.006	208.8	0.320	1.120
28	N06° 02′ 17.4″ E007° 48′ 20.2″	0.018±0.002	156.6	0.240	0.840
29	N06° 02′ 17.5″ E007° 48′ 20.3″	0.021±0.003	182.7	0.280	0.980
30	N06° 02′ 17.7″ E007° 48′ 20.2″	0.024±0.002	208.8	0.320	1.120
31	N06° 02′ 17.8″ E007° 48′ 20.3″	0.023±0.002	200.1	0.307	1.075
	Mean±SD*	**0.022±0.002**	**187.8±34.4**	**0.288±0.045**	**1.007±0.155**
	CV**	**0.09**	**0.18**	**0.16**	**0.15**
	UNSCEAR, (2000)		**84**	**0.48**	**0.290×10^{-3}**

SD* is Standard deviation, CV is coefficient of variation**

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Table 2. Excess lifetime cancer risk due to gamma dose rates at Uburu salt lake area.

Serial number	Geographical location	Average exposure rate $(mR\ h^{-1})$	D $(nGy\ h^{-1})$	AEDE $(mSv\ y^{-1})$	ELCR × 10^{-3}
1	N06° 02′ 55.2″ E007° 44′ 49.3″	0.015±0.001	130.5	0.200	0.700
2	N06° 02′ 55.0″ E007° 44′ 49.2″	0.017±0.002	147.9	0.227	0.795
3	N06° 02′ 54.8″ E007° 44′ 49.2″	0.020±0.005	174.0	0.267	0.935
4	N06° 02′ 54.6″ E007° 44′ 49.1″	0.023±0.001	200.1	0.307	1.075
5	N06° 02′ 54.5″ E007° 44′ 48.9″	0.027±0.001	234.9	0.360	1.260
6	N06° 02′ 54.3″ E007° 44′ 48.8″	0.022±0.002	191.4	0.293	1.026
7	N06° 02′ 54.2″ E007° 44′ 48.1″	0.023±0.004	200.1	0.307	1.075
8	N06° 02′ 54.2″ E007° 44′ 48.8″	0.019±0.001	165.3	0.253	0.886
9	N06° 02′ 53.3″ E007° 44′ 49.6″	0.025±0.002	217.5	0.333	1.166
10	N06° 02′ 53.2″ E007° 44′ 49.7″	0.017±0.001	147.9	0.227	0.795
11	N06° 02′ 53.0″ E007° 44′ 49.8″	0.024±0.002	208.8	0.320	1.120
12	N06° 02′ 52.9″ E007° 44′ 49.9″	0.030±0.001	261.0	0.400	1.400
13	N06° 02′ 52.6″ E007° 44′ 49.8″	0.035±0.001	304.5	0.467	1.635
14	N06° 02′ 55.1″ E007° 44′ 48.5″	0.021±0.001	182.7	0.280	0.980
15	N06° 02′ 55.2″ E007° 44′ 48.2″	0.021±0.002	182.7	0.280	0.980
16	N06° 02′ 55.4″ E007° 44′ 47.2″	0.021±0.003	182.7	0.280	0.980
17	N06° 02′ 55.8″ E007° 44′ 46.6″	0.021±0.002	182.7	0.280	0.980
18	N06° 02′ 56.0″ E007° 44′ 46.4″	0.028±0.002	243.6	0.373	1.306
19	N06° 02′ 56.5″ E007° 44′ 45.3″	0.022±0.002	191.4	0.293	1.026
20	N06° 02′ 56.3″ E007° 44′ 45.1″	0.023±0.002	200.1	0.307	1.075
21	N06° 02′ 56.1″ E007° 44′ 44.8″	0.017±0.002	147.9	0.227	0.795
22	N06° 02′ 55.9″	0.028±0.001	243.6	0.373	1.306

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	E007° 44′ 44.7″				
23	N06° 02′ 55.8″ E007° 44′ 44.5″	0.033±0.003	287.1	0.440	1.540
24	N06° 02′ 55.8″ E007° 48′ 44.4″	0.041±0.002	356.7	0.547	1.915
25	N06° 02′ 55.9″ E007° 44′ 44.1″	0.030±0.003	261.0	0.400	1.400
26	N06° 02′ 55.8″ E007° 44′ 43.9″	0.025±0.003	217.5	0.333	1.166
27	N06° 02′ 55.7″ E007° 44′ 43.7″	0.034±0.002	295.8	0.400	1.400
28	N06° 02′ 55.7″ E007° 44′ 43.3″	0.031±0.001	269.7	0.413	1.446
29	N06° 02′ 55.6″ E007° 44′ 42.0″	0.024±0.004	208.8	0.320	1.120
30	N06° 02′ 55.4″ E007° 44′ 42.6″	0.029±0.002	252.3	0.387	1.355
31	N06° 02′ 55.7″ E007° 44′ 42.5″	0.034±0.002	295.8	0.453	1.586
	Mean±SD*	**0.025±0.02**	**214.1±58.9**	**0.335±0.084**	**1.173±0.537**
	CV**	**0.8**	**0.28**	**0.25**	**0.46**
	UNSCEAR, (2000)		**84**	**0.48**	**0.290**

SD* is Standard deviation, CV is coefficient of variation**

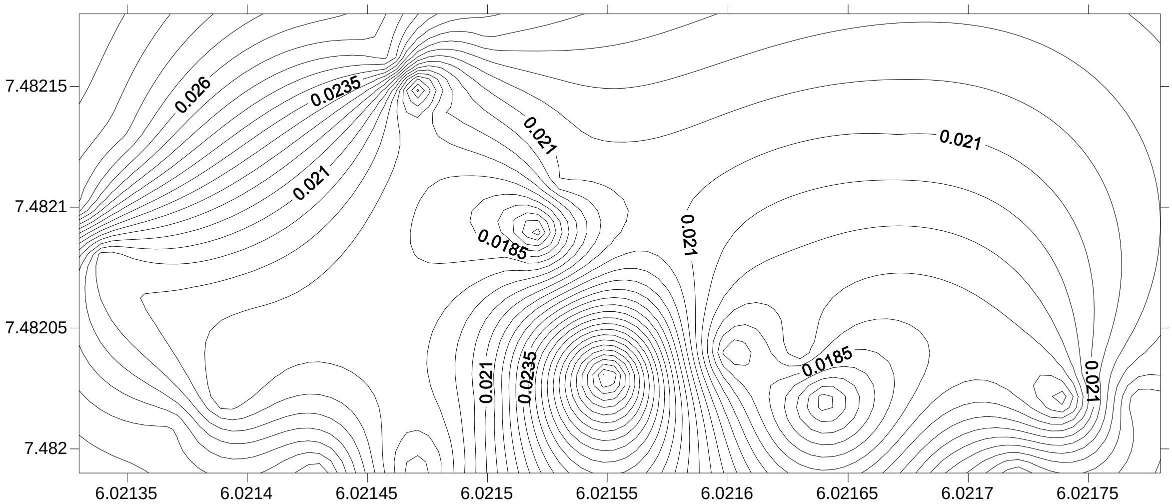

Figure 3. Radiation Contour map of Okposi Okwu Salt Lake

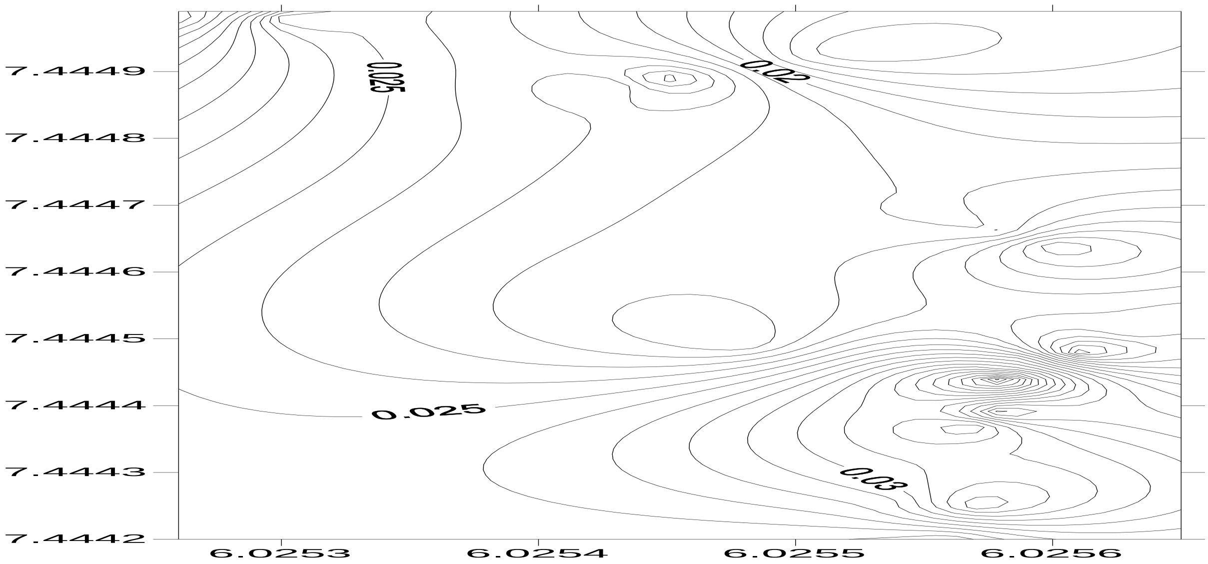

Figure 4. Radiation Contour map of Uburu Salt Lake

DISCUSSION

The mean absorbed dose rate and annual effective dose equivalent for Uburu salt lake slightly exceeded that of Okposi Okwu which could be attributed to the variation of the lithology in the locality of the salt lakes as reported in the literature and variation in concentration of radioactive elements present in the local geological formation. Diverse lithology and associated complex tectonic features contributes to environmental radioactivity [16]. Generally, the bedrock of the area which is made up of sedimentry rocks principally accounts for higher gamma dose rate obtained in this work. The coefficient of variation showed that Uburu salt lake result is more widely dispersed than Okposi Okwu.

Studies on external exposure due to activity concentration of radionuclides present within salt lake environment are relatively not available however it is interesting to compare the results with rocky, mining, oil producing, waste dumpsites and industrial areas as well as sediments of lake water. The absorbed dose rate (D) for the present study were higher than the work conducted in Nile Delta Egypt by [14]; reported work of [12] from Kirklareli Turkey; [16] work in Kumaun Himalaya, India, and [32] in Northern Pakistan.

The mean AEDE result for Okposi Okwu and Uburu respectively were found to be higher than that obtained in Sabo area of Abeokuta [2]; Kitcheener Drain in Nile Delta Egypt [13]; 0.063 $mSv\ y^{-1}$ established by [33] in soil samples collected from Albaha Region located in South west, Saudi Arabia; and the value recorded in FCT, Abuja Nigeria [21]. The AEDE obtained in Okposi Okwu agrees with the reported work of [2] in Abeokuta and Jos both in Southwestern and North central Nigeria. However, the results of the present study were found to be lower than [13] study at Obantoku area; [19] work in Nasarawa State; [34] and [16] works both in India. Comparing the AEDE results of the present study with permissible limit of 0.48 $mSvy^{-1}$ recommended by [10] for general public, it suffice to say that the salt lakes environ are in good agreement with permissible limit and are relatively locations of high background ionizing

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radiation than some reported work in the literature and unsafe for the immediate populace living very close to the lakes.

Furthermore, the calculated mean excess lifetime cancer risk, within Uburu salt lake 1.173×10^{-3} was higher than that recorded in Okposi Okwu salt lake 1.007×10^{-3}. However, the results respectively were about 4.0 and 3.5 times higher than the average standard value of 0.29×10^{-3} [10,12], it means that the probability of developing cancer over a life time is very high in the locality. The relatively higher ELCR values recorded in this work as observed from **Tables 1** and **2** were due to D and AEDE results which may be traceable to enhanced concentration of naturally occurring radioactive materials in the locality. The results of the present study were higher than [12] work from Turkey; [35] in Udi and Ezeagu Local Government Area of Enugu state Nigeria; [30] in Jhelum valley of the state of Azad Kashmir; [32] from Northern Pakistan; [36] from oil producing communities in Nigeria. In addition, Uburu and Okposi Okwu results respectively were in good agreement with 1.12×10^{-3} (Faroun Zone) and 1.05×10^{-3} (Anabta Zone) both at large scale manufacturing industrial areas of Tulkarem Province of Palestine [37]. However, both results were lower than 3.21×10^{-3} obtained in Oguta lake, Imo state, Nigeria [38]. The radiation contour map for Okposi Okwu and Uburu salt lake are shown in .**Figures 3 and 4** respectively.

CONCLUSION

The study showed that the salt lake environs are locations of higher background ionizing radiation than some studies reported in the literature and as a consequence the immediate populace is seriously exposed to high gamma dose rates emanating from the salt lakes environ. Furthermore, the assessment of excess lifetime cancer risk due to gamma dose rate revealed that the probability of developing cancer over the average life span (estimated as 70years) is higher than reported works in the literature. This work provides essential baseline information useful to radiation protection and measurement agencies and for future references in the area. Residential houses and farm lands should be sited far away from the salt lakes and also regular monitoring of background ionizing radiation levels within the environment should be encouraged. Since the areas within the salt lakes produce large quantities of food crops and livestock that are distributed within the neighboring localities, there is therefore need to examine the radionuclide content and radiological risk indices of food crops and livestock produced within the areas.

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