Available online at www.equijost.com

Equity Journal of Science and Technology, 2023 10(1): 36 - 41

ISSN 2354-1814; E-ISSN 2683-5961

EQUIJOST *An Official Publication of Kebbi State University of Science and Technology, Aliero, Nigeria*

In-situ measurements of dose rates in villages near mining sites in Oke-Ogun, Oyo state, Nigeria

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Abstract

The effect of mining activities is not limited to the mining sites only but also linked to the villages near the mining sites via erosion and stockpiling of ores. In-situ measurements of dose rates in four villages near tantalite mining sites in Oke-ogun, Oyo state was investigated using a Gamma RAEIIR survey meter. Radiation dose to risk software was used to estimate radiological parameters related to continuous exposure of villagers on the study area. The radiological parameters were estimated within the age brackets of infants, children and adults respectively. The mean of the measured in-situ dose rates, the estimated annual effective dose rates, the commutative doses and excess lifetime cancer risks for adult, children and infant were 98.30nSv/y, 0.86mSv/y, 60.2mSv,10.3mSv, 0.86 mSv and 30.5×10^{-4}, 5.17×10^{-4} and 0.42×10^{-4} respectively. The mean of the measured dose rates and estimated annual effective dose rates were above the world averages of 84nSv/h and 0.77mSv/y respectively. Some of the considered radiological parameters for the study were above the world average. The villagers are advised not to live their entire life in the villages since this can predispose them to an exposure that may not be suitable for their health.

Keywords: In-situ, Dose Rates, Villages, Mining Sites

1. Introduction

Work activities involving naturally occurring radioactive materials (NORMS) are potential sources of radiation exposure to workers and members of the public [1-4]. Mining activities in Oke-Ogun bring different citizens from different parts of Africa together in the pursuit of earning a living for themselves and their families. Residential houses made of mud and cement are built close to the villages near the mining sites where both the artisan miners and dealers in tantalite retire after tedious mining activities of the day. Schools, mosques, chemists, food canteens, film houses churches are also cited in these villages. Although, these villages are not densely populated but many are reported to have been there for decades. The mining and processing of these ores can further lead to an increase in radionuclide concentrations in the products, by-products, or residues [5] and this may lead to another level of exposure to miners. Also, the artisan miners are known to stockpile their shares of mined tantalite and germ stones in their houses thereby getting exposed to thermal contact and emitting gamma rays from the decay of radionuclide in tantalite ores before possible buyers of the stored tantalite [6]. Furthermore, the dealers of tantalite and gemstones carry out purification of tantalite from the metallic materials associated with the ore by the process called "burretting" which get them exposed to high risk through inadvertent ingestion of particles of tantalite and inhalation of tantalite dust as they crush the Tantalite to determine the grade of the Tantalite. These dust particles find their way into the immediate air in the villages and if these activities go unchecked, may be of negative effect on all the dwellers of these villages. Through an oral interview with the miners, it was also reported that during raining season, flood from these mining sites finds hire ways to the nearby villages through erosion bringing germ stones and other materials from the mining sites. All these activities have the possibility of raising the radiation level in these villages. Although, Ajetunmobi *et al*. [7] worked on dose rates at the mining sites of these area but dose rates at the nearby villages were not reported. It is therefore important to investigate the level of dose rate in these villages. Thus, the current research work aimed at measuring the ambient dose rates at the nearby villages including the residence of the miners using Gamma RAEIIR dosimeter. The work also includes estimation of cancer risk of the miners using dose-rate measurement of Gamma RAEIIR dosimeter as input parameter and radiation dose to risk converter software.

2. Materials and methods

2.1 About the Study Location

The study locations considered for this work are Komu (KO), Sepenteri (SP), Gbedu (GB), and Eluku (EL) villages in Itesiwaju, Saki East, Iwajowa, and Saki Local governments all in Oke-Ogun, Oyo State, Nigeria. Oke – Ogun (7°19'60" N and 4°4'0" E) is among the highly populated areas in Oyo State with a population of about 174,152. It is located at an elevation of 188 meters above sea level [8]. Figure 2.1 shows the location map of the study area.

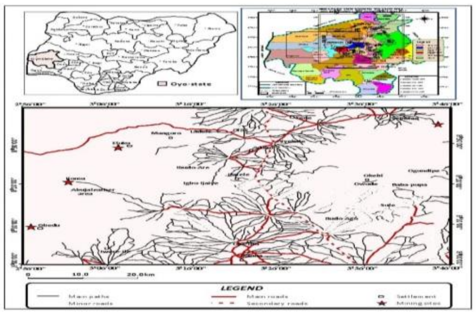

Figure 2.1.: The Location Map for Oke-Ogun [7]

2.2 In-Situ Measurement of Dose Rates in villages near the mining sites

Dose rate measurements inside and outside the caves/open pits were carried out using a dosimeter; Gamma RAE IIR mounted on a stand about one meter above the ground level. Gamma RAE IIR uses CsI (TI) as the detector. It has an in-built daily calibration capacity and factory calibration is not required. Energy range is 0.06MeV-3.0 MeV. Its sensitivity is > 100 cps per µSv/hr. Dose equivalent range (DER) for 137Cs is 0.01-40µSv/h and accuracy of ±30% [9], Figure 2.2 is the picture of Gamma RAE IIR.

Figure 2.2**:** Gamma RAEIIR Dosimeter

2.3 Estimation of Radiological Parameters

The **r**adiation dose to risk software was used to estimate the excess lifetime cancer risk, annual effective dose, and cumulative dose of the villagers which include children, infants and adults. These were estimated using the measured dose rates in the villages as input parameters for the software and selecting the option "continuous" in the interface of the software for 1 year, 12 years, and 70 years for infants, children, and adults respectively.

The age bracket selected for the infants followed the recommendation of the American Academy of Pediatrics [10] (0-1) year, using the upper age limit for the analysis and this was done to estimate the possible higher dose that may be accrued by infants in the villages. Also, the upper limit of the age brackets recommended by the American Academy of Pediatrics (1-12) was used for the analysis of the radiological parameters associated with children's exposure to all the mining sites and the age limit of about 70 years was used for the analysis for adults. The software was also used to estimate other parameters like excess lifetime cancer risk, annual effective dose rates, and cumulative dose of the artisan miners. The Conversion factors of 0.7Sv/Gy, 0.88Sv/Gy and 0.9Sv/Gy were used for adults, Children, and Infants respectively [3]. The validity of the software was reported in [7].

3. Results and discussion

3.1 Measured ambient dose rates for Villages around the mining sites

The results of the measured dose rates at KO villages close to the mining site are presented in Table 3.1 below:

Table 3.1: Estimated radiological parameters for village near KO mining sites

Spots of Dose rate Measurement	Dose Rate (nSv/h)	Annual Effective Dose (mSv/y)	Excess Life Cancer Risk (ELCR) × 10^{-4}		
			Adult	**Children**	**Infant**
1	80	0.701	24.5	4.2	0.4
2	70	0.614	21.5	3.7	0.3
3	60	0.526	18.4	3.2	0.4
4	50	0.436	15.3	2.6	0.2
5	70	0.614	21.5	3.7	0.3
6	100	0.877	30.7	5.3	0.4
7	100	0.877	30.7	5.3	0.4
8	60	0.526	24.5	3.2	0.4
9	60	0.526	24.5	3.2	0.4
10	90	0.789	27.6	4.7	0.4
Mean	**74**	**0.649**	**23.92**	**3.9**	**0.36**

The measured dose rates for the KO mining site ranged from (50–100) nSv/h with a mean of 74nSv/h as indicated in table 3.1. The upper limit of the dose rates is greater than the world average value recommended by UNSCEAR, 2000 with the value of 84 nSv/h. The estimated annual effective dose rates for adults, children, and infants for dwellers in KO village have the range of 0.436–0.877 mSv/y with a mean of 0.649 mSv/y respectively. The mean value for the annual effective dose rates is less than the recommended value by [3,15] with the value of 0.07mSv/y.

Additionally, the estimated excess lifetime cancer risk (ELCR) for adults, children and infant falls within the range $(18.4-30.7)\times10^{-4}, (2.6-5.7)\ 10^{-4}, and\ (0.2-0.4)\ \times10^{-4}$ respectively at KO village and that for the infant is very much lower than the permissible limit recommended by Joyce and Ismael [11] with a value of 2.7×10^{-4} respectively.

For the KO village, the dose rate is slightly skewed to the right with a value of 0.428 ± 0.687 across the KO village as shown in Figure 3.1. Also, Kurtosis which is a statistical measure of the extent to which the frequency distributions of the dose rates are concentrated about the mean value has a negative value of -1.209 ±1.334.

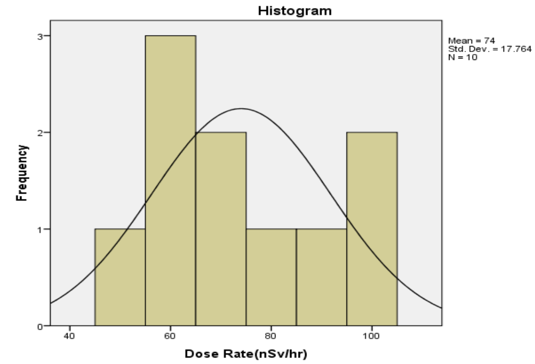

Figure 3.1: Histogram showing the of dose rate (nSv/h) in KO village

Table 3.2: Estimated radiological parameters for village near SP mining sites

Spots of Dose rates Measurement	Dose Rate (nSv/h)	Annual Effective Dose (mSv/y)	Excess Life Cancer Risk (ELCR) × 10^{-4}		
			Adult	Children	Infant
1	90	0.789	27.6	4.7	0.4
2	90	0.789	27.6	4.7	0.4
3	100	0.877	30.7	5.3	0.4
4	90	0.789	27.6	4.7	0.4
5	200	1.753	61.4	10.5	0.9
6	250	2.191	76.7	13.1	0.1
7	130	1.139	39.9	6.8	0.6
8	120	1.051	36.8	6.3	0.5
9	140	1.277	43.0	7.4	0.6
10	110	0.964	33.7	6.3	0.5
Mean	**132**	**1.162**	**40.7**	**6.98**	**0.49**

Again, the result of the study shows that, for the SP village, the measured dose rates, and annual effective dose rates for adult, children and infants ranged from $(90–250) nSv/h$ with a mean of $132\ nSv/h$, and $(0.789-2.191) mSv/y$ with a mean of $1.162\ mSv/y$ respectively. These values are higher than the values of the KO mining site.

Also, the estimated cancer risk for adult, children and infants ranged from $(27.6-76.7)\times10^{-4}, (4.7-13.1)\times10^{-4}, and\ (0.4-0.9)\times10^{-4}$, respectively.

The dose rate distribution for villages close to the SP mining site is positive to the right with a value of 1.551 ± 0.687 (Figure 3.2). Dwellers in the areas where the dose rate seems to be higher are likely to be exposed to more ionizing radiation if activities of the miners and dealers in Tantalite such as stockpiling of Tantalite increase as a result of the increased harvest of Tantalite from the mining site. The Kurtosis has a value of 1.774 ± 1.334.

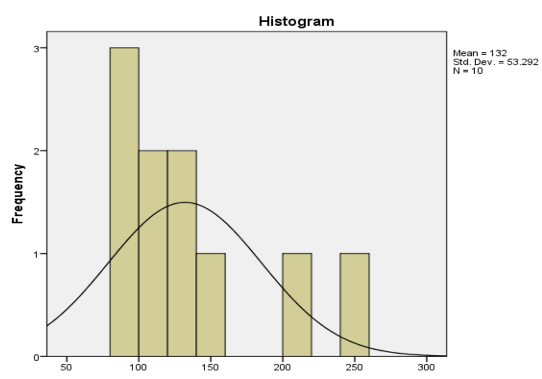

Figure 3.2: Histogram showing the distribution of dose rates (nSv/h) in SP village.

Table 3.4: Estimated parameters for village near GB mining sites

Spots of Dose rates Measurement	Dose Rate (nSv/h)	Annual Effective Dose (mSv/y)	Excess Life Cancer Risk (ELCR) × 10^{-4}		
			Adult	Children	Infant
1	40.0	0.350	12.3	2.1	0.2
2	50.0	0.438	15.3	2.6	0.2
3	40.0	0.350	12.3	2.1	0.2
4	40.0	0.350	12.3	2.1	0.2
5	90.0	0.789	27.6	4.7	0.2
6	60.0	0.526	18.4	3.2	0.4
7	40.0	0.350	12.3	2.1	0.2
8	40.0	0.350	12.3	2.1	0.2
9	70.0	0.614	21.5	3.7	0.3
10	40.0	0.350	12.3	2.1	0.2
Mean	**51.0**	**0.447**	**15.66**	**2.68**	**0.23**

Again, the result of the study shows that, for the GB village, the measured dose rates, and annual effective dose rates for adult, children and infants ranged from $(40–90)nSv/h$ with a mean of $51\ nSv/h$, and $(0.350-0.789)mSv/y$ with a mean of $0.44\ 7mSv/y$ respectively. These values are higher than the values of the KO mining site.

Also, the estimated cancer risk for adult, children and infants falls within the range of $(12.3-27.6)\times10^{-4}, (2.1-4.7)\times10^{-4}, and\ (0.1-0.4)\times10^{-4}$, respectively. The ELCR risk range for an adult is higher than the permissible limit for ELCR set by United Nations Scientific Committee [3] with a value of 2.9×10^{-4} and that for children is a little higher than the permissible limit. However, the range for ELCR for infants is lower than the permissible limit. The health implication of this is that the infants are very much less likely to be at any risk though with ambient dose rate on the high side greater than the world average.

The dose rate distribution in GB village is positively skewed to the right with a value of 1.584 ± 0.687 while the kurtosis value is 1.863 ±1.334 (Figure 3.3). The health implication of the distribution is the same as SP following the same condition of possibly increased activities that have to do with the stockpiling of Tantalite by the dealers in Tantalite and the miners

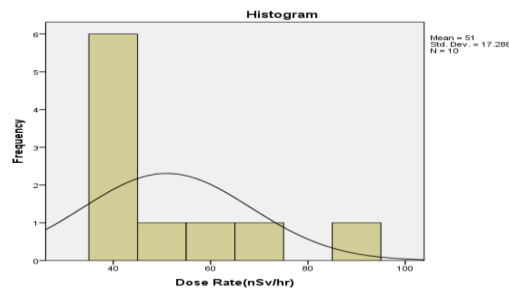

Figure 3.3: Histogram showing the distribution of dose rates (nSv/h) in GB village.

The dose rates measured in all the villages close to the mining sites are lower than reported in the work of Tubosun *et al.* [12] carried out in a Uranium mine in Tanzania in a village called Nwanzi with a dose rate up to 263.69 nSv/h. The estimated annual dose rate for their study was 0.04 mSv/y. However, the dose rate measured at SP village falls within the range of (89–251) nSv/h is greater than the work of [13] carried out at Olode mining site (0.1–0.24) µSv/h with a mean of 0.18 µSv/h but less than the dose rate measured in the work of [14] with the range of (91.7–1159.9) nSv/h. The estimated annual dose rate for [14] is within the range of (0.16–2.06) mSv/y and is greater than (for the upper limit of annual dose) that of GB with an estimated annual dose rate which is within the (0.30–0.80) mSv/y with a mean of 0.45 mSv/y. The value of the dose rate for GB (51.0 nSv/h) is lower than that of the EL site (136.0 nSv/h) and is higher than the world average of 42 nSv/h (60nGy/h).

Table 3.5: Estimated radiological parameters for village near EL mining sites

Spots of Dose rates Measurement	Dose Rates (nSv/h)	Annual Effective Dose (mSv/y)	Excess Life Cancer Risk (ELCR) × 10^{-4}		
			Adult	Children	Infants
1	160	1.402	49.1	8.4	0.7
2	230	2.016	70.6	12.1	1.0
3	130	1.139	39.9	6.8	0.6
4	160	1.402	49.9	8.4	0.7
5	100	0.877	30.7	5.3	0.4

Table 3.5: *Cont.*

6	120	1.051	36.8	6.3	0.5
7	150	1.314	46.0	7.9	0.7
8	110	0.964	33.7	5.8	0.5
9	110	0.964	33.7	5.8	0.5
10	90	0.782	27.6	4.7	0.4
Mean	**136.0**	**1.191**	**41.8**	**7.15**	**0.6**

Lastly, the result of the study shows that, for the EL village, the measured dose rates, and annual effective dose rates for adult, children and infants ranged from $(90–160) nSv/h$ with a mean of $136\ nSv/h$, and $(0.782 - 2.016) mSv/y$ with a mean of $1.191\ mSv/y$ respectively. These values are higher than the values of the KO mining site.

Also, the estimated cancer risk for adult, children and infants ranged from $(27.6 - 70.6) \times 10^{-4}, (4.7 - 12.1) \times 0^{-4}, and\ (0.4 - 1.0) \times 10^{-4}$, respectively.

The dose rate distribution for the EL village is positively skewed as shown in Figure 3.4 with a value of 1.350 ± 0.687 and the kurtosis 2.2 ± 1.334. The same explanation for health implication as explained of GB mining site.

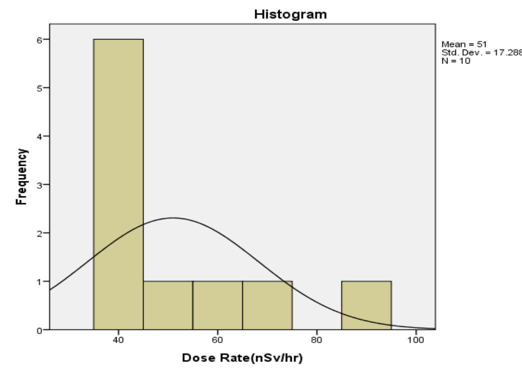

Figure 3.4**:** Histogram showing the distribution of Dose Rates (nSv/h) in EL village.

Table 3.5: Estimated average cumulative dose for villages near mining sites

	Cumulative Dose (mSv)											
Spots	**Adult**				**Children**				**Infant**			
	KO	**EL**	**SP**	**GB**	**KO**	**EL**	**SP**	**GB**	**KO**	**EL**	**SP**	**GB**
1	49.09	98.18	55.22	24.54	8.42	16.83	9.47	4.21	0.70	1.40	0.79	0.35
2	42.95	141.10	55.22	30.68	7.36	24.19	9.47	5.26	0.61	2.02	0.79	0.44
3	36.81	79.77	61.36	24.54	6.31	13.67	10.51	4.21	0.53	1.14	0.88	0.35
4	30.68	98.18	55.22	24.54	5.26	16.83	9.47	4.21	0.44	1.40	0.79	0.35
5	42.95	61.36	122.7	24.54	7.36	10.51	21.03	4.21	0.61	0.88	1.75	0.35
6	61.63	73.63	153.4	55.22	10.51	12.62	26.29	9.47	0.88	1.05	2.19	0.79
7	61.63	92.04	79.77	36.81	10.51	15.77	13.67	6.31	0.88	1.31	1.14	0.53
8	36.81	67.50	73.63	24.54	6.31	11.57	12.62	4.21	0.53	0.96	1.05	0.35
9	36.81	67.50	85.90	24.54	6.31	11.57	14.72	4.21	0.53	0.96	1.23	0.35
10	55.22	55.22	67.50	42.95	9.47	9.47	11.57	7.36	0.79	0.79	0.96	0.61
Mean	**45.40**	**83.45**	**80.99**	**31.29**	**7.78**	**14.30**	**13.88**	**5.36**	**0.65**	**1.19**	**1.16**	**0.45**

As shown in table 3.5, the mean of the cumulative doses for adult, children and infants for the four villages falls within the ranges of $(31.0 - 84.0)$ mSv, $(5.O - 14.5)$ mSv and $(0.6 - 1.2)$ mSv respectively.

4. Conclusion

The excess lifetime cancer risk estimated for adults and children in all the investigated mining sites were greater than the permissible limit of 2.9E-04. Adult and children in all these mining sites may be at risk of cancer, hence the current research suggests that both the miners and their families may relocate to other locations at least during festive periods or when the mining activities of these sites ceases. This is to reduce their time of stay in these villages thereby reducing the possibility of exposure to ionizing radiation in these villages as a result of mining activities at the mining sites close to the villages.

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