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In-situ measurement of outdoor absorbed dose rates at Itagumodi and Iperindo gold mining sites in Osun state, Nigeria

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Abstract: The extraction and usage of natural resources, such as gold, contribute to the variability of ambient radiation levels in the natural environment. The study involved measuring the absorbed dose rate at the Itagunmodi and Iperindo gold mining sites in Osun State, Nigeria, using the BlueGeiger-15 dosimeter. The recorded absorbed dose rate (DR) varied between 0.15 and 0.27 microgray per hour. The annual effective dosage (D_{eff}) was assessed to be between 0.22 and 0.33 millisieverts per year for the Iperindo mine and between 0.18 and 0.27 millisieverts per year for the Itagunmodi mine. The mean values annual effective dose for Iperindo and Itagunmodi were 0.28 ± 0.05 and 0.21 ± 0.03 millisieverts per year, respectively. The study also calculated the excess lifetime cancer risk (ELCR) for the Iperindo and Itagunmodi mines, with average values of 9.68×10^{-4} and 7.16×10^{-4}, respectively. These values are above the global average of 2.9×10^{-4}, suggesting that individuals and workers in the region may have an increased risk of developing cancer during their lifetime.

Keywords: dose rate; BlueGeiger PG-15; cancer risk; background radiation; Nigeria.

1. Introduction

Radiation exposure due to natural sources, particularly in regions associated with mining activities, presents a critical concern for environmental and public health assessments (Brugge 2005; Kamunda, Mathuthu, Madhuku 2016; Agboola et al. 2020). The Itagumodi and Iperindo gold mining sites situated in Osun State, Nigeria, have garnered attention due to their geological richness and the potential for elevated radiation levels associated with mining operations.

Natural radiation is ubiquitous in our environment, inadvertently. Most of the yearly dose of radiation that humans receive is derived from natural sources. Terrestrial and cosmogenic sources contribute to natural radiation (UNSCEAR 2000; UNSCEAR 2008;

Tayyeb, Hamed, Maryam 2012; Adebiyi et al. 2021). Terrestrial radiation arises from the presence of primordial radionuclides belonging to the 235U, 238U, and 232Th series, and 40K. The cosmogenic component comprises cosmic rays that originate from extraterrestrial sources (UNSCEAR 2000; Ugbede et al. 2020). Moreover, terrestrial radiation is greatly affected by the geographical features and geological evolution of the surroundings, while cosmogenic radiation relies on parameters such as the solar cycle, altitude, and latitude (UNSCEAR 2000). Furthermore, anthropogenic sources of background radiation stem from activities that humans engage in such as the extraction and usage of natural resources, as well as nuclear incidents. These contributions have gained significance as a result of the variability in background radiation levels in the environment (Ugbede et al. 2020). Background radiation can be regarded as an environmental pollutant, particularly when it exceeds the threshold value that applies to occupational workers and the public (UNSCEAR, 2000; Agbalagba, Osimobi, and Avwiri 2016; James et al. 2023).

Several studies have been conducted on in situ measurements of background radiation across Nigeria and elsewhere (Agbalagba, Osimobi, and Avwiri 2016; James et al. 2023; Akpabio, Etuk, and Essian 2005; Olarinoye et al. 2010; Sadiq and Agba 2011; Rafique 2013; Ramli 2014; Agbalagba 2017). Although the distributions of radioactivity concentrations in soil and rocks are known, information about the distribution of background radiation is still scanty in this study area. To fill this knowledge gap, this study performed on-site measurements of the absorbed dose rates in the outdoor areas of the Itagumodi and Iperindo gold mining sites. Additionally, the purpose is to assess the annual effective dose rate, calculate the excess lifetime cancer risk (ELCR), and create a contour map depicting the distribution of outdoor absorbed dose rates in the study area. The results of this inquiry have important ramifications for the monitoring of the environment, ensuring safety in the workplace, and safeguarding public health in areas connected to gold mining operations. The information gathered from this study may prove to be an indispensable benchmark for subsequent investigations in this field.

2. Materials and methods

2.1. Study area: Location and accessibility

Itagunmodi is situated within the latitudes of 7.5^0 and 7.6^0 N and longitudes of 4.6^0 and 4.7^0 E in the tropical rainforest region of Africa. Itagunmodi is accessible via a road connected to the Ilesa/Ile-Ife expressway. A significant portion of this study region is impassable, particularly during the rainy season. A road made of asphalt connects the Iperindo gold field, which is situated between the coordinates 7.450 and 7.550 north latitude and 4.80 and 4.850 east longitude (see Figure 1). The field is roughly 18 kilometers south of Ilesa.

Situated in southwestern Nigeria, the location is part of the schist belt. A variety of rock types make up the schist belt: gneisses, pegmatized schist, amphibolite, quartzite, quartz schist, migmatites with pegmatites, schist and epidorite complex, granulite, pegmatized schist, quartzite, and granite gneiss (Fadare 2000). The research area is distinguished by tropical ferruginous red soils, derived from the underlying basement complex material found in the western highland. The soil in this region is generally characterized by their depth and can be divided into two primary groups. The first group is deep clay soil, which is situated on the low, even hilltop and upper inclines. The second category comprises hill wash soil with a higher sand content, primarily found on the lower slopes. The well-drained clay soils found on the hilltop and gradients are crucial because they provide optimal qualities for cultivating cocoa (Theobroma cacao), oil palm (Elaeis guineensis), citrus (Gambeya Africana), and coffee (Coffea brevipes), which are the most lucrative crops in the region. Nevertheless, mining activities have harmed agricultural practices in many villages within the studied region. The Itagunmodi series of soil contain a substantial quantity of gold, making them particularly conducive for growing cocoa trees. The first casualties of the mining of gold surge are the devastation of valuable cocoa plantations, which inhabitants have relied upon for several decades (Adeoye 2015). The primary towns nearest to the mining locations are Itagunmodi, where 18 carats of alluvial gold can be found, and Iperindo, which also yields 18 carats of alluvial gold (Taiwo and Awomeso 2017; Thor Explorations Ltd (TEL). 2019). The study area has two distinct rock types that are separated by the Ifewara Fault Zone, a shear system aligned in the NNE-SSW direction. The occurrence of pellitic rocks, amphibole schist, talc-tremolite, and amphibolites characterizes this zone (Tropical Mines Limited (TML) 1996).

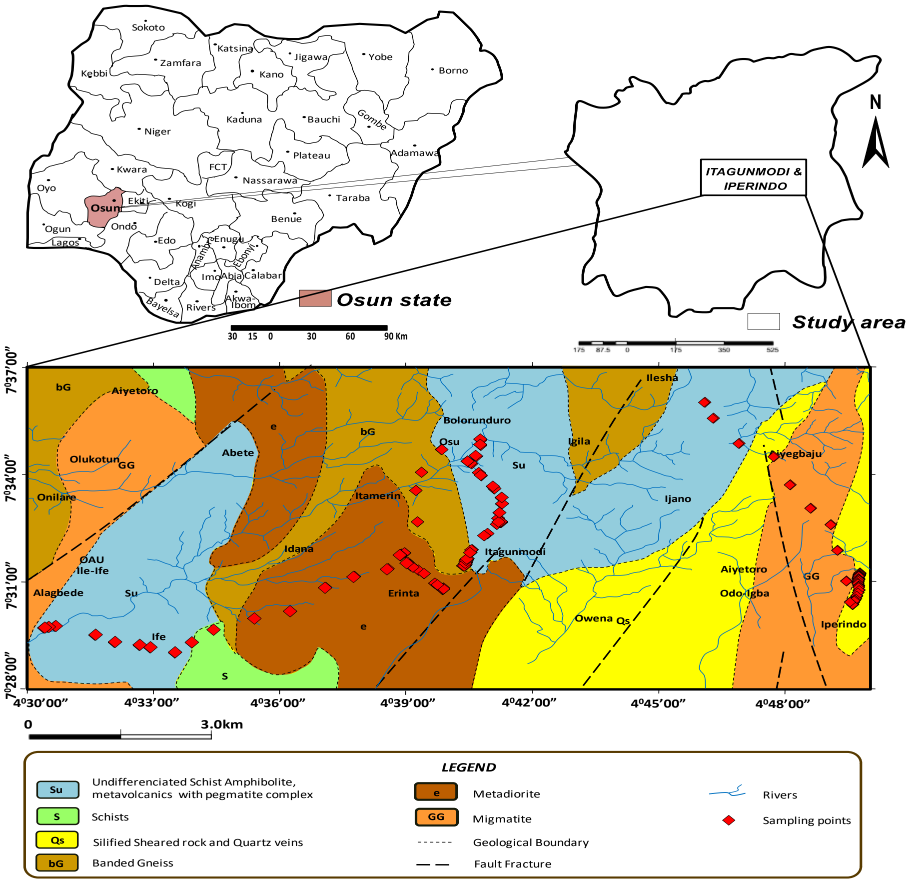

Figure 1. Geological Map of Itagunmodi and Iperindo with sampling points

Schists of quartzite, amphibole, and quartz can be found in the eastern part. The gold deposit is in the eastern region, situated to the east of the Ifewara fault zone. Gold is frequently found in association with several ores, including pyrite, pyrrhotite, and small quantities of chalcopyrite, galena, sphalerite, magnetite, and ilmenite. An assemblage of sericite chlorite and epidote has developed in the granite-gneiss next to the gold-bearing veins following hydrothermal alteration. This collection also includes hematite and pyrite (Ayantobo et al. 2014). Figure 1 depicts the geological geography of the study site.

2.2. On-site measurement of radiation levels in the Iperindo and Itagunmodi mines

Measurements of radiation levels were conducted in the air approximately one meter above the ground within and in the vicinity of the mining excavations using a device called the BlueGeiger PG-15. The device is a compact and user-friendly device capable of measuring ambient radiation levels as well as detecting and measuring high amounts of gamma, beta, and X-ray radiation. The gadget is a Geiger counter that records dosage rates and Global Positioning System (GPS) data when it is connected via Bluetooth to an Android smartphone. Measurements were conducted during between the hours of 12 p.m and 4 p.m. to optimize the radiation meter's sensitivity to radiation (NCRP 1993). The mines in Iperindo and Itagunmodi were divided into 6 and 8 zones, respectively, based on the extent of mining activity in each location. Five measurements were collected for each point, and the standard deviation was calculated for each set of data to account for any possible error (Emumejaye and Daniel-Umeri 2018).

2.3. Calculation of the annual effective dose (D_{eff}) and excess lifetime cancer risk (ELCR)

To determine the D_{eff}, which was expressed in millisieverts per year, an occupancy factor of 0.2 was utilized in conjunction with the average absorbed dose rates (UNSCEAR 2000 and UNSCEAR 2008). The occupancy factor denotes the ratio of the time an individual is being exposed to radiation to the overall time (Ramli 2014). The calculation of D_{eff} was performed using Equation 1

$$D_{eff} = DR\left(\mu\frac{Gy}{h}\right) * 8760 * OF * C_F * 0.001 \quad (1)$$

where DR is the absorbed dose rate, the number 8760 is the total hours in a year, OF is the outdoor occupancy factor taken to be 0.2 (UNSCEAR 2008). The conversion factor, CF, for converting the dose rate in the air to an effective dose is 0.7 Sv/Gy. The value of 0.001 is the conversion coefficient for converting from micro to milli.

The ELCR was computed utilizing Equation 2, a well-known model in the literature (Ugbede et al. 2020; Rafique et al. 2014; Agbalagba, Osimobi, and Avwiri 2016). The ELCR assesses the risk of cancer that may arise from exposure to ambient natural radiation in the area.

$$ELCR = D_{eff} * R_f * D_L \quad (2)$$

where Rf denotes the risk factor per sievert for fatal malignancy. The R_f value for the general population is 0.05 in areas with low background radiation, which is linked to stochastic effects (ICRP 1990). D_L refers to the mean lifespan, which is typically around 70 years.

3. Results and discussion

The outdoor absorbed dose rate, measured in air at a height of 1 meter above the ground, is presented in Table 1 for various sampling stations and towns (namely Igun, Igbadae, and Ijana) surrounding the mines. The Iperindo mine exhibited radiation levels ranging from 0.18 to 0.27 µGy/h, and an average of 0.23 ± 0.04 µGy/h. The lowest and highest values recorded for the Itagunmodi mines were 0.15 and 0.22 µGy/h, correspondingly, and an average value of 0.17 ± 0.03 µGy/h. The calculated D_{eff} for Iperindo was 0.28 ± 0.05 mSv/y, whereas for Itagunmodi it was 0.21 ± 0.03 mSv/y, with the latter result being somewhat lower. The disparity in the estimated effective dose could be attributed to the presence of rocks in Iperindo that are not in Itagunmodi mine due to difference in geology. Furthermore, it is widely acknowledged that locations at greater elevations are linked to increased levels of external gamma radiation, and Iperindo happens to be situated at a somewhat higher height than Itagunmodi (UNSCEAR 2000).

Table 1. The absorbed dose rate values in Iperindo and Itagunmodi mines

	Location	DR (µGy/h)	D_{eff} (mSv/y)	ELCR (x 10^{-4})
	Iperindo			
	IPERI1	0.27	0.33	11.55
	IPERI2	0.27	0.33	11.55
	IPERI3	0.18	0.22	7.70
	IPERI4	0.19	0.23	8.05
	IPERI5	0.23	0.28	9.80
	IPERI6	0.22	0.27	9.45
Average	**0.23 ± 0.04**		**0.28 ± 0.05**	**9.68 ±1.65**
	Itagunmodi			
	ITAGU1	0.18	0.22	7.70
	ITAGU2	0.18	0.22	7.70
	IGUN1	0.15	0.18	6.30
	IGUN2	0.15	0.18	6.30
	IJANA1	0.16	0.20	7.00

IGBAD1	0.15	0.18	6.30
IGBAD2	0.15	0.18	6.30
ITAGU3	0.21	0.26	9.10
ITAGU4	0.22	0.27	9.45
IGUN3	0.15	0.18	6.30
IGUN4	0.15	0.18	6.30
Average	**0.17 ± 0.03**	**0.21 ± 0.03**	**7.16±1.21**

However, the average dose levels measured in this study are lower than the recommended limit of 1 mSv/y for individuals in the general population, but it is also higher than the worldwide average of 0.07 mSv/y (UNSCEAR 2000; ICRP 1991). The findings of the study conducted in these mines show a high degree of correlation with the findings of comparable studies conducted in other locations (Sadiq and Agba 2011; Darko et al. 2010).

The frequency distribution of dose rates in the Iperindo mine is shown in Figure 2. The dose rate is positive to the right, with a skewness value of 0.062 ± 0.845. Residents in the vicinity where the dose rate appears to be elevated are prone to experiencing increased exposure to ionizing radiation. The Kurtosis value has a value of 1.823 ± 1.741.

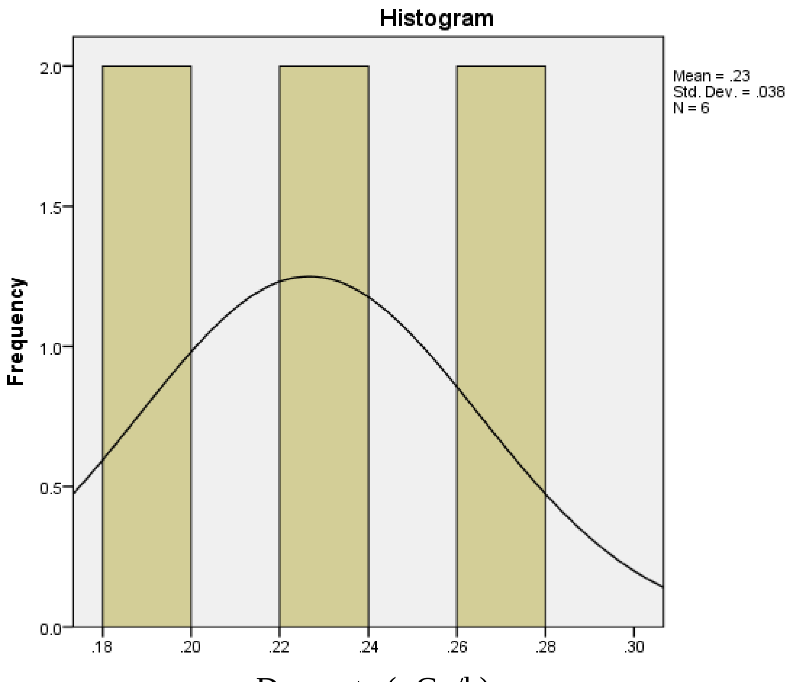

Figure 2. Histogram showing the distribution of dose rate in Iperindo

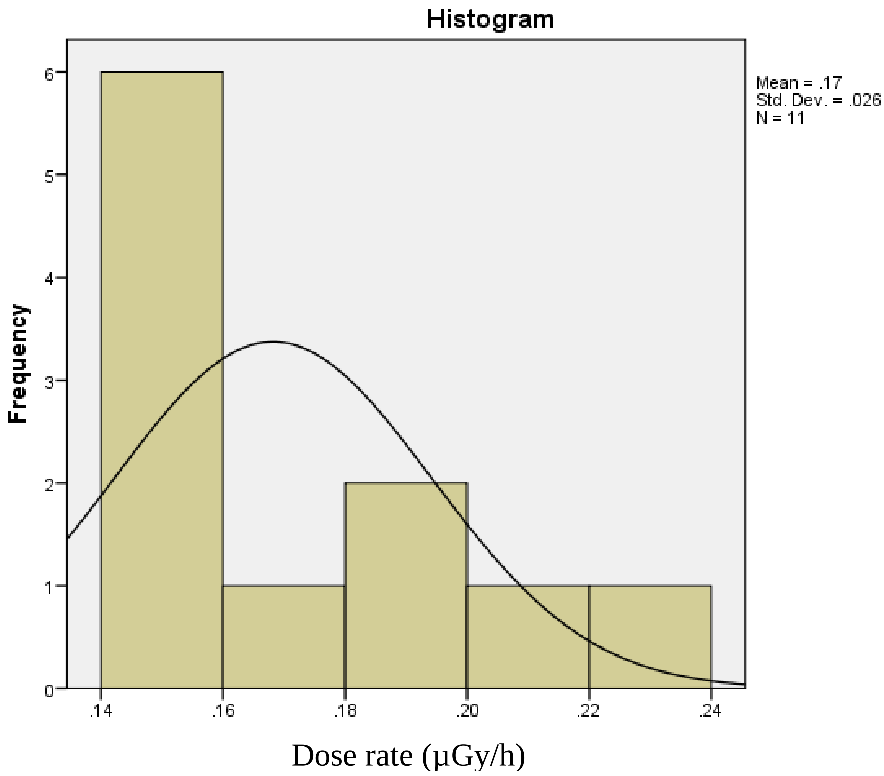

Figure 3. Histogram showing the distribution of dose rate in Itagunmodi

Figure 3. gives the frequency distribution of the dose rate for the Itagunmodi gold mine, which is positively skewed to the right with a value of 1.243 ± 0.661 and a Kurtosis value of 0.229 ± 1.279. This distribution is similar to that of the Iperindo mining area, which implies that the populace is exposed to a higher level of ionizing radiation where the dose rates are high.

Figure 4 displays the contour map illustrating the absorbed dose rates in the air at the research site. The data reveals an uneven distribution of the absorbed dose rate of air at a one-meter height from the ground. The dose rate for the entire research area, including Iperindo, Itagunmodi, and the surrounding areas, varied between 0.15 and 0.27 µGy/h, with an average value of 0.23 ± 0.04 µGy/h.

The calculated values of ELCR for the Iperindo mine vary between 7.77 x 10^{-4} and 11.55 x 10^{-4}, with an average of 9.68 x 10^{-4}. The Itagunmodi gold mine has a minimum value of 6.30 x 10^{-4} and a maximum value of 9.10 x 10^{-4}, having an average value of 7.16 x 10^{-4}. The ELCR readings exceed the global average of 2.9 x 10^{-4} (UNSCEAR 2000).The lifetime cancer risk is somewhat elevated, and there exists the potential for individuals residing and working in the vicinity to develop cancer. The ELCR values surpass those reported by Agbalagba et al. (Agbalagba, Osimobi, and Avwiri 2016) and they are below the values described by Zarghani and Jafari (Zarghani and Jafari 2017; Jafaria, Mohammadi, and Zarghania 2017).

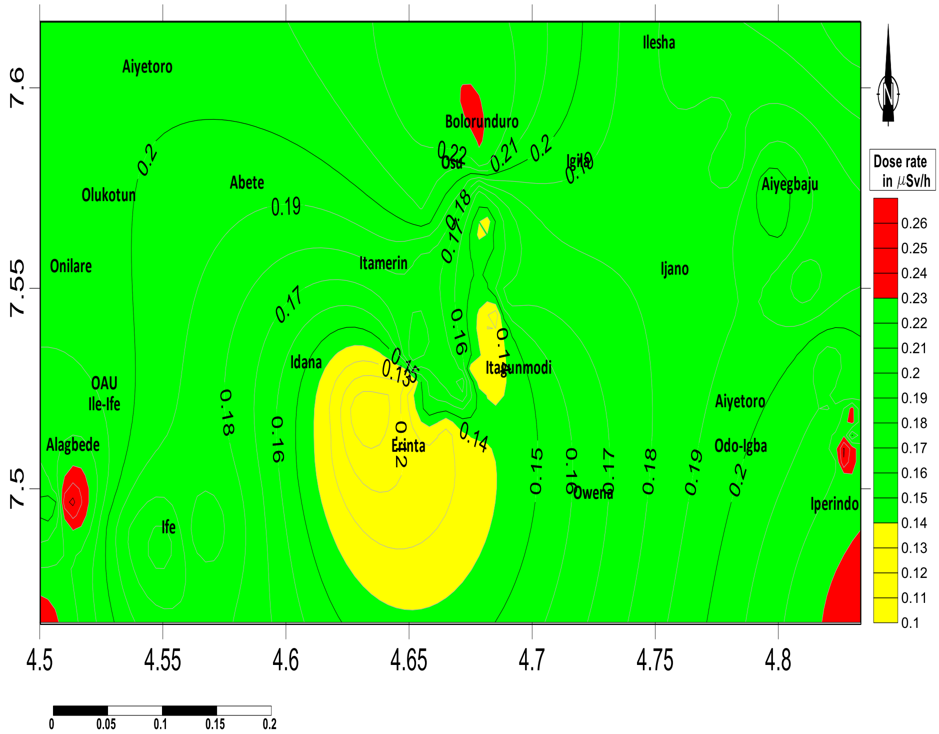

Figure 4. Contour map showing the distribution of outdoor dose rate in Iperindo and Itagunmodi.

4. Conclusion

The purpose of this study was to quantify the absorbed dose rates and estimate the annual effective dose, as well as the ELCR, in the gold mining areas of Itagunmodi and Iperindo, located in Osun State, Nigeria. A contour map depicting the absorbed dose rate was also created. The average values of effective dose (Deff) in the Iperindo mining site are greater than those in the Itagunmodi mining site, while they remain below 1 millisievert (mSv) for the public. The average ELCR assessments are above the global norm of 2.9 x 10^{-4}, suggesting that the population is at a heightened danger of having malignancy over their lifetime. The outcome of this study would furnish basic information for subsequent radiological studies in the region.

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