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Background Radiations Exposure within the Iva-Valley Area of Enugu, Enugu State, Nigeria

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Abstract

Natural background ionizing radiation, stemming from NORM sources, constitutes an often underestimated yet ever-present facet of our daily lives, influenced by geographical location, geological characteristics, and altitude. The study presents measurements of background ionizing radiation (BIR), along with calculations for the Annual Effective Dose Rate (AED) and Excess Lifetime Cancer Risk (ELCR). BIR levels spanned from 0.008 µSv/hr to 6.985 µSv/hr, with the majority residing within a range of minimal exposure, signifying negligible health risks. Approximately seven locations surpassed the global average dose rate of 0.274 µSv/hr attributed to natural radiation. AED values exhibited a wide spectrum, ranging from 0.014 mSv/yr to 12.238 mSv/yr, reflecting varying levels of radiation exposure. AED values below 1 mSv/yr are generally regarded as low and safe, whereas values within the range of 1-10 mSv/yr may entail a modest increase in long-term health risks. Values exceeding 10 mSv/yr raise concerns about acute radiation effects and heightened cancer risk. This study identified two specific locations where AED levels surpassed the recommended threshold of 1 mSv/yr for the public, while others adhered to established guidelines. Excess Lifetime Cancer Risk (ELCR) values exhibited a considerable range, spanning from 0.049 to 42.832 per 10^3, signifying significant disparities in cancer risk linked to various levels of exposure. ELCR values substantially exceeding 1 indicate a heightened cancer risk, with values surpassing the global average (0.29×10^{-3}) warranting concerted risk mitigation efforts. This comprehensive assessment underscores the paramount importance of comprehending and vigilantly monitoring NORM-related radiation levels to ensure public safety and inform strategic risk mitigation measures in affected regions

Keywords: Naturally occurring radionuclide materials (NORM), Background ionizing radiation (BIR), Annual effective dose rate, Excess lifetime cancer risk, Ionizing radiation, Absorbed dose rate.

1.0 Introduction

Naturally occurring radionuclide materials (NORM) are radioactive materials found naturally in our environments. These types of materials are ubiquitous in our environment since they are not man-made, but rather come from the decay of naturally occurring elements in the Earth's crust. NORM can be found in a variety of places, including soil, rocks, water, air, and building materials (Adel *et al.*, 2022) and contribute immensely to the natural background ionizing radiation of an area. These natural background ionizing radiation permeates our existence, representing a pervasive yet frequently underappreciated facet of our daily lives (Bonnett, 2020). Within the complex tapestry of our environment, it serves as an inherent and ever-present element. However, the extent of exposure to this ionizing radiation is far from uniform, fluctuating significantly according to geographical location, geological features, and altitude above sea level.

The diverse origins of natural background ionizing radiation (BIR) span a wide spectrum. Terrestrial sources include radioactive isotopes found within Earth's crust, such as uranium, thorium, and radon gas, which release radiation as part of their natural decay processes (May & Schultz, 2021). Simultaneously, cosmic sources, primarily originating from outer space and the Sun, contribute to this background radiation through the relentless bombardment of high-energy particles. The intricacies of this radiation's distribution become particularly evident when considering geographical factors. Evaluating natural background radiation in coal mining areas is a multifaceted endeavor that involves assessing the radiological risks associated with mining activities and the presence of naturally occurring radioactive materials (NORM) in coal deposits and surrounding geology (Chambers, 2015). This evaluation is crucial for the safety and well-being of miners, nearby communities, and the environment. In this context, evaluating natural background ionizing radiation necessitates a comprehensive understanding of its manifold sources and the varying degrees of exposure individuals may encounter. Such knowledge is fundamental not only for assessing potential health risks but also for informing radiation protection measures, environmental management strategies, and public health policies. In essence, unraveling the complexities of this natural phenomenon provides invaluable insights into our interaction with the radiation-laden world that surrounds us.

Many researchers have made efforts in mapping out the background ionizing radiation in various parts of Nigeria. Ugbede (2018), evaluated the baseline radiation levels in agricultural areas resulting from the application of fertilizers and agricultural chemicals and the related radiation health factors in farmlands situated within the communities of Ishielu Local Government Area (LGA) in Ebonyi State, Nigeria; here the mean values of their measuremnts of 0.016±0.002 mR/h where observed to be higher than 0.013 mR/h ICRP recommendations for normal environment. In the study conducted by Agbalagba *et al.* (2016), they conducted an evaluation of the impact of industrial operations and their waste discharge on the external background ionizing radiation (BIR) levels in the Ughelli metropolis and the surrounding areas. They utilized a digilert 100 nuclear radiation monitor along with a geographical positioning system for GIS mapping. The comprehensive findings from their assessment of radiation exposure rates and the calculated radiological indices indicate that 73.5% of the locations they sampled exceeded the acceptable radiation limits. There have been many such studies across mining and non-mining areas of Nigeria, works like that of Omogunloye *et al.* (2021); Ekong *et al.* (2019); Echeweozo & Ugbede (2020); Onuk *et al.* (2022); Agbalagba *et al.* (2016); Ademola (2008); Usman *et al.* (2022).

The primary objective of this study is to illuminate the measurement, and health consequences linked to natural background ionizing radiation. This endeavor seeks to establish a solid basis for making well-informed decisions in the domains of radiation safety, environmental stewardship, and public health. Within this exploration lies an in-depth examination of the intricate relationship between the Earth's inherent radioactivity and its effects on living organisms, providing valuable perspectives into the intricate nature of this natural occurrence.

2.0 Materials and Methods

2.1 Study Area

This study was carried out within the Iva valley locality, located in the city of Enugu, in Enugu state. The locality is the site of the Okpara Coal Mine. Production in the mine declined from a peak of 3,040 tons in 1984 to 1016 tons in 1990 and was closed down. The mine was later reopened in 1999 and operated till 2004/2005 when it was abandoned due to economic reasons (Nganje *et al.*, 2010). The coal mine spoils which are not treated and are scattered in the area consist of a mixture of variable fragments of carbonaceous shale, sandstones, clay and coal. Pyrite and marcasite are found to be associated with these minerals. The study area is located between latitudes 06^{o} 22`N and 06$^{o}$ 27`N and longitudes 007° 25` E and 007°30` E at about 5 km west of Enugu town and about 15 km to the Akanu Ibiam International Airport in Enugu North L.G.A of southeastern Nigeria. It is closer to the neighbouring town of Enugu Ngwo (about 4.7 km) and Hill tops of Enugu in the Ogbette and Enugu Coal Camp layout just in the periphery of the city near the Iva valley.

2.2 Background radiation measurements

The measurement of background ionizing radiation levels in this study was conducted using a precisely calibrated digital Geiger-Muller Counter known as the GCA-04W. This sophisticated device quantifies Natural Background Radiation rates in both counts per minute (CPM) and counts per second (CPS). It possesses the capability to detect alpha, beta, and gamma radiations. At the heart of this detector lies a probe or tube containing a gas-filled chamber. The tube's structure comprises a thin metal cylinder (cathode) encasing a central electrode (anode). Additionally, it features a thin mica window at the front, facilitating the detection of alpha particles. The interior of the tube is filled with a combination of Neon, Argon, and Halogen gases. The coordinates of the sampling locations where taking with the help of Google Maps App for android devices.

Sixty six (66) sample points in twenty three locations were considered, the sampling locations are shown in Figure 1. At each sampling point, three (3) readings were taking and the average of the three readings were taking as the background radiation of the point. The GM counter was set to µSv/hr and readings were taken after 1 min. The counter was held at about 1 m above the ground level at an open space, this was done in other to represent the human gonadal level.

2.3 Annual effective dose (AED) and excess lifetime cancer risk (ELCR)

The average BIR (Background Ionizing Radiation) dose rates, expressed in µSv/hr units, were utilized to calculate the annual effective dose (AED) according to the formula presented in equation 1 (see Echeweozo & Ugbede, 2020).

$$AED\ (mSv/yr) = DR \times T \times OF \times 10^3 \qquad ...1$$

Where DR represents the measured absorbed dose rate in µSv/h, T denotes the total hours per year (equivalent to 8760 hours), and OF stands for the outdoor occupancy factor, which is explicitly defined as 0.2 (as per UNSCEAR, 2000).

In order to evaluate the potential cancer risk associated with exposure to Background Ionizing Radiation (BIR) among the residents of the Iva Valley, we employed a robust approach to estimate the Excess Lifetime Cancer Risk (ELCR). This crucial risk assessment parameter was computed utilizing a widely recognized model, as delineated in Equation 2 (Echeweozo

Figure 1: The coordinates of sampling locations

& Ugbede, 2020). The ELCR serves as a pivotal tool in radiological risk assessment, offering insights into the likelihood of an individual developing cancer over the course of their lifetime due to prolonged exposure to low-dose radiation (Khandoker, 2017). The significance of the ELCR lies in its ability to provide a quantitative estimation of the cancer risk linked to the observed levels of background ionizing radiation. By using this model, we can better comprehend and communicate the potential health implications of BIR exposure, thereby aiding in informed decision-making and public health management for the Iva Valley community. This comprehensive risk assessment approach underscores the importance of addressing radiation-related health concerns and striving for effective protective measures to mitigate potential risks.

$$ELCR = AED \times DL \times RF \times 10^{-3} \quad ...2$$

Where DL represents the typical lifespan, which is conventionally taken as 70 years (Ajibola *et al.* 2022). Additionally, RF denotes the cancer risk factor per Sievert (Sv^{-1}). When it comes to low-dose background radiation, which is associated with the potential for stochastic effects (randomly occurring health impacts), the International Commission on Radiological Protection (ICRP, 2007) has advised a cancer risk factor of 0.05 Sv^{-1} for exposure experienced by the general public.

3.0 Results and Discussion

The findings from our investigation have been presented in Table 1, which include data on the measured background ionizing radiation (BIR) levels, as well as calculations for the annual effective dose rate and the associated excess lifetime cancer risk. The measurement of ionizing radiation in a specific environment, expressed as the absorbed dose rate in micro Sieverts per hour (μSv/hr), offers insights into the extent of potential harm to living tissues and the heightened risk of various health consequences, such as cancer.

3.1 Absorbed Dose Rates

The recorded absorbed dose rates spanned from 0.008 μSv/hr to 6.985 μSv/hr, with a majority falling within the extremely low range of ionizing radiation exposure. At these levels, the health risk to individuals is exceedingly minimal. Exposure to such minimal doses of radiation is improbable to cause immediate harm or significantly elevate the long-term risk of health issues. However, it's worth noting that exposure at the higher end of this range (6.985 μSv/hr) could potentially lead to a slight increase in the long-term risk of radiation-related health effects, especially if individuals experience consistent exposure over an extended period. Several findings from this study resembled those of Ugbede *et al.* (2022) in Enugu's urban areas, albeit some of our results registered notably higher levels, possibly due to the influence of coal mining activities in the study's investigated area. About 7 locations in this study showed radiation absorbed dose rate higher than the worldwide average dose rate 0.274 μSv/hr due to natural radiation (UNSCEAR, 2000).

3.2 Annual Effective Dose (AED)

The Annual Effective Dose (AED) serves as a pivotal metric within the realm of radiological protection, employed to gauge the potential health hazards tied to exposure to ionizing radiation (Mortazavi *et al.* 2020). This metric offers an estimation of the dose of ionizing radiation an individual could potentially receive over the course of a year. Notably, AED values span a broad spectrum, ranging from an exceedingly low 0.014 mSv/yr to a relatively high 12.238 mSv/yr, signifying substantial diversity in radiation exposure levels. This variability can be attributed to the local geological characteristics of the area under consideration.

AED values that fall within the lower range (below 1 mSv/yr) are generally considered low and typically do not pose immediate health risks. On the other hand, AED values within the moderate range (1-10 mSv/yr) may marginally elevate the risk of long-term health consequences, such as cancer, although this risk remains relatively low. AED values that significantly surpass the 10 mSv/yr threshold are a cause for concern. Such elevated levels may heighten the risk of acute radiation effects, such as radiation sickness, and increase the likelihood of cancer and other radiation-related ailments developing over time.

In this study, two specific locations have reported AED levels exceeding the recommended 1 mSv/yr threshold established by the International Commission on Radiological Protection (ICRP) for members of the public. Conversely, all other locations have adhered to the recommended AED values.

3.3 Excess Lifetime Cancer Risks

Excess lifetime cancer risk is a measure used in environmental and occupational health to assess the potential increase in the risk of developing cancer due to exposure to ionizing radiations. The ELCR values span a wide range, starting from a minimum of 0.049 and going up to a maximum of 42.832 per 10^3. This variation signifies significant differences in the potential cancer risk linked to various exposures. Values exceeding 1 indicate that the exposure is associated with a higher risk of cancer when compared to the baseline risk in the general population. The higher the value, the greater the increase in risk. It's worth noting that exposures with ELCR values substantially above 1, such as 42.832 and 30.182, are a cause for particular concern. Most of the ELCR values obtained in this study exceeded the world average of $0.29 \times 10^{"3}$ (as reported by Nduka et al. in 2022). Such exposures are linked to a significantly elevated risk of cancer and should be prioritized for risk reduction or mitigation efforts.

Values around 1 (e.g., 1.006, 1.061, 1.116) indicate a relatively modest increase in the risk of cancer. While these values do suggest an elevated risk compared to the general population, the extent of the increase might be less than some of the more concerning exposures. The health implications of these ELCR values depend on several factors, including the duration and intensity of exposure, the specific types of cancer involved, and individual susceptibility.

Table 1: Absorbed dose rate, annual effective dose and excess lifetime cancer risk

S/N	Dose rate (uSv/hr)	AED (mSv/yr)	ELCR ($\times 10^{-3}$)
1	0.546	0.957	3.348
2	0.260	0.456	1.594
3	0.225	0.394	1.380
4	0.182	0.319	1.116
5	0.208	0.364	1.275
6	0.216	0.378	1.325
7	0.164	0.287	1.006
8	0.199	0.349	1.220
9	0.364	0.638	2.232
10	0.286	0.501	1.754
11	0.268	0.470	1.643
12	0.173	0.303	1.061
13	0.260	0.456	1.594
14	0.199	0.349	1.220
15	0.268	0.470	1.643
16	0.112	0.196	0.687
17	0.242	0.424	1.484
18	0.130	0.228	0.797
19	0.216	0.378	1.325
20	0.121	0.212	0.742
21	0.130	0.228	0.797
22	0.130	0.228	0.797
23	0.164	0.287	1.006
24	0.199	0.349	1.220
25	0.147	0.258	0.901
26	0.156	0.273	0.957
27	0.104	0.182	0.638
28	0.182	0.319	1.116
29	0.208	0.364	1.275
30	0.190	0.333	1.165
31	0.112	0.196	0.687
32	0.190	0.333	1.165
33	0.234	0.410	1.435
34	0.156	0.273	0.957
35	0.164	0.287	1.006
36	0.190	0.333	1.165
37	0.104	0.182	0.638
38	0.234	0.410	1.435
39	0.104	0.182	0.638
40	0.112	0.196	0.687
41	0.164	0.287	1.006
42	0.112	0.196	0.687
43	0.216	0.378	1.325

continuation of Table 1

S/N	Dose rate (uSv/hr)	AED (mSv/yr)	ELCR ($\times 10^{-3}$)
44	0.225	0.394	1.380
45	0.182	0.319	1.116
46	0.147	0.258	0.901
47	0.190	0.333	1.165
48	0.251	0.440	1.539
49	0.182	0.319	1.116
50	0.225	0.394	1.380
51	0.173	0.303	1.061
52	0.182	0.319	1.116
53	0.225	0.394	1.380
54	0.147	0.258	0.901
55	0.121	0.212	0.742
56	0.208	0.364	1.275
57	0.190	0.333	1.165
58	0.078	0.137	0.478
59	0.086	0.151	0.527
60	0.095	0.166	0.583
61	0.008	0.014	0.049
62	6.985	12.238	42.832
63	0.286	0.501	1.754
64	0.286	0.501	1.754
65	4.922	8.623	30.182
66	0.338	0.592	2.073
Mean	0.365	0.639	2.237

4.0 Conclusion

This research delved into the assessment of background ionizing radiation exposure stemming from the Iva-valley old coal mine vicinity in Enugu. The investigation employed a meticulously calibrated Geiger Muller counter. The determined absorbed dose rates spanned from 0.008 μSv/hr to 6.985 μSv/hr, with a predominant portion falling within the category of exceedingly low ionizing radiation exposure. Such exposure levels pose minimal immediate hazards or substantial long-term health risks. However, it should be noted that the upper limit of this range could engender a slight elevation in long-term health effects attributable to radiation, especially when there is sustained exposure.

The Annual Effective Dose (AED) values exhibited considerable variability, ranging from 0.014 mSv/yr to 12.238 mSv/yr, primarily contingent on the localized geological characteristics. AED values below 1 mSv/yr are regarded as low and typically do not entail immediate health hazards. In the range of 1-10 mSv/yr, AED values may marginally heighten the risk of enduring health consequences, such as cancer. When AED values surpass 10 mSv/yr, there is cause for concern as this may give rise to acute radiation effects and an increased risk of cancer.

The Excess Lifetime Cancer Risk (ELCR) values displayed a wide spectrum, ranging from 0.049 to 42.832 per 10^3. ELCR values surpassing 1 indicate an elevated cancer risk compared to the general population, with higher values signifying a more substantial escalation in risk. The majority of ELCR values in this study exceeded the global average of $0.29 \times 10^{"3}$, indicating a notably heightened risk of cancer. Values around 1 suggest a relatively modest increase in cancer risk, but the actual health implications hinge on numerous factors, including the duration and intensity of exposure, the types of cancer, and individual susceptibility.

Conclusively, this investigation underscores that while the majority of surveyed locations exhibited low levels of ionizing radiation exposure with minimal immediate health risks, a select few exceeded recommended AED thresholds, signifying significantly elevated cancer risks. These findings underscore the critical importance of monitoring and mitigating ionizing radiation exposure in specific areas to safeguard public health.

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