Assessment of Natural Radiation Exposure Level in Ekiti State Nigeria

Alaba Tolulope Agbele[1,*], Emmanuel Akinbami Oyelade[3], Kalid Abayomi Bello[1],
Victor Shegun Oluwatuyi[2], Esther Abosede Bamise[1]
[1]Department of Basic Medical Sciences, Ekiti State College of Health Sciences and Technology, Ijero-Ekiti, Ekiti State Nigeria
[2]Department of Public Health, Ekiti State College of Health Sciences and Technology, Ijero-Ekiti, Ekiti State Nigeria
[3]Department of Science Education, Federal University of Lafia, Nasarawa State, Nigeria

Abstract:- The natural environmental radiation levels were assessed within a mine tunnel in Ijero-Ekiti, Ijero Local Government Area of Ekiti State. The assessment of the radiation level within the mine tunnel was carried out so as to know whether the radiation dose rates could lead to any radiological health implications to the workers on site as well as the general public by comparing the evaluated dose rates with the national standard exposure dose rate limit. Thermoluminescence dosimeters and radiation survey meter were used in assessing the radiation levels. Our results showed that the average evaluated dose rate; 8.433 mSv/yr and 7.924 mSv/yr for depth dose and shallow dose respectively within the tunnel was higher than the public exposure dose rate limit but fell below the international standard of occupational exposure limit of 20 mSv/yr. This was attributed to the level of radioactivity in the tunnel as a result of the high level of mining activities in the site and this may pose health risk to the workers on site if they are exposed to more doses of natural ionizing radiation more than the evaluated doses which was recorded at the tunnel when averaged over five years. It is therefore very important that workers should be encouraged to use radiation protective wears as well as radiation monitoring devices.

Keywords:- *Ionizing Radiation; Exposure Limit; Radiation Dose; Thermoluminescence Dosimeters; Radiation Survey Meter; Radionuclide;*

I. INTRODUCTION

Ionizing radiation (IR) has been of great importance to the existence of man in several ways including medical, industrial as well as agricultural use. In recent times, it has also attracted negative aims such as for terrorism. Radiation is naturally present everywhere around us as it occurs both naturally as well as artificial. Most radiation exposure to human arises from the medical use as well as the naturally occurring radiation which emanates from our environment. The light which emanates from the sun form part of the nuclear reactions which is essential to life's existence on the surface of the earth. Naturally, radioactive materials occur throughout the entire environment that we lived in and our systems contain some amount of radioactive materials [1]. Carbon-14, Potassium-40, Radon-226 and Thorium-232 are sources of terrestrial radionuclides which are found in the earth's crust and they can be considered as the major contributor to natural radiation exposure sources. They contribute about 13.8%, 55.8% and 14% for potassium, radon and thorium respectively to radiation exposure [2–4].

The natural radionuclides which are present everywhere in our environment constitutes the largest percentage of human exposure to IR [5]. There are two factors that contributes to the natural background radiation exposure levels; firstly, the high-energy cosmic rays that are incident on the earth's atmosphere and secondly, radioactive nuclides that originates from the earth's crust [2]. Cosmic rays are mainly photons, high energy electrons, protons with the presence of few heavy nuclei. When they enter into the atmosphere, interaction takes place within the atom molecules in which there is production of neutrons, muons, kaons, protons as a secondary particle [3, 6].

Over the years, there have been numerous complaints from members of the public, authorities of many developing nations and the international communities have shown an outmost interest in the subject of the natural radiation exposure levels [7−11]. The natural environmental radiation exposure is made up of indoor radon exposure and outdoor radiation exposure to natural gamma radiation as a result of the disintegration of natural radionuclides as well as other radiations of cosmic origin. There are also radiation exposures with artificial origin owing to nuclear weapons manufacturing tests, nuclear power plant accidents, nuclear emission assessment from the industries as well as nuclear waste from different dumps sites [8].

Radiation produced as a result of nuclear disintegration falls in the category of IR simply because of their energy or charge, they also have the potential to change neutral atoms into ions through the process known as ionization. Ions are found throughout nature and they are essential to many physical and biological processes. Furthermore, when these ions are formed in certain areas of the cells of the human body, it is highly debiliterous to the human health that is, when IR hits a certain atom which is comprised of the deoxyribonucleic acid (DNA), there could be a change in the chemical bond properties of the atom, and thereby, physically altering the DNA. When the DNA and the cell survives, mutation would have occurred, and it can be lethal or non-lethal, depending on where the mutation occurs in the DNA molecule [12].

The location of the IR's is of outmost important; if the radiation is emanating from outside of the human body, then someone need to be concern about how penetrating the radiation could be. It is worthy to note that gamma radiation has greater chances of penetrating deep and being absorbed in the human body. When the radiation is from the inside the body, alpha particles will have a greater chance of not being to be absorbed deeply in the body thereby emanating out of the body [12].

The United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR) [2] opined that there is a significant exposure of workers to natural sources of radionuclide emanating from dust during the processing and handling of quantities of minerals and other materials. Such activity may require regulatory control to monitor and record occupational exposures at such operation sites. It was therefore noted that there is little awareness of workers' exposure from enhanced level of natural radiation by various human activities including mining. This present study therefore aimed at evaluating the natural environmental radiation levels within and around the mining site so as to ascertain whether the radiation dose that emanates from the tunnel could pose any radiological health effects on the workers and compare the dose rate with the international standard for occupational exposure dose limit.

II. GEOLOGY OF IJERO-EKITI

Ijero-Ekiti located on latitude 7° 48' 54.50" N and longitude 5° 04' 1.78" E is a town in Ekiti State, South-western Nigeria. It is the headquarters of Ijero Local Government which is situated in the north-western part of Ekiti State with a population of 221,406 according to the year 2006 National Population Commission. Ijero-Ekiti also covers an area of 391 km2. The language spoken by Ijero-Ekiti indigenes is Ekiti dialect as well as the Yoruba language.

III. MATERIALS AND METHODS

The assessment of natural environmental radiation level was evaluated in a mine tunnel located along Ikoro-Ekiti road in Ijero-Ekiti. These tunnels were selected for the purpose of this research work based on the fact that there are continual mining activities at the mining site. Thirty-six (36) thermoluminescence dosimeters (TLDs) and a radiation survey meter were used in evaluating the radiation level around the tunnel. The TLDs were enclosed in TLD cards and holders. Each card consists of 2 hot-pressed Lithium Fluoride (LiF-100) chips encapsulated between the two sheets of Teflon 10 mm and 0.07 mm thick which is then mounted on an aluminium substrate. The TLD badges were 25 to 30 m (horizontal distance and it ranged between 10 to 15 m below the sea level). Four (4) TLD badges were placed at tunnel A, four (4) TLD badges at tunnel B and three (3) TLD badges at tunnel C. In addition, three (3) TLD badges were placed at the first pre-processing site and two (2) TLD badges each were placed at the second and third pre-processing sites respectively. The radiation survey meter was used to take the readings of the background gamma ray exposures around the mining site at distance intervals of 2 m, the initial and final readings were taken at each point in time to complement the readings on the TLD badges. The first sets of eighteen (18) TLD badges were exposed for a period of thirteen (13) days, after which the badges were taken to the laboratory for reading. A HARSHAW TLD reader as shown in figure 1 was used to read the TLD badges, the reader was calibrated in the unit of micro-Sievert (µSv). After the reading, the badges were annealed and returned to the site for a repeat of the experiment for the same number of days as shown in figure 2. At each point in time, the initial and final readings of dose rates were also taken using the radiation survey meter.

Fig. 1:- HARSHAW 4500 TLD Reader.

Fig. 2:- TLD badge at the mine tunnel.

IV. ANALYSIS OF DATA

The radiological effects of gamma ray exposure are usually determined through the use of the whole body effective dose which is measured in Sievert (Sv) or its sub units. In estimating the effective dose rate, the exposure measurements were multiplied by an element correction coefficient (ECC: 1.5637×10^{-2}) and divided by the reader calibration factor (RCF: 1.8032×10^{-2}) for the deep/body dose and shallow/skin dose respectively, in order to convert the exposure-count to absorbed dose in micro-Sievert (µSv). The absorbed dose values were then converted to absorbed dose rate by dividing by 312 hours the period which the TLD badges were exposed; thereby arriving at micro-Sievert per hour (µSv/hr) using "(1)".

ISSN No:-2456-2165

$$\boxed{D = \frac{ECC \ x \ Q}{RCF}} \quad \text{..} \quad (1)$$

Where D is the dose Integral; Q is the amount of charge on each TLD badge; ECC is the element correction coefficient; RCF is the reader calibration Factor.

The ECC is the tolerance on each TLD badge that is, it is a factor that compensates for the variation in response of different energy incident on the TLD cards. It is unique for each TLD and does not repeat itself throughout the process of reading the cards, unlike the RCF which is constant all through the reading process.

V. RESULTS AND DISCUSSION

Tables 1, 2 and 3 shows the first and second readings of the TLD dose rates at points A, B and C respectively with ("#" denoting the depth/body/organ doses and "*" denoting the shallow/skin doses). The natural background radiation doses measured with the radiation survey meter at 2 m intervals away from the mining site is shown in table 4. The radiation associated with the depth dose and the skin dose in μSv, μSv/hr and mSv/yr evaluated from the measured exposure doses were measured under the same environmental conditions. The doses were analysed based on 6 hours of average daily work as the workers worked for 6 days in a week (Table 5) as the minimum, maximum and range values of the evaluated dose rates based on this 6 hours of daily work is shown graphically in figure3.

S/N	Dose (μSv)	Dose (μSv/hr)	Dose (mSv/yr)
#1	2106.7	6.752	12.64
#2	1014.4	3.251	6.086
#3	756.7	2.425	4.540
*4	1786.7	5.727	10.72
*5	901.05	2.888	5.406
*6	664.14	2.129	3.985
#7	2427.6	7.781	14.57
#8	1735.7	5.563	10.41
#9	982.16	3.148	5.893
#10	704.82	2.259	4.229
*11	2303.9	7.384	13.82
*12	1466.5	4.700	8.799
*13	794.49	2.546	4.767
*14	677.91	2.173	4.068

Table 1:- First and second reading of dose rates at tunnel A:

S/N	Dose (μSv)	Dose (μSv/hr)	Dose (mSv/yr)
#1	1203.5	3.857	7.221
#2	1180.9	3.785	7.085
#3	1131.8	3.628	6.791
#4	866.16	2.776	5.197
*5	857.26	2.748	5.144
*6	971.7	3.114	5.830
*7	1159.2	3.715	6.955
*8	928.09	2.975	5.569
#9	2255.9	7.230	13.55
#10	1203	3.856	7.218
#11	956.93	3.067	5.742
#12	704.82	2.259	4.229
*13	1907.9	6.115	11.45
*14	1296.2	4.155	7.777
*15	1315.3	4.216	7.892
*16	677.91	2.173	4.068

Table 2:- First and second reading of dose rates at tunnel B:

S/N	Dose (μSv)	Dose (μSv/hr)	Dose (mSv/yr)
#1	2744.6	8.797	16.47
#2	1557.6	4.992	9.346
#3	1467.8	4.701	8.807
#4	883.11	2.830	5.298
*5	2607.8	8.358	15.65
*6	1435.2	4.600	8.611
*7	1428.4	4.578	8.570
*8	735.75	2.358	4.415
#9	2074.1	6.648	12.45
#10	1036.3	3.322	6.218
#11	922.11	2.956	5.533
#12	558.55	1.790	3.351
*13	2073.8	6.647	12.44
*14	1017.8	3.262	6.107
*15	765.86	2.455	4.595
*16	501.25	1.607	3.008

Table 3:- First and second reading of dose rates at tunnel C:

S/N	Dose (µSv/hr)	Dose (mSv/yr)	Dose (µSv/yr)
1	0.040	0.075	2.137E-05
2	0.030	0.056	1.603E-05
3	0.050	0.094	2.671E-05
4	0.060	0.112	3.205E-05
5	0.080	0.149	4.274E-05
6	0.090	0.169	4.808E-05
7	0.110	0.206	5.876E-05
8	0.200	0.374	0.0001068
9	0.170	0.318	9.081E-05
10	0.020	0.043	1.229E-05
11	0.140	0.262	7.479E-05
12	0.070	0.131	3.739E-05
13	0.010	0.019	5.342E-06
14	0.190	0.356	0.0001015
15	0.027	0.051	1.442E-05

Table 4:- Natural background radiation reading of dose rates measured with survey meter at several points away from the mining area:

The evaluated dose rates at mine tunnel A ranged from 10.35mSv/yr for the depth dose to 9.839mSv/yr for the shallow dose (Table 5) with an average of 8.338mSv/yr and 7.367mSv/yr for depth dose and shallow dose respectively (Table 6). Tunnel B ranged from 9.307mSv/yr for the depth dose to 7.380mSv/yr for the shallow dose (Table 5) with an average value of 7.127mSv/yr and 6.835mSv/yr for depth dose and shallow dose respectively (Table 6) while tunnel C ranged from 13.12mSv/yr for the depth dose to 12.64mSv/yr for the shallow dose (Table 5) with an average value of 8.433mSv/yr and 7.924mSv/yr for depth dose and shallow dose respectively (Table 6). From the results given above, mine tunnel C has the highest value ranged of 13.1163mSv/yr and 12.6365mSv/yr for depth dose and shallow dose respectively. This difference in values could be attributed to high level of mining activities at mine tunnel C as compared to tunnels A and B.

Values:	Point A	Point B	Point C
Minimum: #	4.229	4.229	3.351
Minimum: *	3.985	4.068	3.008
Maximum: #	14.57	13.54	16.47
Maximum: *	13.82	11.45	15.65
Range: #	10.35	9.307	13.12
Range: *	9.839	7.380	12.64

Table 5:- Evaluated annual doses of workers based on (6 hours) average daily hours of work (mSv/yr):

Mine points:	Evaluated annual effective dose (mSv/yr)	Public dose limit (mSv/yr)	Occupational dose limit (mSv/yr)
#A	8.338	1	20
*A	7.367		
#B	7.127	1	20
*B	6.835		
#C	8.433	1	20
*C	7.924		

Table 6:- Average evaluated effective annual dose rates compared with public dose limit and occupational dose limit:

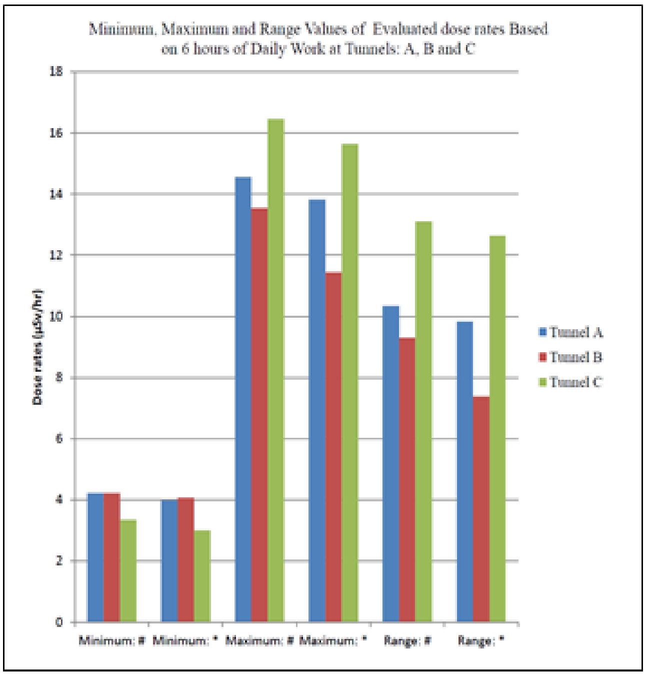

Fig. 3:- Graphical representation of evaluated dose rates based on 6 hours of daily work at tunnels A, B and C respectively

It was found that the evaluated effective dose values using radiation survey meter and TLD within the mine tunnels were higher than the public exposure limit and it fell below the occupational exposure limit of 1mSv/yr and 20mSv/yr respectively for public and occupational exposure limits (Table 6) [13, 14]. However, researches has showed that ionizing radiation exposure levels in and around many industries over the years have been carried out and the inferences drawn out by researchers can be based on certain locations by using radiation dose measuring instruments that may be different from survey metre and TLDs [15].

VI. CONCLUSION

From our study it was observed that the evaluated effective doses in the mining tunnels was found to be higher than the public and lower than the occupational exposure limits when compared with the international occupational exposure limit of 20 mSv/yr, the evaluated doses were 8.433 mSv/yr and 7.924 mSv/yr for depth dose and shallow dose respectively and it was higher than the natural environmental background radiation doses. This shows that the levels of mining activities in the tunnels can pose radiological health risk to the workers in the mining industry if they are exposed to more doses of natural environmental radiation, more than the evaluated doses recorded at the tunnels when averaged over five years. Finally, the workers should be encouraged to use radiation protective wears as well as radiation monitoring devices.

ACKNOWLEDGEMENTS

The authors are grateful to the management of the mining industry for the approval, assistance as well as the cooperation received from the workers on site during the period the TLD detectors were exposed in their workplace.

REFERENCES

[1]. J. Ford, “Radiation, people and the environment”. 2004.

[2]. UNSCEAR. United Nations Scientific Committee on Effects of Atomic Radiation, “Sources and effects of ionizing radiation,” Annex A&B (New York: United Nations Publications); 2000.

[3]. S. Jozef, and W. Pao-shan, “Introduction to radiation protection dosimetry,” World scientific; 1995.

[4]. M. Ngachin, M. Garavaglia, C. Giovani, M.K. Njock, and A. Nourreddine, “Radioactivity level and soil radon measurement of a volcanic area in Cameroon,” Journal of environmental radioactivity. 2008;99(7):1056-60.

[5]. M.O. Isinkaye, and M.B. Shitta, “Natural radionuclide content and radiological assessment of clay soils collected from different sites in Ekiti State, south-western Nigeria,” Radiation protection dosimetry. 139(4): pp. 590-596, 2010.

[6]. A. Martin, “An Introduction to Radiation Protection,” 6E: CRC Press; 2012.

[7]. M. Eisenbud, and A.S. Paschoa, “Environmental Radioactivity,” Nucl. Instrum. Methods Phys. Res. B. 1989.

[8]. I.R. Ajayi, and O.S. Ajayi, “Estimation of absorbed dose rate and collective effective dose equivalent due to gamma radiation from selected radionuclides in soil in Ondo and Ekiti State, south-western Nigeria,” Radiation protection dosimetry. vol 86(3) pp. 221-224, 1999.

[9]. C.J. Chen, P.S. Weng, and T. Chichu, “Evaluation of Natural Radiation in Houses Built with Black Schist,” Health Phys. vol 64, pp. 74–78, 1993.

[10]. A.S. Paschoa, R.R. Pinho, and D.A.C. Binns, “Monitoring Radon and Environmental Gamma Radiation Indoors and Outdoors at PUC RJ, Brazil In: Proc. of Radon Monitoring in Radioprotection,” Environmental Radiation and Earth Sciences (World Scientific) pp. 381–389, 1989.

[11]. B.A. Marouf, A.S. Mohammed, and J.S. Taha, “Assessment of Exposure Rate and Collective Effective Dose Equivalent in the city of Baghdad due to Natural Gamma Radiation,” Sci. Total Environ. Vol 133, pp. 133–137, 1993.

[12]. F.W. Whicker, and V. Schultz, “Radioecology: nuclear energy and the environment,” CRC press Boca Raton, FL; 1982.

[13]. NiBRR. Nigerian Basic Ionizing Radiation Regulation (NiBRR) of the Nigeria Nuclear Regulatory Authority NNRA, “Radiation Regulatory Limit,” 2001.

[14]. ICRP. International Commission on Radiation Protection, “The 2001 Recommendations of the International Commission on Radiation Protection,” ICRP Publication 103: Annals of ICRP 37(2-4), 2007

[15]. G. Dietze, and H.G. Menzel, “Dose Quantities in Radiation Protection and their Limitations,” Radiation Protection and Dosimetry 112(4): pp. 457-463, 2004.