World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Check for updates

Evaluation of outdoor background ionizing radiation level around radiological sections in Federal Teaching Hospital Gombe, Gombe State Nigeria

Abiodun Ibrahim Olanrewaju *, Muhammad Nuruddeen Abdulkareem and Isiaka Onaolapo Raheem

Department of Physics, Federal University of Kashere, Gombe State, Nigeria.

World Journal of Advanced Research and Reviews, 2023, 19(02), 196–203

Publication history: Received on 19 June 2023; revised on 30 July 2023; accepted on 01 August 2023

Article DOI: https://doi.org/10.30574/wjarr.2023.19.2.1520

Abstract

This study presents the results of ambient radioactive radiation, radiation health hazard indices and excess lifetime cancer risk estimation around radiological sections in Federal Teaching Hospital Gombe, Gombe State, Nigeria using a well calibrated Rados-200 meters and a Global Positioning System (Garmin 765). The mean annual outdoor equivalent dose of 0.078 mSv/y. was measured. Mean annual outdoor effective doses of 0.1358 mSv/y. and 0.0950 mSv/y. were computed respectively, that were less than 1 mSv/y. maximum recommended limit for general public. The mean outdoor ELCR values of 0.3330 x10^{-3} was also estimated. The results though below the world's average, are comparable with those of some other locations similar to the study area.

Keywords: Equivalent Dose; Effective Dose; Excess Lifetime Cancer Risk; Federal Teaching Hospital Gombe

1. Introduction

The background radiation that affects humans comes from both natural and artificial sources. Generally, natural radionuclides of both terrestrial and cosmogenic origin account for 85% of a person's yearly total radiation dosage [1][2]. Ionizing radiation has been used in medicine more and more, and it is now widely recognized as a crucial tool for both diagnosis and treatment. The enormous benefits that patients receive from well performed operations have encouraged the extensive use of medical radiography, which has led to the medical radiation exposures becoming a significant portion of the population's overall radiation exposure. Medical exposures are currently the most significant single source of ionizing radiation in the majority of developed nations with established healthcare systems [2]. Because of the recognized effects of high dosages, radiation from hospitals and medical research facilities has been a major source of worry. The increase in background ionizing radiation (BIR) and radiation levels of patients as well as many occupational workers has been attributed to the exposure of patients to radiographic examinations, including computerized tomography, fluoroscopic procedures, dental diagnosis, and routine exposure to x-rays [3]. Inhaling radionuclides and long-term radiation exposure have detrimental impacts on one's health [4]. Radiation exposure has been linked to a number of medical procedures, including x-rays, computed tomography scans, mammograms, and other radiological tests. This has led to a rise in background radiation, which has an adverse impact on both the public and the workforce. According to a number of reports, normal routine monitoring may be able to lessen the potential radiological effect or problem that patients and staff may face in and around radiological examination sites. James et al [5] investigated the monitoring of background ionizing radiation levels both indoors and outdoors at Kwali General Hospital in Abuja. The results are generally within the standard permissible limits established by the International Commission on Radiological Protection (ICRP) and the area is radiologically safe. The mean dose equivalent ranged from 0.100±0.001 Sv/hr to 0.122±0.003 Sv/hr with an average of 0.108±0.003 Sv/hr for outdoor measurement. The radiation levels in some X-ray centers in Owerri, Imo state, Nigeria, were assessed in 2016 by Orji et al. [6]. The results from various medical and diagnostic facilities showed that the background ionizing radiation levels were comparatively

* Corresponding author: Olanrewaju AI

low. Exposure to radiation have been recorded in several medical procedures such as x-ray, computed mammography and ultrasound have in turn increase the background radiation which has advance effect on the workers and the public.

2. Radioactivity Measurements

Humans do not possess any sense organs that can detect ionizing radiation. There are no ionizing radiation-detecting sense organs in the human body. The in-situ measurements of background radiation from the outdoor sections of Federal Teaching Hospital Gombe (FTHG) was carried out in an undisturbed manner. These were accomplished using the Rados-200 Universal Survey Meter, a well-calibrated radiation monitoring equipment, with the model number RDS-200 and serial number 300091. The instrument was calibrated to detect and measure equivalent dosage in (μSvhr^{-1}). Each time radiation enters the tube, it causes ionization to result in a pulse current. Every pulse is detected and electronically counted. The radiation meters were programmed to measure exposure rate in micro-Sievert per hour (μSvhr^{-1}) and were calibrated with a source of a particular energy. The meter has a ±15% accuracy. For this study, the radiation measurement, powered by a 9V battery, was set to the μSvhr^{-1} range. Additionally, the research locations were geographically identified using a GPS device to determine their latitude and longitude.

2.1. System of measurements

A total of 4 (four) departments locations within the study area were selected for the experiment. They include; Radiotherapy and Oncology, Radiology Department, Power Generating Unit and Pharmacy Department. Forty-eight (48) in-situ measurements were taken in the entire study area by holding the radiation monitor 1 m above the ground for each target time and in each department a concentric outdoor pattern (FBRL, where F-Front, B-Back, R-Right, L-Left) were considered at distances 0 m (Source-just by the building wall), 2 m and 5 m away. The mean value was calculated with standard deviation estimated.

2.2. Radiation indices measurements

Medical procedures and the presence of radioactive elements such as Potassium-40, Thorium-232, Radium-226, and Cobalt-60 in the environment expose workers and the general public to radioactive radiations, including gamma rays and alpha particles [7]. The impact of doses accumulated as a whole is influenced by these factors and others. Radiation indices such as equivalent activity or equivalent dosage, annual equivalent dose, outdoor and indoor doses, annual effective dose, and excessive lifetime cancer risk were monitored and calculated in order to quantify in a single parameter.

2.2.1. Equivalent Dose Rate

Considering the expression given by Tayyeb *et al* and UNSCEAR [8][9], the mean equivalent dose rate in μSv/hr obtained from processing the in-situ measurement was used to compute the corresponding annual equivalent dose rate in mSv/y.

$$Annual\ Outdoor\ Equivalent\ Dose\ Rate, AEDR\ (mSv/y) = \delta \times \mu \times 24 \times 365 \times 10^{-3} \quad 1$$

Where: δ = Equivalent dose rate (μSv/hr), μ= Occupancy factor, 0.2 for outdoor. Therefore, we apply the calculations below to get the outdoor annual equivalent dose rate.

2.3. Annual Effective Dose Equivalent (AEDE)

Radiation absorbed dose estimates the radiation energy that might be received by a possible exposed person as a result of a certain exposure by measuring the amount of energy absorbed per unit mass. The amount effective dose equivalent is used for whole-body exposure to calculate the dose that was absorbed entirely by the body. In radiation assessment and protection, the annual effective dose equivalent (AEDE) is used to calculate the annual dose absorbed by the entire body. With the outdoor occupancy factor of 0.2, the conversion factor (0.7 Sv/Gy) from absorbed dose rate in air in nGy/h to effective dose rate in mSv/y is used to estimate the AEDE. The following expressions were used to determine the AEDE [2][10] UNSCEAR and Etuk et al.

$$\text{Outdoor AEDE(mSv/y)} = D_{out}\text{(nGy/h) x 8760 (h) x 0.2 x 0.7 Sv/Gy x } 10^{-3} \ \ldots\ldots\ldots\ldots\ldots 2$$

Where,

$$D_{out}(\frac{nGy}{h}) = \frac{EDRO \times (\frac{uS}{y}) \times 10^{-7}}{Q} \ \ldots\ldots\ldots 3$$

Where Q is the quality factor which equals unity

2.4. Excess Life Cancer Risk (ELCR)

Although there is no proof of radioactive component outbreaks, the possibility of workers and study area residents developing cancer in this environment can be used to compute excess lifetime cancer risk (ELCR). According to the Linear No Threshold (LNT) hypothesis, extrapolation from indication sustained, high-dose reactions to low-dose responses, all acute ionizing radiation exposures down to zero are detrimental [11]. No matter how low the dosage rate, the harm is proportionate to the dose and accumulates over time [12]. This study concentrates on the conventional late (stochastic) outcomes of international radiation safety standards that are centered on the LNT hypothesis [13]. The ELCR (Excess Lifetime Cancer Risk) equation was estimated using the annual effective dose.

$$\text{ELCR} = \text{AEDE} \times \text{Average duration of life(DL)} \times Riskfactor(RF) \quad \ldots\ldots\ldots\ldots\ldots\ldots.4$$

where AEDE, DL and RF is the annual effective dose equivalent, duration of life (70 years) and risk factor (Sv^{-1}), fatal cancer risk per sievert.

ICRP 60 adopts values of 0.05 for the public exposure for low dose background radiation that was thought to create stochastic effects [4][14].

3. Results

Table 1 Outdoor Background Ionization Radiation of Radiotherapy and Oncology

Distance		**Mean Background radiation equivalent dose (μSv/hr)**	**Annual outdoor equivalent dose**	**Absorbed dose D_o (nGy/h)**	**Annual effective dose (mSv/y)**	**Excess lifetime cancer risk (10^{-3})**
	L	0.09±0.02	0.1577	0.00009	0.1104	0.3863
	R	0.12±0.03	0.2161	0.000123	0.1513	0.5294
	F	0.10±0.02	0.1694	9.67E-05	0.1186	0.4149
	B	0.07±0.03	0.1168	6.67E-05	0.0818	0.2862
Source	Mean	0.09±0.02	0.1650	9.42E-05	0.1155	0.4042
	L	0.07±0.03	0.1285	7.33E-05	0.0899	0.3148
	R	0.08±0.01	0.1343	7.67E-05	0.0940	0.3291
	F	0.06±0.02	0.1051	0.00006	0.0736	0.2575
	B	0.08±0.03	0.1343	7.67E-05	0.0940	0.3291
2 m away	Mean	0.07±0.01	0.1256	7.17E-05	0.0879	0.3076
	L	0.08±0.03	0.1343	7.67E-05	0.0940	0.3291
	R	0.10±0.02	0.1694	9.67E-05	0.1186	0.4149
	F	0.08±0.03	0.1460	8.33E-05	0.1022	0.3577
	B	0.07±0.02	0.1285	7.33E-05	0.0899	0.3148
5 m away	Mean	0.08±0.01	0.1445	8.25E-05	0.1012	0.3541
Mean		0.09	0.1577	0.00009	0.1104	0.3863

Table 2 Outdoor Background Ionizing Radiation of Radiology Department FTHG

Distance		Mean Background radiation equivalent dose (μSv/hr)	Annual outdoor equivalent dose	Absorbed dose D_o(nGy/h)	Annual effective dose (mSv/y)	Excess lifetime cancer risk (10^{-3})
	L	0.08±0.01	0.1402	0.00008	0.0981	0.3434
	R	0.07±0.02	0.1226	0.00007	0.0858	0.3005
	F	0.07±0.01	0.1226	0.00007	0.0858	0.3005
	B	0.07±0.01	0.1226	0.00007	0.0858	0.3005
Source	Mean	0.07±0.01	0.1270	7.25E-05	0.0889	0.3112
	L	0.07±0.02	0.1226	0.00007	0.0858	0.3005
	R	0.06±0.03	0.1110	6.33E-05	0.0777	0.2719
	F	0.09±0.02	0.1518	8.67E-05	0.1063	0.3720
	B	0.07±0.01	0.1168	6.67E-05	0.0818	0.2862
2 m away	Mean	0.07±0.01	0.1256	7.17E-05	0.0879	0.3076
	L	0.08±0.01	0.1402	0.00008	0.0981	0.3434
	R	0.07±0.02	0.1168	6.67E-05	0.0818	0.2862
	F	0.08±0.02	0.1343	7.67E-05	0.0940	0.3291
	B	0.06±0.03	0.1110	6.33E-05	0.0777	0.2719
5 m away	Mean	0.07±0.01	0.1256	7.17E-05	0.0879	0.3076
Mean		0.07	0.1226	0.00007	0.0858	0.3005

Table 3 Outdoor Background Ionizing Radiation of Power Generating Unit FTHG

Distance		Mean Background radiation equivalent dose (μSv/hr)	Annual outdoor equivalent dose	Absorbed dose D_o(nGy/h)	Annual effective dose (mSv/y)	Excess lifetime cancer risk (10^{-3})
	L	0.10±0.03	0.1810	0.000103	0.1267	0.4435
	R	0.09±0.02	0.1518	8.67E-05	0.1063	0.372
	F	0.09±0.03	0.1518	8.67E-05	0.1063	0.372
	B	0.08±0.03	0.1343	7.67E-05	0.0940	0.3291
Source	Mean	0.09±0.01	0.1548	8.83E-05	0.1083	0.3792
	L	0.04±0.02	0.0759	4.33E-05	0.0531	0.186
	R	0.08±0.03	0.1343	7.67E-05	0.0940	0.3291
	F	0.09±0.03	0.1635	9.33E-05	0.1145	0.4006
	B	0.07±0.02	0.1285	7.33E-05	0.0899	0.3148
	Mean	0.07±0.02	0.1256	7.17E-05	0.0879	0.3076
2 m away						
5 m away	L	0.08±0.01	0.1343	7.67E-05	0.0940	0.3291

	R	0.08±0.02	0.1402	0.00008	0.0981	0.3434
	F	0.06±0.02	0.1051	0.00006	0.0736	0.2575
	B	0.08±0.03	0.1402	0.00008	0.0981	0.3434
	Mean	0.07±0.01	0.1299	7.42E-05	0.0910	0.3184
Mean		0.07	0.1226	0.00007	0.0858	0.3005

Table 4 Outdoor Background Ionizing Radiation of Pharmacy Department FTHG

Distance		**Mean Background radiation equivalent dose (μSv/hr)**	**Annual outdoor equivalent dose**	**Absorbed dose D_o(nGy/h)**	**Annual effective dose (mSv/y)**	**Excess lifetime cancer risk (10^{-3})**
	L	0.07±0.01	0.1226	0.00007	0.0858	0.3005
	R	0.11±0.02	0.1986	0.000113	0.1390	0.4865
	F	0.05±0.03	0.0934	5.33E-05	0.0654	0.2289
	B	0.08±0.02	0.1343	7.67E-05	0.0940	0.3291
Source	Mean	0.08±0.03	0.1372	7.83E-05	0.0961	0.3362
	L	0.09±0.02	0.1577	0.00009	0.1104	0.3863
	R	0.08±0.02	0.1343	7.67E-05	0.0940	0.3291
	F	0.09±0.01	0.1518	8.67E-05	0.1063	0.3720
	B	0.09±0.03	0.1518	8.67E-05	0.1063	0.3720
2 m away	Mean	0.09±0.01	0.1489	0.000085	0.1042	0.3649
	L	0.10±0.03	0.1752	0.0001	0.1226	0.4292
	R	0.07±0.02	0.1285	7.33E-05	0.0899	0.3148
	F	0.06±0.02	0.1051	0.00006	0.0736	0.2575
	B	0.11±0.02	0.1927	0.00011	0.1349	0.4722
5 m away	Mean	0.09±0.02	0.1504	8.58E-05	0.1053	0.3684
Mean		0.08	0.1402	0.00008	0.0981	0.3434

Table 5 Summary of the mean concentric outdoor background radiation doses and other radiation parameters

Departments	**Mean Background radiation equivalent dose (μSv/hr)**	**Annual outdoor equivalent dose**	**Absorbed dose D_o(nGy/h)**	**Annual effective dose (mSv/y)**	**Excess lifetime cancer risk (10^{-3})**
Radiotherapy and Oncology unit	0.09	0.1577	0.00009	0.1104	0.3863
Radiology unit	0.07	0.1226	0.00007	0.0858	0.3005
Power Generating unit	0.07	0.1226	0.00007	0.0858	0.3005
Pharmacy unit	0.08	0.1402	0.00008	0.0981	0.3434
Mean	0.078	0.1358	0.00008	0.0950	0.3330

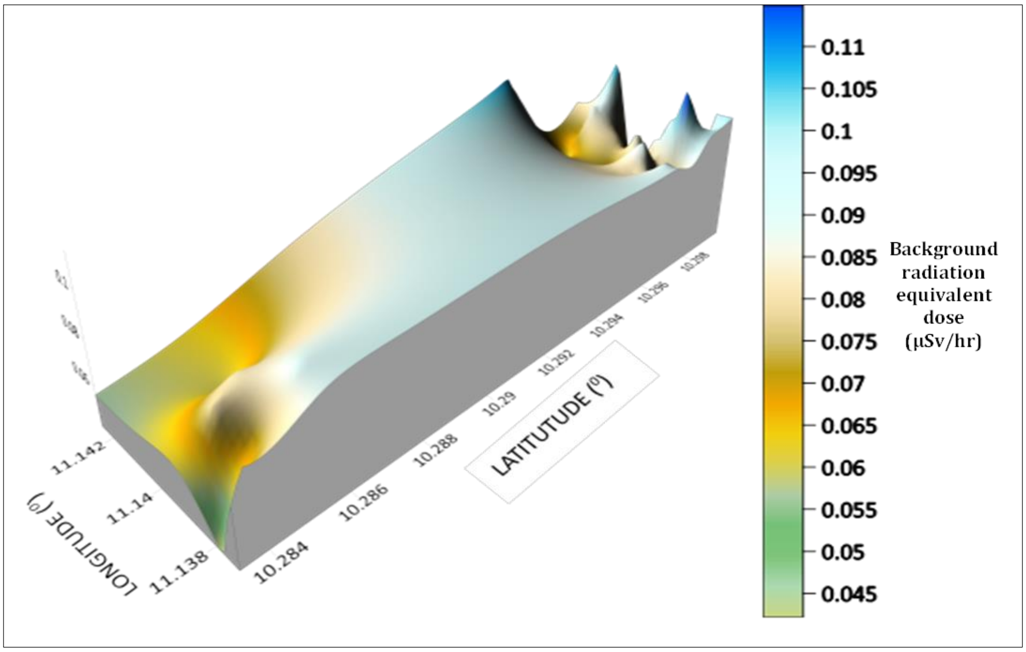

Figure 1 Contour 3D showing the distribution of outdoor background radiation equivalent dose (μSv/hr)

4. Discussion

Based on the estimation carried out and reported in Tables 1 to 4 the values of background radiation equivalent doses ranges from 0.08±0.01 (5 m) to 0.09±0.02 μSv/hr. (source) in Radiotherapy and oncology unit, 0.07±0.01 (5 m) μSv/hr. in all distances around radiology unit, 0.07±0.01 (5 m) to 0.09±0.01 μSv/hr. (source) in Power generating units and 0.08±0.03 (Source) to 0.09±0.02 μSv/hr. (5 m) in Pharmacy unit respectively. The equivalent dose measured for the outdoor areas in all the unit's ranges between 0.07 to 0.09 μSv/hr. with the mean value of 0.078 μSv/hr. The results are as shown in Table 5 respectively. The results may be attributed to the sum up of ionizing radiation coming out through the openings from the radiological sections and the outdoor background radiation. This result shows that exposure to background radiation equivalent dose in all the sample points of the study area contributes insignificantly to the radiation dose in the nearby environment. Fig. 1 represents the radiation 3D contour of the entire study areas. The relative spacing of the contour lines indicates the relative slope of the surface. Fig. 1 shows the distribution of background radiation equivalent dose of high value of 0.10 μSv/hr. and above in the areas bounded by latitudes $11^0.138'$ to $11^0.142'$ and longitudes $10^0.284'$ to $10^0.298'$ and the areas include Radiotherapy and Oncology unit, Radiology unit, Power Generating unit and Pharmacy unit of the Federal Teaching Hospital Gombe State. These areas are characterized with sharp spikes of steady hilly zones of the Federal Teaching Hospital Gombe State in light to deep blue color with elevated background radiation equivalent doses of 0.09 - 0.11 μSv/hr. in Radiotherapy and Oncology unit while lowland distribution areas of the oil spill sites are yellow colored with background radiation equivalent dose 0.04 - 0.07 μSv/hr. in Power Generating unit. The distribution of doses in the study area indicates high value around the Radiotherapy and Oncology unit of the study area. Many factors such proper shielding and compliance with protection regulations, may have contributed to the low-level of doses obtained in the study area, as a diagnostic procedure do takes place in the indoor environment. The annual equivalent dose was estimated from the background equivalent radiation dose values using equation (2). The results were shown in Tables 1-4 and Table 5 as summary respectively. The values ranges from 0.1226 to 0.1577 mSv/y with a mean values of 0.1358 mSv/y. The relative high values obtained in the outdoor environment could be related to leakages from the radiological machine pipes which might lead to increase in the ionizing radiation. The values obtained were far less than the range reported by Oladele and Arogunjo [15] for a study in radiology department across Ondo areas whose values were 0.63±0.32 to 1.17 ±0.45 mSv/y. The results obtained were below the value stipulated by UNSCEAR for world average equivalent dose of 2.4 mSv/y for human being [2]. Similarly, for the general public, the results of the study areas were below the recommended annual stochastic limit of 1 mSv/y as reported by Lewis et al [16]. The total time in the outdoor area which an individual is exposed to the radiation doses within the study areas was estimated by employing the relation for the outdoor annual effective dose. As shown in Table 5, the summary value obtained ranges from 0.0858 to 0.1104 mSv/y. with a mean value 0.0950 mSv/y, the values in every unit were higher than the world's average of 0.07 mSv/y stated in Qureshi et al (2014) report [17]. The results show that the highest annual effective dose rates was obtained in Radiotherapy and oncology unit of the study area and the least values were obtained in the Power generating unit of the areas respectively. The mean annual effective doses were observed to less than the criterion limits of 1 mSv/y stipulated by ICRP-60 for the general public and 20 mSv/y for occupational workers. The excess lifetime cancer risk (ELCR) which is the product of the annual effective dose value was estimated using the assumption of Linear No Threshold (LNT) for the outdoor locations of the study areas. The values ranges from 0.3005 x 10^{-3} to 0.3863 x 10^{-3} with a mean value of 0.3330 x 10^{-3}. These high values of ELCR could be attributed to possibility of machines producing some level of radiation when they are energized coupled with other radiation background source in the outdoor environment. The study areas were within Federal Teaching Hospital Gombe State where structure of new buildings including other laboratories are being carried out with various types of building materials such as different rocks, metal rods, paints, metals, cement and different soil types: sand, gravels, granites and others being brought in for building activities. These and other materials could contribute to background radiation concentration and radioactivity, influencing the equivalent radioactive dose and effective dose, hence excessive lifetime cancer risk.

5. Conclusion

The medical examination or diagnostic procedures have contributed to the background radiation dose in the study areas, therefore, varied equivalent doses which in turn affected other radiation indices. The following conclusion was made that the mean equivalent dose for the outdoor measurements were below the world average radiation exposure dose rate. The annual equivalent dose estimated were within the recommended value by UNSCEAR. The annual effective doses and excess lifetime cancer risks were higher than the recommended values by UNSCEAR and world average.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to disclosed.

References

[1] Belivermis, M., Kılıç, N., Çotuk Y. & Topcuoğlu, S. (2010). The effects of physicochemical properties on gamma emitting natural radionuclide levels in the soil profile of Istanbul. Environ Monit Assess. 163 (1 -4): 15–26.

[2] UNSCEAR, 2000). United Nation Scientific Committee on the Effects of Atomic Radiation. (2000). Sources and Effects of Ionizing Radiation. Report to General Assembly with Scientific Annexes. United Nations; New York.

[3] Avwiri, G. O. (2011). Radiation the Good, the Bad and the Ugly in our Environment. An Inaugural Lecture 79th Series University of Port Harcourt.

[4] Taskin, H., Karavus, M., A.P., Topozoglu, A., Hindiroglu, S. & Karahan, G. (2009) Radionuclide concentrations in soil and life time cancer risk due to gamma radioactivity in Kirklareli, Turkey. Journal of Environmental Radioactivity.;100:49-53.

[5] James, I.U., Moses, I.F., Vandi, J.N. & Ikoh, U.E. (2015). Measurement of Indoor and Outdoor Background Ionising Radiation Levels in Kwali General Hospital, Abuja. Journal of Applied Science and Environmental Management.

[6] Orji, E., Chikwendu, E.C., Benedict, A. M. Chijioke, N.O., Emmanuel, A, F. & Okafor, C.C. (2016). Evaluation of Background Ionizing Radiation Levels in Some X-ray Centres in Owerri, Imo state Nigeria.

[7] Mazzili B. and Saueia (1999). Radiological implications of using phosphogysum as building material in Brazil. Radiation Protection Dosimetry. 86(1): 63 – 67. https://doi.org/10.1093/oxfordjournals.rpd.a032927 .

[8] Tayyeb et al., 2012; Tayyeb, A.P., Hamed, B. & Maryam, S. (2012). Evaluation of High-Level Environmental Background Radiation Areas and its Variation in Ramsar. Iranian Journal of Medical Physics Vol. 9, No. 2, 87-92.

[9] UNSCEAR Report (1988) Sources, effects and risk of ionizing ra-diation. United Nations Scientific Committee on the Effects of Atomic Radiation. Report to the General Assembly with Annexes

[10] Etuk, S.E., Essiett, A.A., Okechukwu, E. & Agbasi, O.E. (2017) Measurement of Outdoor Ambient Radioactive Radiation and Evaluation of Radiation Indices and Excess Lifetime Cancer Risk within Uyo, Unity Park, Uyo, Nigeria JGEESI, 9(4): 1 -9.

[11] Olanrewaju A.I., AbdulKareem, N.M., & Raheem I. O. (2020). Assessment of Radiation Exposure Level in Blacksmithing Workshop in Gombe, Gombe State. FUDMA Journal of Sciences. Vol. 4 (4), pp 19-25. doi.org/10.33003/fjs-2020-0404-270.

[12] Mishra, K.P. (2017). Carcinogenic risk from low dose radiation exposure is overestimated. Journal of Radiation Cancer Res.; 8:1 -3.

[13] Stewart, F.A., Akleyev, A.V., Hauer J.M., Hendry, J.H. & Kleiman, N.J. (2012). ICRP publication 118: ICRP statement on tissue reactions and early and late effects of radiation in normal tissues and organs –Threshold doses for tissue reactions in a radiation protection context. Ann ICRP.;41:1- 322.

[14] Mohammed, A., Obeissi, K., Omar, E.S., Khaled, Z. & Ibrahim R. (2014). Assessment of indoor and outdoor radon levels in South Lebanon. Springer.;214-226.

[15] Oladele B. Blessing and Arogunjo A. Muyiwa. (2018) Assessment of Background Radiation Levels in Selected Diagnostic Radiology Department across Ondo State, Nigeria. Nigeria Journal of Pure & Applied Physics, Vol. 8, No. 1, pages 16 - 19, 2018 https://dx.doi.org/10.4314/njpap.v8i1.2

[16] Lewis, B.J., Tume, P., Bennett, G.I., Pierre, M., Green, A.R., Cous-ins, T., Hoffarth, B.E., Jones, T.A. and Brisson, J.R., (1999). Cos-mic Radiation Exposure on Canadian-based Commercial Airline Route. Radiation Protection Dosimetry. Vol. 86. No.1, pp. 7 – 24. https://doi.org/10.1093/oxfordjournals.rpd.a032929.

[17] Qureshi, A.A., Tariq, S., Din, K.U., Mauzoor, S., Calligaris, C. and Waheed, A. (2014). Evaluation of excessive lifetime cancer risk due to natural radioactivity in the rivers sediments of Northern Pa-kistan. Journal of Radiation Research and Applied Sciences, Else-vier 7: 438 – 447. https://doi.org/10.1016/j.jrras.2014.07.008.