

Evaluation of Health Effect of Gamma Radiation from Uburu and Okposi-Okwu Salt-Lakes in Ebonyi State, During Rainy and Dry Seasons

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Abstract: A comparative study of the gamma radiation in Uburu and Okposi-Okwu Salt-Lakes located in Ohaozara Local Government Area of Ebonyi State, during rainy and dry seasons was carried out using a hand-held RadEye G20-ER10 gamma survey meter and a geographical position system. Three samples were taken randomly from five different points of the two Salt-Lakes and their host communities during both seasons and their averages were recorded. An in-situ exposure rate measurements were used to evaluate the absorbed dose rate, the annual effective dose and the Excess Lifetime Cancer Risk. The results obtained were compared with the world average so as to determine the health risk to the studied environment. The mean exposure rate, absorbed dose rate (ADR), annual effective dose (AED), and excess lifetime cancer risk (ELCR) from Uburu and Okposi-Okwu Salt-Lakes during rainy season were 0.139 $\mu\text{Sv/h}$, 138.8 nGy/h, 0.170mSv/y and 0.596×10^{-3} ; 0.123 $\mu\text{Sv/h}$, 121.8 nGy/h, 0.149mSv/y and 0.523×10^{-3} respectively. Also, the mean exposure rates, ADR, AED, and ELCR from Uburu and Okposi-Okwu Salt-Lake during dry season were 0.177 $\mu\text{Sv/h}$, 176.6 nGy/h, 0.216mSv/y and 0.758×10^{-3} ; 0.174 $\mu\text{Sv/h}$, 173.3 nGy/h, 0.213mSv/y and 0.746×10^{-3} respectively. All the assessed results are higher than the world standard value for the general public. These results showed that the studied areas are radiation contaminated. The results within the Salt Lake environment are higher than the results from their host communities. This may be attributed to the activities within the Salt Lake environment such as local salt processing. Also, the results from the two studied areas during dry season were higher than that of the rainy season.

Keywords: Excess Lifetime Cancer Risk, Gamma Radiation, Uburu and Okposi-Okwu Salt-Lake, Rainy and Dry Season

1. Introduction

Man is naturally exposed to varying amounts of background radiation with or without his consent since the creation of the earth. The amount of radiation coming from the background radiation is greater than the amount of radiation from all manmade sources [1]. Radioactive materials occurs naturally in our environment and our body also contain some of the radioactive materials like carbon-14, potassium-40 and polonium-210 [2]. It is present in the food we eat, the water we drink, the building materials used in building our homes and even in the air we breath [3].

The main sources of background radiation are cosmic radiation and terrestrial radiation [4]. Cosmic radiation comes from the sun and outer space and varies with altitude and latitude and the level of its exposure increases with altitude because there is less air overhead to act as a shield [5]. The terrestrial radiation are radiation due to the presence of radioactive materials such as uranium, thorium, and radium and their decay product such as radon in the soil, water and rocks which exist naturally since the birth of the earth. Radon can be found in the air we breathe [5], it contributes majorly to the total doses received from natural background sources [6]. Its concentration differ from one location to another, but

locations with uranium deposit will have higher concentration of it [5]. The natural radiation sources is enhanced by human activities such as the release of natural radionuclides into the environment in mineral processing, fossil fuel combustion and quarry activity, causing higher radiation exposures. Some people are exposed to this enhanced levels of natural radiation at their homes (people that lives close to quarry site), places of work like the underground miners, workers involved in mineral processing [1].

Radiation can cause several hazards to man and the environment when exposed to unregulated radiation, hence it is expected that the background radiation within our homes, schools, place of work be evaluated and ensure that our exposure is within the world acceptable range to avoid the risks associated with them. Some of the radiation exposure risks include cancer induction, genetic deformations, neonatal death, malformations, growth retardation, congenital defects and cancer induction on fetus, cataracts, skin effect [7]. Since radiation cannot be totally removed from our environment and none of its dose rate is safe, it is expected that the radiation absorbed doses be reduced as low as reasonably achievable (ALARA). This can be done by maintaining distance from sources of radiation and shielding of radioactive sources, limiting the time spent in areas where radioactive materials are, shielding of radiation workers [8], proper managing of radioactive waste in accordance with the lay down rules [9].

The natural radionuclides emits gamma radiation which is the main source of external irradiation of the human body. It may be acquired unknowingly by inhalation, absorption or ingestion [10]. Even though radiation from these sources are generally of low doses, it can pose health risks. A research carried out by [11] recorded that the Uburu and OkposiOkwu Salt Lakes have high background radiation. The Uburu and OkposiOkwu host communities were not included in their research measurement neither did their work extend to raining season, hence, to evaluate the absorbed dose rate, annual effective dose rate and the excess lifetime cancer risk within the Uburu and OkposiOkwu Salt Lakes and their host communities during rainy and dry seasons are the aims of this study. The obtained results from this study will serve as base line information in the studied areas for future references.

2. Materials and Method

2.1. Study Area

The Uburu and OkposiOkwu Salt Lakes are located within Ohaozara Local government area of Ebonyi State, Nigeria. The two towns lie between $06^{\circ} 02' 60''\text{N}$; $07^{\circ} 44' 52''\text{E}$ and $06^{\circ} 02' 20''\text{N}$; $07^{\circ} 48' 37''$ respectively. The bedrock of this place comprises of sedimentary rocks which has a place with the Asu river group of Cenomanian age [12]. Farming activities and small scale salt production by some of the women are the main occupations of those living around this area. Their major villages include: Okposi, Mgbo, Mebi,

Umuka, Amechi, Amenu; Uburu, AroAkeEze. The picture of Uburu and OkposiOkwu Salt Lakes are shown in the Figures 1 and 2 below;



Figure 1. Uburu Salt Lake.



Figure 2. OkposiOkwu Salt Lake.

2.2. Field Measurement

The exposure rate in air within the Salt Lakes and their host communities during rainy and dry seasons at 1m above the soil surface was measured using a hand-held RadEye G20 – ER10 gamma survey meter. RadEye G20 – ER10 is a hand-held gamma survey meter with 17 kev to 1.3 Mev flat energy response curve according to ambient equivalent dose rate $H^*(10)$. Its model have a measuring range of $0.01 \mu\text{Sv/h}$ to 100 mSv/h and a temperature range of 20°C to $+50^{\circ}\text{C}$. It has quick response even below $1 \mu\text{Sv/h}$, rugged and compact design with a thick protective rubber cover, a huge internal data memory, and earphone output for operation in a noisy environment, a bright backlit LCD display.

The in-situ background radiation level evaluation within these Salt Lakes and its environments was conducted for both rainy and dry seasons (July, 2019 to March, 2020) so as to account for any alteration in environmental parameters due to seasonal situation, and to account for radiation fluctuating nature. Three measurements were conducted randomly at each sampling point (four different points within each of the

Salt Lake area and a total of sixteen different sampling points for both seasons, a point within their host communities and a total of four sampling points for both seasons) and their average were taken as shown in Tables 1, 3, 5 and 7 below. Sample code E and O are the sampled points from Uburu Salt Lake's host community during rainy and dry season respectively whereas J and T are the sampled points from OkposiOkwu Salt Lake's host community. The measured exposure rate in $\mu\text{Sv/h}$ from the field were converted to absorbed dose rate in nGy/h using equation (1) [13].

$$ABR(\text{nGy} / \text{h}) = \frac{\text{Exposure rate}(\mu\text{Sv} / \text{h})}{Q} \times 10^{-3} \quad (1)$$

$$\text{Effective dose rate}(\text{mSv} / \text{y}) = D(\text{nGy} / \text{h}) \times 8760\text{hrs} \times 0.2 \times 0.7(\text{Sv} / \text{Gy}) \times 10^{-6} \quad (2)$$

Where;

D=absorbed dose

8760=24hrs \times 365days

0.2=occupancy factor

0.7=conversion coefficient

2.4. Excess Lifetime Cancer Risk (ELCR)

The excess lifetime cancer risk is a measure of the probability that an individual or a group exposed to a certain level of external gamma radiation will develop cancer over a lifetime. An increase in ELCR increases the rate of breast, blood or prostate cancer development [16]. The excess lifetime cancer risk from the measured samples was calculated using eq. (3) [17].

$$ELCR = AED(\text{mSv} / \text{y}) \times DL(\text{yrs}) \times RF(\text{Sv}^{-1}) \quad (3)$$

Where;

AED=Annual effective dose

DL=duration of life assumed to be 70yrs for stochastic

Where;

Exposure rate ($\mu\text{Sv} / \text{h}$) =exposure rate measured in ($\mu\text{Sv} / \text{h}$)

ABR (nGy / h) =absorbed dose rate in (nGy / h)

Q=quality factor which is 1 for gamma radiation [14]

2.3. Annual Effective Dose (AED)

For the annual effective dose (AED) estimation, the 0.7 Sv/Gy conversion coefficients from the absorbed dose in air to effective dose, and 0.2 occupancy factor were used as recommended by [14]. The effective dose rate (mSv/y) of the study area was calculated using equation (2) as given by [15].

effects

RF=fatal cancer-risk factor, which is 0.05 for the general public

3. Results and Discussion

The exposure rate in $\mu\text{Sv/h}$ and their average, measured from Uburu Salt Lake and its host community during rainy and dry seasons are presented in 1 and 3 respectively. The calculated absorbed dose rate (ABR) in nGy/h , the annual effective dose (AED) and the excess lifetime cancer risk (ELCR) from the Uburu Salt Lake during rainy and dry seasons are also presented in Tables 2 and 4 respectively. Also, the exposure rate in $\mu\text{Sv/h}$ and their average, measured from OkposiOkwu Salt Lake and its host community during rainy and dry seasons are presented in Tables 5 and 7 respectively. Their calculated ABR in nGy/h , the AED and the ELCR from the same Salt Lake during rainy and dry seasons are presented in Tables 6 and 8 respectively.

Table 1. Exposure rate in $\mu\text{Sv/h}$ measured at 1 m above the ground level in Uburu Salt Lake during rainy season.

Sample Code	Geographical Location	Exposure rate 1 ($\mu\text{Sv/h}$)	Exposure rate 2 ($\mu\text{Sv/h}$)	Exposure rate 3 ($\mu\text{Sv/h}$)	Average
A	N06°02'54.8" E07°44'49.2"	0.16	0.15	0.17	0.16
B	N06°02'54.9" E07°44'49.3"	0.15	0.12	0.11	0.13
C	N06°02'55.2" E07°44'49.4"	0.15	0.17	0.16	0.16
D	N06°02'55.6" E07°44'49.8"	0.14	0.15	0.12	0.14
E	N06°02'58.2" E07°44'50.8"	0.13	0.09	0.11	0.11

Table 2. Calculated ABR in nGy/h , the AED in mSv/y and the ELCR measured at 1 m above the ground level from Uburu Salt Lake during rainy season.

Sample Code	ADR (nGy/h)	AED (mSv/y)	ELCR 10^{-3}
A	160.00	0.20	0.69
B	127.00	0.16	0.55
C	160.00	0.20	0.69
D	137.00	0.17	0.59
E	110.00	0.14	0.47
Meanvalue	138.80	0.17	0.60

Table 3. Exposure rate in $\mu\text{Sv/h}$ measured at 1 m above the ground level in Uburu Salt Lake during dry season.

Sample Code	Geographical Location	Exposure rate1 ($\mu\text{Sv/h}$)	Exposure rate 2 ($\mu\text{Sv/h}$)	Exposure rate 3 ($\mu\text{Sv/h}$)	Average
K	N06°02'54.6" E07°44'49.0"	0.19	0.20	0.22	0.20
L	N06°02'54.7" E07°44'49.2"	0.17	0.18	0.21	0.19
M	N06°02'54.9" E07°44'49.3"	0.16	0.17	0.18	0.17
N	N06°02'55.4" E07°44'49.6"	0.16	0.17	0.18	0.17
O	N06°02'58.0" E07°44'50.4"	0.14	0.15	0.17	0.15

Table 4. Calculated ABR in nGy/h, the AED in mSv/y and the ELCR measured at 1 m above the ground level from Uburu Salt Lake during dry season.

Sample Code	ADR (nGy/h)	AED (mSv/y)	ELCR $\times 10^{-3}$
K	203.00	0.25	0.87
L	187.00	0.23	0.80
M	170.00	0.21	0.73
N	170.00	0.21	0.73
O	153.00	0.19	0.66
Meanvalue	176.60	0.22	0.76

Similarly, the exposure rates in $\mu\text{Sv/h}$ at 1m above the ground level measured directly from the OkposiOkwu Salt Lake during rainy and dry seasons are presented in Tables 5 and 7 respectively and their calculated absorbed dose rate in nGy/h are presented in Tables 6 and 8 below;

Table 5. Exposure rate in $\mu\text{Sv/h}$ measured at 1 m above the ground level in OkposiOkwu Salt Lake during rainy season.

Sample Code	Geographical Location	Exposure rate 1 ($\mu\text{Sv/h}$)	Exposure rate 2 ($\mu\text{Sv/h}$)	Exposure rate 3 ($\mu\text{Sv/h}$)	Average
F	N06°02'15.2" E07°48'20.4"	0.15	0.14	0.11	0.13
G	N06°02'15.6" E07°48'20.10"	0.12	0.14	0.13	0.13
H	N06°02'15.7" E07°48'20.12"	0.14	0.12	0.13	0.13
I	N06°02'15.9" E07°48'20.13"	0.10	0.11	0.13	0.11
J	N06°02'18.5" E07°48'23.4"	0.11	0.10	0.10	0.10

Table 6. Calculated ABR in nGy/h, the AED in mSv/y and the ELCR measured at 1 m above the ground level from OkposiOkwu Salt Lake during rainy season.

ADR (nGy/h)	AED (mSv/y)	ELCR $\times 10^{-3}$
133.00	0.16	0.57
130.00	0.16	0.56
130.00	0.16	0.56
113.00	0.14	0.49
103.00	0.13	0.44
121.80	0.15	0.52

Table 7. Exposure rate in $\mu\text{Sv/h}$ measured at 1 m above the ground level in OkposiOkwu Salt Lake during dry season.

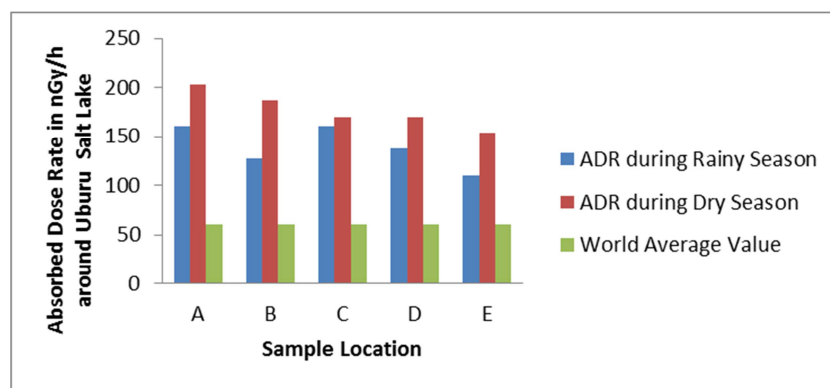
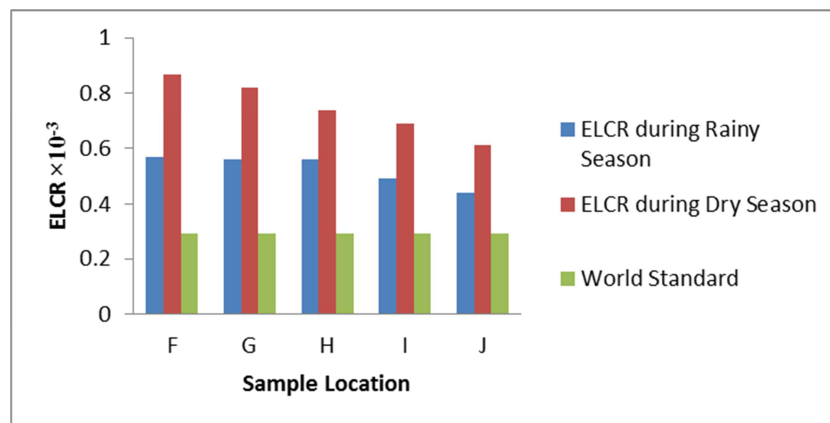
Sample Code	Geographical Location	Exposure Rate 1 ($\mu\text{Sv/h}$)	Exposure Rate 2 ($\mu\text{Sv/h}$)	Exposure Rate 3 ($\mu\text{Sv/h}$)	Average
P	N06°02'15.0" E07°48'20.2"	0.15	0.18	0.28	0.20
Q	N06°02'15.4" E07°48'20.6"	0.15	0.17	0.25	0.19
R	N06°02'15.8" E07°48'20.11"	0.15	0.17	0.20	0.17
S	N06°02'15.12" E07°48'20.16"	0.15	0.16	0.17	0.16
T	N06°02'18.9" E07°48'23.8"	0.14	0.15	0.14	0.14

Table 8. Calculated ABR in nGy/h, the AED in mSv/y and the ELCR measured at 1 m above the ground level from OkposiOkwu Salt Lake during dry season.

Sample Code	ADR (nGy/h)	AED (mSv/y)	ELCR $\times 10^{-3}$
P	203.00	0.25	0.87
Q	190.00	0.23	0.82
R	173.00	0.2	0.74
S	160.00	0.20	0.69
T	143.00	0.18	0.61
Mean value	173.30	0.21	0.75

Table 9. Mean Exposure Dose Rate and the Estimated Hazard Parameters from the two Salt Lakes during both rainy and dry seasons.

S/N	Sample Area	Average Exposure Rate (μ Sv/h)	Absorbed Dose Rate (nGy/h)	Annual Effective Dose (mSv/y)	ELCR $\times 10^{-3}$
1	Uburu Salt Lake during raining season	0.14	138.80	0.17	0.60
2	Uburu Salt Lake during dry season	0.18	176.60	0.22	0.76
3	OkposiOkwu Salt Lake during raining season	0.12	121.80	0.15	0.52
4	OkposiOkwu Salt Lake during raining season	0.17	173.30	0.21	0.75
	World Standard	0.13	60	0.07	0.29

**Figure 3.** Comparison of the absorbed dose rate during rainy season with the absorbed dose rate during dry season around Uburu Salt Lake and its host community and the World average value.**Figure 4.** Comparison of the ELCR during rainy season with the ELCR dry season around OkposiOkwu Salt Lake and its host community and the world standard.

From figures 3 and 4 above, we observed that the absorbed dose rate and the excess lifetime cancer risk during dry season within the two Salt Lakes are higher than that of the rainy season and the world standard value. It was also observed that as one move away from the Salt Lake environment, the absorbed dose rate decreases.

3.1. Absorbed Dose Rate

The absorbed dose rate determines the amount of radiation

energy absorbed by an exposed person. The averaged exposure rates in air measured at 1m above the ground level were converted to absorbed dose rate using equation (1). From Tables 2 and 4, we observed that the calculated absorbed dose rate from Uburu Salt Lake and its host community during rainy season ranged from 110 to 160 nGy/h with a mean value of 138.8 nGy/h whereas that of dry season ranged from 153 to 203 nGy/h with a mean value of 176.6. Also from tables 6 and 8, we saw that the absorbed rate from OkposiOkwu Salt Lake and its host community

during rainy season ranged from 103 to 133 nGy/h with a mean value of 121.8 while that of dry season ranged from 143 to 203 with a mean value of 173.3 nGy/h. These absorbed dose rates from the two study area are much higher than the world weighted average of 60.00 nGy/h [14]. The above absorbed dose rate shows that this study area is contaminated by radiation. However, there may be no immediate health effects at this level to the inhabitants of the area but the possibility of long term health effects due to radiation accumulated dose from this area is high. The mean absorbed dose rate is higher than “12.3 nGy/h, 17.27 nGy/h and 18.87 nGy/h” reported by [2] in Ohimini and Gwer-East Granite Quarry sites, Benue State Nigeria, 66.396 nGy/h, 59.511 nGy/h, 83.739 nGy/h, 100.011 nGy/h and 112.752 nGy/h reported in Egypt by [18] from quarries raw materials in El-Minya Governorate, and the mean outdoor external dose of 87.47 nGy/h reported by [19] from Northern Pakistan river sediments. However, the mean absorbed dose rate from the study are lower than 181.2 ± 66.8 nGy/h, 167.2 ± 43.0 nGy/h and 191.6 ± 29.6 nGy/h obtained in Mine tailings in Southwestern Uganda by [21], and the mean result of 541.4 nGy/h reported by [10] from the Tabaka soapstone quarries of the Kisii Region, Kenya.

3.2. Annual Effective Dose (AED)

The annual effective dose (mSv/y) of the studied areas was calculated using equation (2) and their results are presented in Tables 2, 4, 6 and 8. From Tables 2 and 4, we observed that the calculated annual effective dose from Uburu Salt-Lake and its host community during rainy season ranged from 0.135 to 0.196 mSv/y with a mean value of 0.170 mSv/y whereas that of dry season ranged from 0.188 to 0.249 mSv/y with a mean value of 0.216 mSv/y. Also from Tables 6 and 8, we saw that the annual effective dose from OkposiOkwu Salt Lake and its host community during rainy season ranged from 0.126 to 0.163 mSv/y with a mean value of 0.149 mSv/y while that of dry season ranged from 0.175 to 0.249 mSv/y with a mean value of 0.213 mSv/y. The mean AED from the two Salt Lakes during rainy season are two times higher than the world average value of 0.07 mSv/y [20; 14] whereas that of dry season are three times higher than the world average. The Uburu result during rainy season is in good agreement with 0.17 ± 0.04 mSv/y reported by [20] in Delta state of Nigeria while that of OkposiOkwu is in agreement with 0.159 ± 0.03 mSv/y reported by [15] in Fimie market Port Harcourt Metropolis and 0.155 ± 0.006 mSv/y reported by [22] in Emene Industrial Layout of Enugu State, Nigeria. However, the results from the two studied Salt Lakes in both dry season and wet season are lower than 0.92 mSv/y reported by [19] in Northern Pakistan, “ 0.37 ± 0.14 mSv/y, 0.34 ± 0.09 mSv/y and 0.39 ± 0.06 mSv/y”, reported by [21] in Southwestern Uganda and 0.44 mSv/y reported by [10] in Kisii Region, Kenya.

3.3. Excess Lifetime Cancer Risk (ELCR)

The excess lifetime cancer risk from the measured samples

was calculated using equation (3) and are presented in Tables 2, 4, 6 and 8. The calculated Excess lifetime cancer risk from Uburu Salt lake during rainy season ranged from 0.496×10^{-3} to 0.686×10^{-3} with a mean value of 0.596×10^{-3} whereas its value during dry season ranged from 0.658×10^{-3} to 0.872×10^{-3} with the mean value of 0.758×10^{-3} . Also, the ELCR from OkposiOkwu Salt Lake during rainy season ranged from 0.441×10^{-3} to 0.571×10^{-3} with a mean value of 0.523×10^{-3} while that of dry season ranged from 0.613×10^{-3} to 0.892×10^{-3} with a mean value of 0.746×10^{-3} . The mean values of ELCR from the two Salt Lakes during dry and rainy seasons are 2.6 and 2 times higher the world average value of 0.29×10^{-3} respectively [14]. These high values show that there is probability of developing cancer by the residents of these studied areas who will spend their entire life time within these areas. The results from both Salt Lakes during rainy season are in good agreement with $0.541 \pm 0.032 \times 10^{-3}$ reported by [22] in Emene Industrial Layout of Enugu State, Nigeria, $0.61 \pm 0.14 \times 10^{-3}$ reported by [20] in Delta state of Nigeria. Also, the results from these studied areas during both dry and raining seasons are lower than $1.4 \pm 0.2 \times 10^{-3}$ reported by [21] in Southwestern Uganda, 3.21×10^{-3} reported by [19] in Northern Pakistan, 0.95×10^{-3} reported by [23] from Soil Samples in Tulkarem Province of Palestine. However, the obtained results from this present study are higher than 0.08×10^{-3} reported by [13] in Calabar, cross river state, Nigeria.

In addition, the mean exposure rate, absorbed dose rate, annual effective dose rate and the excess lifetime cancer risk results from Uburu Salt Lake during dry season were higher than that of the rainy season likewise the results from OkposiOkwu Salt Lake as shown in Table in nine. This increase may be due to change in environmental parameters due to seasonal conditions. Also, the results within the Salt Lakes environment are higher than the results from their host communities; this may be attributed to the activities within the Salt Lake environments such as local salt processing.

4. Conclusion

The study of the background gamma ionizing radiation from Uburu Salt Lake, Okposiokwu Salt Lake and their host communities during rainy and dry seasons showed that the gamma radiation exposure rate, absorbed dose rate, effective dose rate, and excess lifetime cancer risk within these environments are much higher than the background radiation standard for the general public. This high radiation level may emanate from the terrestrial and cosmic radiation in these environments. Also, the mean exposure rate, ADR, AED and the ELCR results from Uburu Salt Lake during dry season were higher than that of the rainy season likewise the results from OkposiOkwu Salt Lake as shown in Table in nine. This increase may be due to change in environmental parameters due to seasonal conditions. The results within the Salt Lake environments are also higher than the results from their host communities, which may be attributed to the activities that goes on within the Salt Lake environment such as local salt

processing. The mean values of the ELCR from the two Salt Lakes during dry and rainy seasons are 2.6 and 2 times higher than the world average value of 0.29×10^{-3} respectively. These high values show that there is probability of developing cancer by residents of these studied areas who will spend their entire life time within these areas. Since soils from these areas are used for building of houses and for cultivation of crops, there is need to also estimated the soil radioactivity level within this environment so as to ascertain if it is safe for planting of crops and building of houses.

Conflict of Interest Statement

All the authors do not have any possible conflicts of interest.

References

- [1] Sadiq, A., & Agba, E.. (2011). Background radiation in Akwanga, Nigeria. *ResearchGate*, 8 (1), 7–11.
- [2] Samuel, O. O. (2018). Radiation exposure level in some granite quarry sites within Ohimini and Gwer-East Local Government Areas of Benue State Nigeria. *Journal of Medical Physics and Applied Sciences*, 2 (3), 1–5. <https://doi.org/10.21767/2574-285X.100019>.
- [3] Zakariya, N. I., & Kahn, M. (2014). Benefits and biological effects of ionizing radiation. *Scholars Academic Journal of Biosciences*, 2 (9), 583–591.
- [4] Department of Minerals and Energy Republic Of South Africa. (2005). *Understanding radioactivity and radiation in everyday life*.
- [5] UNEP. (2016). *Radiation and sources*. Austria.
- [6] Washington State Department of Health. (2002). *Background radiation natural versus man-made*.
- [7] Dance, D. R., Christofides, S., Maidment, A. D. et al. (2014). *Diagnostic Radiology Physics*. Austria.
- [8] Muhammed, A., Eli, D., & Maxwell, I. (2015). Evaluation of background radiation level at Shanu village in Minna, Niger State, Nigeria. *International Journal Of Technology Enhancements And Emerging Engineering Research*, 3 (10), 66–70.
- [9] IRSN. (2013). *Radioactive waste management*. France.
- [10] Kinyua, R., Atambo, V. O., & Onger, R. M. (2011). Activity concentrations of 40 K, 232 Th, 226 Ra and radiation exposure levels in the Tabaka soapstone quarries of the Kisii Region, Kenya. *African Journal of Environmental Science and Technology*, 5 (9), 682–688.
- [11] Nwaka, B. U., Avwiri, G. O., & Enyinna, P. I. (2018). Outdoor gamma dose rates and excess lifetime cancer risks due to exposure rates at salt water Lakes, Ebonyi State, Nigeria. *Current Journal of Applied Science and Technology*, 26 (3), 1–10. <https://doi.org/10.9734/CJAST/2018/39145>.
- [12] Boniface, C. E. E., & Uma, K. O. (1986). Hydrogeochemistry, contaminant transport and tectonic effects in the Okposi-Uburu salt lake area of Imo State, Nigeria. *Hydrological Sciences*, 31 (2), 205–219.
- [13] Archibong, B. E., & Chiaghanam, N. O. (2020). Radiation emission levels from a waste dumpsite in Calabar, cross river state, Nigeria. *Science and Technology*, 6 (21), 20–27.
- [14] UNSCEAR. (2000). *Sources and effects of ionizing radiation*. New York.
- [15] Ononugbo, C. P., & Oduware, S. (2017). Baseline Studies of Terrestrial Outdoor Gamma Dose Rates of Ten Selected Markets in Port Harcourt Metropolis. *Current Research International*, 10 (2), 1–13. <https://doi.org/10.9734/ACRI/2017/37124>.
- [16] Avwiri, G. O., Egieya, J. M., & Ononugbo, C. P. (2013). Radiometric assay of hazard indices and excess lifetime cancer risk due to natural radioactivity in soil profile in Ogba / Egbema / Ndoni Local Government Area of Rivers State, Nigeria. *Academic Research International*, 4 (5), 54–65.
- [17] Nkuba, L. L., & Nyanda, P. B. (2017). Natural radioactivity levels and estimation of radiation exposure from soils in Bahi and Manyoni Districts in Tanzania. *Brazilian Journal of Radiation Sciences*, 05 (03), 1–17.
- [18] Ibrahim, M. S., Atta, E., & Zakaria, K. M. (2014). Assessment of natural radioactivity of some Quarries Raw Materials in El-Minya Governorate, Egypt. *Arab Journal of Nuclear and Application*, 47 (1), 208–216.
- [19] Qureshi, A. A., Tariq, S., Din, K. U., Manzoor, S., & Waheed, A. (2014). Evaluation of excessive lifetime cancer risk due to natural radioactivity in the rivers sediments of Northern Pakistan. *Journal of Radiation Research and Applied Sciences*, 7 (4), 438–447. <https://doi.org/10.1016/j.jrras.2014.07.008>.
- [20] Ezekiel, A. O. (2017). Assessment of excess lifetime cancer risk from gamma radiation levels in Effurun and Warri city of Delta state, Nigeria. *Integrative Medicine Research*, 11, 367–380. <https://doi.org/10.1016/j.jtusci.2016.03.007>.
- [21] Silver, T. E. R., Jurua, E., Oriada, R., Mugaiga, A., & Ben, E. D. D. (2016). Determination of natural radioactivity levels due to Mine Tailings from selected Mines in Southwestern Uganda. *Journal of Environment and Earth Science*, 6 (6), 154–163.
- [22] Ugbede, F. O., & Benson, I. D. (2018). Assessment of outdoor radiation levels and radiological health hazards in Emene Industrial Layout of Enugu State, Nigeria. *International Journal of Physical Science*, 13 (20), 265–272. <https://doi.org/10.5897/IJPS2018.4763>.
- [23] Thabayneh, K. M., & Jazzar, M. M. (2012). Natural radioactivity levels and estimation of radiation exposure in environmental soil samples from Tulkarem. *Open Journal of Soil Science*, 2, 7–16.