Determination of Ionizing Radiation Exposure Levels within Four Local Mining Sites Selected from Sardauna Local Government Area of Taraba State - Nigeria

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Abstract Miners and the people living close to mining sites are exposed to elevated levels of ionizing radiation with or without their consent. This study determined the background ionizing radiation of four mining sites from Sardauna local government area of Taraba state using an inspector alert nuclear radiation meter manufactured by S.E. International, Inc USA with serial number 35440. The meter has a halogen- quenched Geiger Muller tube with a ± 45 mm effective diameter and mica window density of 1.5- 2.0 mg/cm^3. The Geiger tube in the meter generates a pulse of electrical current each time radiation is incident on the tube and causes ionization. The measured values ranged from 0.19 - 0.40 mSv/yr across all the mining sites and 500 m away from the sites. These results were found to be far less than the standard of 1.0 mSv/yr set by International Commission on Radiological Protection (ICRP) for the general public and 20.0 mSv/yr set by the Nigeria Basic Ionization Radiation Regulation (NiBIRR) for the whole body of adult radiation protection workers which means that the miners and inhabitants of this areas are safe. Nevertheless, there could be long term variations in the consequences arising from the effects of ionizing radiation among the miners and even the inhabitants. Strong correlations were found between the equivalent doses at the excavating and the processing points of the sites which mean that the miners and people living close to these mining sites are subjected to uniform distribution of consequences arising from ionizing radiation. We do recommend that policy makers and regulatory bodies should apply mitigation measures to the effects by means of creating awareness to the miners at various mining sites and the use of modern mining strategies to protect other natural resources especially water.

Keywords: *ionizing radiation, equivalent annual dose, mining sites, correlation and equivalent dose*

1. Introduction

The exposure of human beings to ionizing radiation from natural sources is a continuing and inescapable phenomenon on earth. Ionizing radiation and radioactivity are found naturally within the environment and their level depends generally on the distribution of natural radionuclides within the environment. Human activities involving mining, the use and processing of radionuclide or items which contain radionuclides can enhance the levels of environmental radiation [1,2]. Some people are exposed to enhanced levels of natural radiation at their places of work, such workers includes underground miners, some workers involved in mineral processing and aircraft flight crews [3].

Mining workers and their neighbors such as present in Sardauna local government area of Taraba state have been for long exposed to ionizing radiation with or without their consent [4]. Exposure to radiation leads to damage on different levels of the biological system of an organism.

The clinical risk of damages posed by radiation and the resulting radiation syndromes may vary to a great extent depending on exposure conditions like the nature of radiation, time and the affected organs [5]. These injuries and clinical symptoms may include chromosomal transformation, cancer induction, free radical formation, bone necroses and radiation catractogenesis [6].

The two main contributors to natural ionization exposure are high-speed cosmic ray particles incidents in the earth's atmosphere and the primordial radionuclides present in the earth's crust which are ubiquitous including the human body. Some exposure to natural radiation sources are modified by human activities like mineral processing and quarry activity. The people of Sardauna local government area of Taraba state are known for their engagement in sapphires, gold, gravel and other precious stones mining locally at commercial levels. The miners are exposed to radioactive elements like Uranium-238, Uranium-235 and Thorium-232. It has been found that all soil samples had concentration of Uranium-238 [7]. Exposure to ionizing radiation also arises from other terrestrial radionuclides present in trace levels in all soil

types. Radiation emitted by these radionuclides within 15-30 cm of the top soil reach the earth surface [8]. Only those radionuclides with half lives comparable to the age of the earth, and their decay product exist in significant quantities in these materials. One of the heavy radionuclide products is naturally occurring radon gas which contributes to high amount of potentially lethal doses and it has also been reported to be the cause of majorities of lung cancer death and risk of lung cancer from exposure to radon is also reported to be higher than other causes [9,10].

Ike *et al.* [4] and Agba *et al.*, [9] investigated the radiation levels in mining sites of Plateau and Benue state respectively and found that ionization radiation was present in the mines though within a healthy range. Because of the lethal effects of ionizing radiation, the assessment of exposure to it is an important goal of regulatory bodies and radiation scientists. It is intended in this study to monitor and assess the levels of exposure to ionizing radiation in some selected mining sites from Sardauna local government area of Taraba state and hence recommends measures of keeping the miners' exposure level to ionizing radiation as low as possible.

Since little or no data exist on this subject, it is hoped that the data generated in this study will form a base line for policy makers and regulatory bodies in the state and also assist them to put in place proper checks and regulations on the activities of the miners in order to achieve low exposure levels to ionizing radiation and sustainable development in Sardauna local government area of Taraba state and Nigeria in general.

2. Materials and Methods

2.1. Sampler and Analytical Procedures

The sampling tool used in this study was an inspector alert nuclear radiation meter manufactured by S.E. International, Inc USA with serial number 35440. The meter has a halogen quenched Geiger-Muller tube $\pm$ 45 mm effective diameter and mica window density of 1.5- 2.0mg/cm^3. The Geiger tube generates a pulse of electrical current each time radiation is incident on the tube and causes ionization. Each pulse is electronically detected and registered as a count in a choice mode of the operator. The meter was held one meter above the ground surface to reflect the abdominal level of human and twelve readings in count per minute (CPM) and Roentgens per hour (R/hr) were taken at each point of the four sampling sites. The readings were taken at the excavation and processing point of each of the mining sites. Areas of

normal background were also selected 500m away from each of the mining site based on metropolitan's population or the presence of an access path leading to the village and the mining sites. The mean readings in roentgens per hour were then calculated from the expression in equation 1.

$$\text{Mean}\left(\overline{x}\right) = \frac{\sum F}{N} \qquad (1)$$

Where $\sum F$ = Sum of all the observed values at a site.
N = Total number of times observations are recorded at a site.

The mean readings in roentgens per hour were further converted to microsieverts per hour which serve as the equivalent dose according to the conversion factor in equation 2

$$1R / h = 10 \, \mu Sv / hr. \qquad (2)$$

UNSCEAR, 1988 recommended outdoor occupancy factor of 0.2 to be the proportion of the total time during which an individual is exposed to a radiation field. 8760 hrs/yr was used to convert readings in hours from equation 2 to annual equivalent doses in mSv/yr according to equation 3

$$Ed_A \left(mSv / yr\right) = 0.2\beta\left(\mu Sv / hr\right) x \, 8760 \, hrs / yr \, x10^{-3} \quad (3)$$

Where Ed_A = Annual equivalent dose rate in mSv/yr and β = observed readings in μSv/hr.

2.2. Study Area

The study area covers four mining sites from Sardauna local government area of Taraba state which are located in Nguroje and Gembu towns all in southern part of Taraba state. The area lies within latitude $06^0 \, 05^{'}$ – $06^0 90^{'}$ N and longitude $11^0 \, 15^{'}$ – $11^0 \, 65^{'}$ E and covered approximately 4,603km^2. The population of the inhabitants is approximately 397,438 according to 2006 census figure [11]. 90% of the people are engaged in mining, farming and grazing activities as major occupation. The miners use blunt implements such as hoes, diggers and bare hands to dig the earth in search of the precious stones. The cold weather of the area provides a clement atmosphere for the miners to work throughout the day.

2.3. Sampling Sites Selection/Site Code

The sampling sites selected from the villages of the study area and their assigned codes are presented in Table 1.

The four sites were chosen based on high human activities of mining in the local government area as carefully observed by the researcher.

Table 1

S/N	Town	Mining Site / Site Code	Coordinates	
			Lat.	Long.
1	Nguroje	Mayo-Sina Sapphires mining site (M$_1$)	6.80 N	11.56 E
2	Nguroje	Mayo-Ndaga Quarry Site (M$_2$)	6.82 N	11.60 E
3	Nguroje	Mayo-Ndaga gold mining site (N$_1$)	6.72 N	11.41 E
4	Gembu	Mbamnga sand mining site (G$_1$)	6.42 N	11.16 E

3. Results and Discussion

The mean of the ionizing radiation data collected in roentgen per hour and the total count in count per minutes at the excavation point, processing point and 500 m away from each of the mining site is calculated using equation 1 and presented in Table 2. Table 3 is the converted results using equation 2 and 3 respectively.

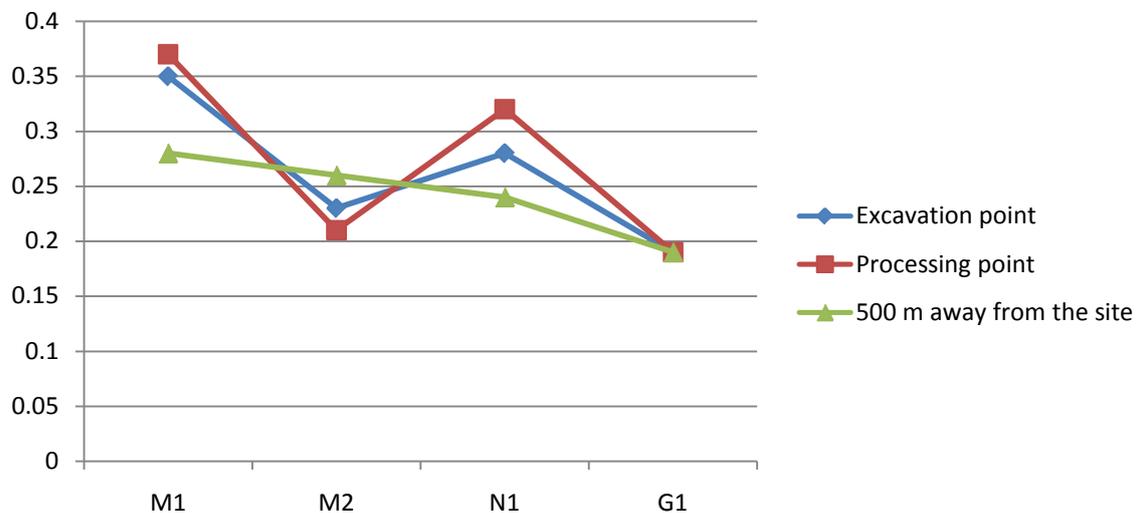**Table 2. Mean values of ionizing radiation measured from the mining sites**

S/N	Mining site	Excavation point		Processing point		500 m away from the site	
	Code	R/hr	CPM	R/hr	CPM	R/hr	CPM
1	M_1	0.020	74.0	0.021	82.0	0.016	60.0
2	M_2	0.013	46.0	0.012	43.0	0.015	53.0
3	N_1	0.016	60.0	0.018	65.0	0.014	46.0
4	G_1	0.011	34.4	0.011	43.0	0.011	35.8

Table 3. Mean background radiation at the excavation point, processing point and 500 m away from site

S/N	Mining site	Excavation point			Processing point			500 m away from the site		
	Code	Ed (μSv/hr)	Ed_A (mSv/yr)	CPM	Ed (μSv/hr)	Ed_A (mSv/yr)	CPM	Ed (μSv/hr)	Ed_A (mSv/yr)	CPM
1	M_1	0.20	0.35	74.0	0.21	0.37	82.0	0.16	0.28	60.0
2	M_2	0.13	0.23	46.0	0.12	0.21	43.0	0.15	0.26	53.0
3	N_1	0.16	0.28	60.0	0.18	0.32	65.0	0.14	0.24	46.0
4	G_1	0.11	0.19	31.0	0.11	0.19	43.0	0.11	0.19	36.0
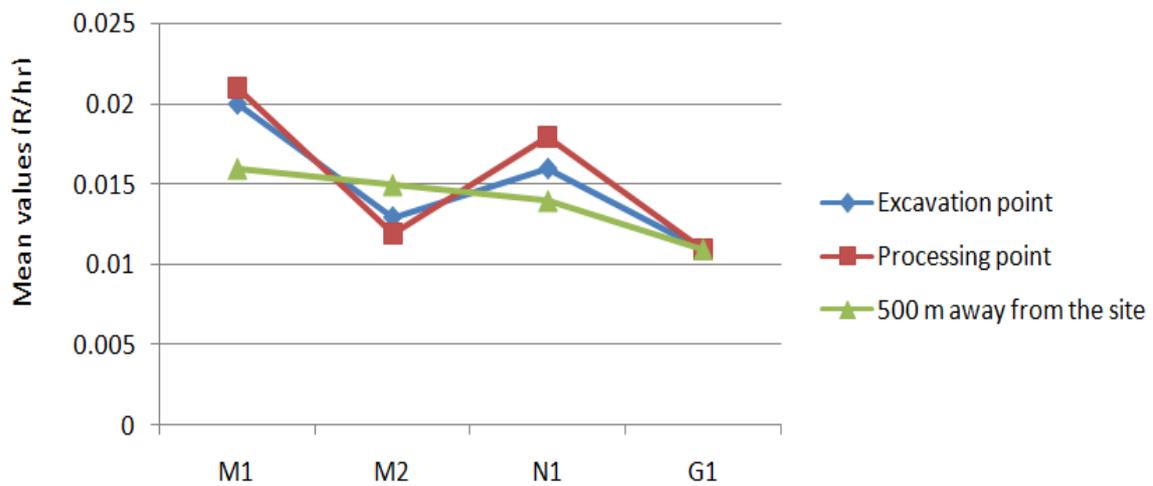
Figure 1. Mean values of ionizing radiation collected from the mining sites

Figure 2. Mean annual background radiation and the mining site represented with site code

4. Discussion

The mean ionizing radiation measured at the excavation point, processing point and 500 m away from the mining sites as presented in Table 2 and Figure 1 shows that Mayo-Sina sapphires mining site has highest value of ionizing radiation at all the three points followed by Mayo-Ndaga gold mining site with the highest value at the excavation and processing point. But for the case of 500 m away from the mining site it is Mayo-Ndaga quarry site that came second to Mayo-Sina sapphires mining site with the value of 0.015 R/hr. The lowest values were recorded At Mbamnga sand mining site at all the point and these values were the same. The mean annual background radiation at the excavation point of Mayo-Sina sapphires mining site (M_1) top with the value of 0.35 mSv/yr followed by 0.28 mSv/yr which was measured at the excavation point of Mayo-Ndaga gold mining site (N_1) in Nguroje. Then the results from Mayo-Ndaga quarry site (M_2) and Mbamnga sand mining site (G_1) in decreasing order (Table 3 and Figure 2). These high values are probably due to local evaporation procedures involved in the excavation processes as well as the geographical altitude of the site. The investigation also revealed that a maximum annual dose rate contribution to the background radiation of 0.37 mSv/yr was measured at the processing point of Mayo-Sina sapphires mining site (M_1) while Mayo-Ndaga gold mining site (N_1) and Mayo-Sina quarry site (M_2) followed with 0.32mSv/yr and 0.21 mSv/yr (Table 3 and Figure 2). For Mbamnga sand mining site (G_1) where the value is least, the annual background radiation is 0.19 mSv/yr and same for all the point. The higher value recorded at the processing point could be attributed to escaping steam containing radionuclides in the form of aerosols as a result of the miners' activities at the point. All the annual background radiation recorded 500 m away from the mining site have values less than those recorded at the excavating and processing point of all the site except for Mayo-Ndaga quarry site (M_2) where the background radiation is 0.26 mSv/yr and for Mbamnga sand mining site (G_1) where the results is the same at all the points. The higher levels of ionizing radiation recorded at the excavating and processing points confirms the fact that mining activities contributed to enhanced levels of ionizing radiation and the same results for all the points at Mbamnga sand mining site established that background radiation here depends on geographical/meteorological factors of the area like location, altitude and temperature. Additionally to the assessment of the annual equivalent dose rate of all the mining sites, strong correlations were found to exist between the equivalent dose rate at the excavating point and the processing point of the mining sites. This means that the contribution to background radiation of the mining sites arises from similar natural and anthropogenic influences and hence the sites have uniform distribution of negative consequences arising from ionizing radiation. The correlation coefficient r is described by the relation:

$$ r = \frac{n\sum Ed_e\,_{Ed_p} - \sum Ed_e \sum Ed_p}{\sqrt{\left[n\sum Ed_e^2 - \sum (Ed_e)^2 \right]\left[n\sum Ed_p^2 - \sum (Ed_p)^2 \right]}} \quad (4) $$

Where n is the number of pairs of data and Ed_e, Ed_p are equivalent dose rate at the excavation and processing point of a mining site. The correlation coefficient r (4) ranged from 0.70 – 1.0 across all the sites. The highest value of r(4) is 0.97 determine for Mbamnga sand mining site while the least value is 0.76 found for Mayo-Ndaga gold mining station.

5. Conclusion

The background ionizing radiation of four mining sites from Sardauna local government area of Taraba state have been measured and the results were found to be within the range of 0.19 – 0.40 mSv/yr in the mining sites and 500 m away from the sites. These results are within the range of literature values published by many other authors and hence confirmed our sampling procedures. The results are far less than the permissible limit value of 20.0 mSv/yr set by the Nigerian Basic Ionizing Radiation Regulation (NiBIRR) for the whole body of an adult radiation protection worker and 1.0 mSv/yr set by the International Commission on Radiological Protection (ICRP) for the general public [12]. This signifies that the miners and the people living close to these mining sites are safe. The strong correlations between the equivalent dose rate at the excavation point and processing point of the mining sites means that there is uniform distribution of consequences arising from background ionizing radiation across all the mining sites. We do recommend that policy makers should apply mitigation measures to the effects by creating awareness to the miners at various mining sites and also enforce compliance to the use of modern mining strategies to protect our natural resources especially water.

Acknowledgements

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