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Estimation of Background Radioactivity around a Goldmine Deposit and the Probability of a Resultant Cancer Risk

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Abstract: ***Humans are exposed to radiation in their environment with or without their consent; and the exposure to natural background radiation is an unpreventable event on earth. This study has estimated the background nuclear radiation in Iperindo town as a result of some mining activities from the surrounding goldmine deposit using the radiation scanner 500VBR. In each location, at least 5 readings were taken in order to ensure reliability of data. The mean absorbed dose rate in air was estimated to be 165.30±22.02 nGy/hr. the annual effective dose rate was estimated at a value 0.301±0.040m Sv/yr while the excess lifetime cancer risk for the study area is (1.201±0.160) x10^{-3}. This value is higher than the world average of 0.29 x 10^{-3}and implies that there is a significant risk excess lifetime cancer in the study area. This work can be used as a baseline research data for further research work, serving as reference for dosimetry in the event of futuristic action against the menace of harmful radiation.***

Keywords: Goldmine; Radiation; Iperindo; Dosimetry; Cancer risk

1. Introduction

Radiation is a phenomenon that has existed way back before the world's development and advancement in technology and has continued to evolve with mankind. This Phenomenon is generally defined as the transfer of energy in form of waves or sub-atomic particles (Garg, 2016). In our daily activities, we are exposed to a range of naturally occurring radiation either from cosmic rays, terrestrial or aquatic sources.

Background radiation dose consists of the radiation doses received from natural and man- made radiation sources. For someone residing in the US, the annual background doseis approximately 360 millirem (mrem), but in some locations can be much higher (USFDA, 2006). The highest known level of background radiation affecting a substantial population is in Kerala and Madras States in India where some 140,000 people receive an annual dose rate which averages over 1500 mrem per year from gamma, plus a similar amount from radon, for a total of 3000 mrem. (Monica et al, 2016).

Radiation exposure from radon is indirect. Radon has a short half-life (4 days) and decays into other solid particulate radium-series radioactive nuclides. These radioactive particles are inhaled and remain lodged in the lungs, causing continued exposure. Radon is thus assumed to be the second leading cause of lung cancer after smoking, and accounts for 15,000 to 22,000 cancer deaths per year in the US alone. (EPA, 2009).

Our environment is laden with all amounts of Natural Occurring Radioactive Materials (NORMs), which have existed since earth was formed. Their availability in the environment is generally at levels that are not potentially harmful to human health. However, these levels could be tampered with through human practices such as Mining or natural hazards like Earth quakes resulting in Health Risks. In nature, mining involves the production of large quantities of waste, which may contaminate soils over a large area, thereby negatively impacting the environment as well as human health (USEPA, 2009). Mining is one of the major causes of increasing NORM concentrations on the earth's surface causing health risks to humans, most especially by inhalation or ingestion. The most important NORMs in radiation protection are radionuclides from ^{238}U, ^{232}Th decay series. Also, ^{40}K also contributes significantly to human exposure in the environment. (Ziajahromi et al, 2014).

The series NORMs produced from these mining activities continue to decay until a stable nuclide is formed. This decay causes emission of ionizing radiation which causes biological damage to human organs. For instance, epidemiological studies have shown high mortality rates from respiratory diseases and lung cancer in miners working underground in the Erzmountains of Eastern Europe. The surrounding communities, which are referred to as nonoccupationally exposed populations, reside in close proximity to the gold mining activities and can be affected at various levels.The adverse health effects may result from environmental exposures to air, water, soil, and noise pollution. (USEPA, 2009).

High activity concentration has been associated to presence of Uranium waste which is a by-product of gold mining, and it can expose workers to radiation levels higher than the yearly limit of 20 mSv a year (Carina, 2013: Caspah. et al, 2016). Caspah. et al (2016) carried out Evaluation processes to assess radiological hazards associated with exposure to Naturally Occurring Radionuclide Materials (NORMs) from gold mine tailings in the province of Gauteng in South Africa. This was done by comparing soil sample results with that of a control area. The activity concentrations of these soil samples were measured using a Broad Energy Germanium (BEGe) detector. The presence of ^{238}U, ^{232}Th and ^{40}K were detected. The Value of ^{238}U were comparably higher than the worldwide average while those of ^{232}Th, and ^{40}K were comparable to the worldwide average. Also, the average dose rate in air from terrestrial Gamma Rays were found to be higher than the world average of 59 nGy/hr. Anjos et al (2015) carried out Radon and gamma radiation level measurements inside the La Carolina mine, one of the oldest gold mining camps of southern South America, which is open for touristic visits nowadays. CR-39 track-etch detectors and thermoluminescent dosimeters of natural CaF_2 and LiF TLD-100 were exposed at 14 points along the mine tunnels in order to estimate the mean ^{222}Rn concentration and the ambient dose equivalent during the summer season. The value for the ^{222}Rn concentration at each monitoring site is about three times the upper action level recommended by ICRP for workplaces (ICRP, 1990).

Augustine et al (2011) carried out studies in a Goldmine in Ghana to determine the exposure of the public to naturally occurring radioactive materials from processing of gold ore using direct gamma spectrometry and neutron activation analysis techniques. Thetotal annual effective dose to the public was estimated to be 0.69 mSv which compared well with typical world average values. The results indicate an insignificant exposure of the public from the activities of the Goldmine.

The aim of this study is to measure the natural background radiation level that arises as a result of the gold mine deposit and extraction in Iperindo area of Osun State in other to assess the radiological impact of the radiation on the environment and the human living in the study area.Over the years, Radiation has evolved with man and technology. This evolution has seemed helpful in many areas and in several cases, dangerous. The occurrence of radiation presented as a biological risk has demonstrated the need to assess the potential risk associated with living close and working in the goldmine site.

2. Research Methodology

2.1 Study Area

The research was carried out in Iperindo Town, a goldmine site in Osun State, Nigeria, which is located in the South-western geopolitical zone of Nigeria. Osun State is bounded in the north by Kwara State, in the east partly by Ekiti State and partly by Ondo State, in the south by Ogun State and in the west by Oyo State. It is located entirely within the tropics.The primary occupation in Iperindo is Trading of petty goods. Another source of occupation is vehicular transportation of people and goods as there exist quite a number of motorcycle and bus parks in the area. Another major Socioeconomic activity that the Iperindo town are involved in is Small scale farming.

Iperindo town is located in the Atakumosa East Local Government Area of Osun State and its coordinates are: 7°30′00″N 4°49′00″E. The area is characterized with goldmine deposit right at the edge of the town. The goldmine is quite underdeveloped and underutilised and has become a hub for illegal mining which has posed a threat to environmental safety and development, health of human as mining could be a very hazardous task.

2.2 Measuring Instrument and Research Procedure

The instrument used is the Radiation scanner model 500 VBRwhich candetect gamma rays, alpha and beta particles. In this mode, the detector measures the number of nuclear particles detected. The mode for measurement is counts per minute. When an ionizing particle enters the counter, ionization takes place and few ions are produced. If the Applied Potential difference is strong enough, they multiply by collisions; the movement of electrons is what generates the current impulse which is later amplified so that singles particles can be registered. The detector can also give cumulative counts per hour.Also, a GPS device was used to detect the coordinates of the sapling area.

In situ measurements were obtained at specific locations within Iperindo town. The reading on the instrument changes after a minute and up to five readings were taken and recorded for each location. The average of the five readings in sampling spot was obtained and subsequently used for further estimations. The coordinates of the specific locations where obtained with the aid of GPS and recorded.The dosimetry quantities were derived from the average count per minute.

Absorbed Dose rateThis is defined as ameasure of the radiation energy absorbed by a unit mass of a medium such as air. The readings in Average Counts per minute (cpm) for each location will be converted to NanoGray per hour (nGy/hr) using the formula (Akoma, 2014):

$$\text{Absorbed Dose rate in Air } (\mu Gy/hr) = \frac{Average\ cpm\ x\ 10\ \mu Gy/hr}{1095\ cpm} \quad (1)$$

Annual Outdoor Effective Dose Equivalent: The outdoor Effective dose equivalent can be calculated using the outdoor occupation factor. The outdoor occupancy factor is defined as the amount of time a person is exposed to outdoor radiation. This factor has an equivalent of 0.3 in rural areas (such as Iperindo) as recommended by the United Nation Scientific Committee on the Effect of Atomic Radiation (UNSCEAR, 2000). Thus, an average person spends 4.8 hours outdoor daily. Also, maintaining the conversion factor of 1 Gy= 0.7 Sv. The formula for calculating the Outdoor Effective Dose Equivalent (OEDE) is given as:

OEDE (Sv/y)= 0.7 Sv/Gy**x**(0.3)Occupancy Factor **x** T (8760 hr) **x** Mean Absorbed Dose Rate in Air (µGy/hr) (2)

Where T= time which is 1 year, equivalent to 8760 hours.

Excess Lifetime Cancer Risk (ELCR**):** ELCR is employed to calculate or estimate the increased risk of cancer as a result of a lifetime exposure to an agent by ingestion or inhalation.ELCR is usually used to quantitatively evaluate the effects of prolong exposure to the γ– radiation associated with the measured natural occurring radionuclidesBased upon calculated values of AEDE, Excess Lifetime Cancer Risk (ELCR) is calculated using equation 3:

ELCR = AEDE x Average duration of life (DL) x Risk Factor (3)

The average life duration is 70 years and ELCR is measured in Sievert. The Risk Factor is the cancer risk per Sievert. For low dose stochastic background radiation, ICRP 103 suggested the value of 0.057 for public exposure. (ICRP, 2007)

3. Results and Discussion

The Absorbed dose rate in air was taken in counts per minute as measured by the Radiation scanner. Table 1 shows the range of the Counts per minute of each of the 10 locations in Iperindotown.

Table 1: Table showing the absorbed dose in air of specific locations in Iperindo town

Location	Range (cpm)	Mean (cpm)	ADR (nGy/hr)
Ibironke Petrol Station	14.00-25.00	19.40	177.169
Ilerin Junction	16.00-25.00	19.60	178.995
Iperindo B/Stop (Orogbo-Ijesha)	12.00-17.00	24.40	131.507
Iperindo Arc	15.00-21.00	21.20	193.607
Iloro Street	11.00-200	15.40	140.639
Assemblies of God Church	19.00-24.00	17.40	158.904
Deeper Life Bible Church	15.00-25.00	20.40	186.301
Cemetery road	11.00-21.00	15.20	138.813
Motorcycle Park, Odo-Odi	14.00-21.00	18.00	164.384
Akande street	13.00-24.00	20.00	182.648
Average		18.10	165.297
Standard deviation		2.289	22.023

3.1 Absorbed Dose Rate in Iperindo Town

Based on the calculation of absorbed dose rate shown in Table 1, as well as the representation of the Absorbed Dose rate on the Bar chart in Fig 1, it is seen that Iperindo Arc area in Iperindo town records the highest absorbed dose rate of 193.61nGy/hr while Iperindo Bustop (Orogbo-Ijesha) has the lowest absorbed dose rate of 131.51 nGy/hr. Also, the Mean Absorbed Dose rate is 165.30±22.02 nGy/hr. The table 1 shows the average cpm and absorbed dose rate for each location in Iperindo.

3.2 Annual Outdoor Effective Dose Equivalent in Iperindo

The annual OEDE measured in Sv/yr was calculated using equation 2, The outdoor occupancy factor of 0.3 is used because Iperindo town is a rural area. The values ranged from 0.239 to 0.353 mSv/yr with the resulting average Outdoor Annual Effective dose of 0.301±0.040mSv/yr, which is higher than the worldwide average of 0.07 mSv/yr. (Mohammed et al., 2014).

3.3 Excess Lifetime Cancer Risk (ELCR)

Excess lifetime cancer risks factor was directly determined using the Annual Effective Dose radiation which is solely dependent on the measured radiation dose rate in the area of study. Based upon calculated values of AEDE, Excess Lifetime Cancer Risk (ELCR) is calculated using equation 3. The calculated values of ELCR ranged from 0.925 to 1.407 (x 10^{-3}) with mean values of (1.209±0.160) x 10^{-3}.Notably, this is much higher than the world average of 0.29 x 10^{-3}(Taskin, *et al*., 2009).Table 2 gives a comparison of the Annual Effective Dose Equivalent(AEDE) with the Excess Lifetime Cancer Risk (ELCR).

Table 2: Table showing the AEDE (mSv/yr) with ELCR

Location	*ADR (nGy/hr)*	*AEDE (mSv/yr)*	*ELCR (*10^{-3})*
Ibironke Petrol Station	177.169	0.323	1.287
Ilerin Junction	178.995	0.326	1.300
Iperindo B/Stop (Orogbo-Ijesha)	131.507	0.239	0.955
Iperindo Arc	193.607	0.353	1.407
Iloro Street	140.639	0.256	1.022
Assemblies of God Church	158.904	0.289	1.154
Deeper Life Bible Church	186.301	0.339	1.353
Cemetery road	138.813	0.253	1.009
Motorcycle Park, Odo-Odi	164.384	0.299	1.194
Akande street	182.648	0.333	1.327
Mean	**165.300**	**0.301**	**1.201**
Standard deviation	**22.023**	**0.040**	**0.160**

4. Discussion

The results shown in Table 1 indicate that the absorbed dose rate around Iperindo arc has the highest value while that of Orogbo-Ijesha is the lowest. This is because the Arc is at the entrance of the town and the closest area to the Goldmine site. Conversely, Orogbo-Ijesha is farthest from the Goldmine (based on the locations measured) and hence records the lowest absorbed dose rate in air. The results as seen above have shown that the farther the residents of Iperindo town live from the goldmine site, the lower the risk of exposure to nuclear background radiation. The value of mean absorbed dose rate in air obtained for the study area is higher than the world average of 59nGy/hr. (UNSCEAR, 2000). Also, in comparison with other mining and non-mining areas in Nigeria such as Itagunmodi (Ademola et al., 2014) and Ota (Oyeyemi *et al*, 2017)with the total average absorbed dose rate in the living area as20.4 ± 2.1 nGy/hr and 148.22 nGy/hr respectively, the values obtained at the Iperindo living area are much higher.Fig. 2 below illustrates the comparison of the absorbed dose rate of each location measured with the world average of 59 nGy/hr.

The average annual Effective Dose Equivalent in the study area is given as 0. 301 mSv/yr. Hence, comparing to the world average for terrestrial background radiation as recommended by UNSCEAR (2000) which is 0.07 mSv/yr, it is more than 4 times higher than the UNSCEAR average and also substantially higher than the Nigerian average of 0.098mSv/yr(Farai & Jibir, 2000). However, it is less than the recommendations of ICRP (2007) of 1.0 mSv/yr but is within the limits of the average from high natural background radiationarea by UNSCEAR (2000) which is 2.4mSv/yr. this obtained value is also lesser than value obtained from a Goldmine site in Ghana (Augustine et al, 2011), of 0.69mSv/yr.

The Excess Lifetime Cancer Risk at the Iperindo arc has the highest value. This is the implication of the attended nuclear radiation emission from the goldmine site and it implies that those living around the goldmine site risk higher exposure to background radiation. Furthermore, mean Excess Lifetime Cancer Risk due to Background radiation calculated as (1.201) x 10^{-3} is about 4 times higher than the world average of 0.29 x 10^{-3}. This value (1.201 x 10^{-3}) is higher than the estimated ELCR values at Ota (Oyeyemi et al, 2017) and Itagunmodi (Ademola et al., 2014) of 0.635 x 10^{-3} and 0.324x 10^{-3} respectively.

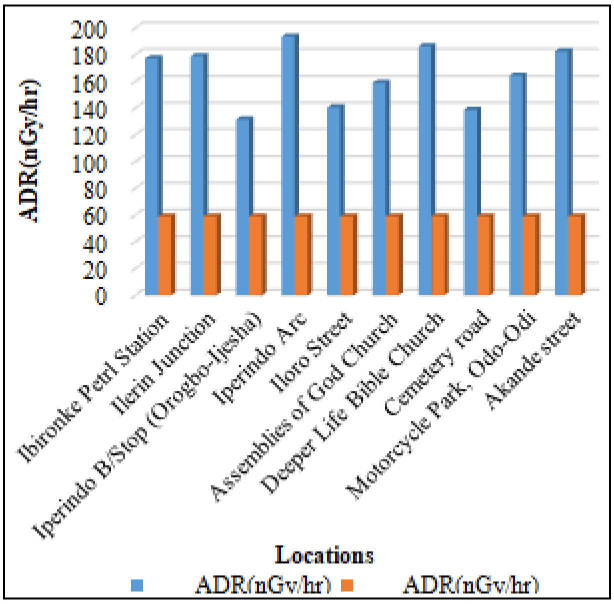

Figure 1: Absorbed dose rate in different locations in Iperindo in comparison with the worldwide average of 59nGy/hr

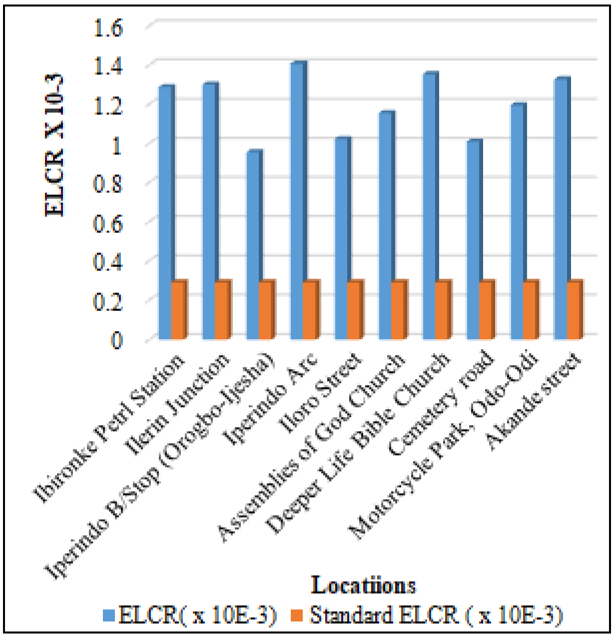

Figure 2: Comparison of the ELCR values of different locations with the world average

5. Conclusion

This present study has measured the absorbed dose rate in air of 10 specific locations in Iperindo town a gold mine exploration area, using a Radiation scanner. Annual Effective Dose was calculated by standard procedure for assessing Excess Lifetime Cancer Risk of the population living in these locations. The result of this work has provided a database for dosimetry quantities in these locations.

The values of the Absorbed Dose Rates, Annual Effective Dose Equivalent and Excess Lifetime Cancer Risk all exceeded the permissible Limits of 59 nGy/hr, 0.07 mSv/yr and 0.29 x 10^{-3}, respectively.This shows that there is a possibility of an elevated cancer risk to the people of Iperindotown as a result of the emission of radiation from the gold mine deposit and exploration, with residents living closest to the goldmine site at a higher risk than those living farther away from the site.

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