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MEASUREMENT OF AMBIENT DOSE RATES IN TANTALITE MINING SITES IN OKE−OGUN, SOUTHWEST, NIGERIA

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ABSTRACT

The work scenarios involved in the mining of tantalite a radioactive material expose the miners to ionizing radiation from the ore and the surrounding environment. The dose level in the mine air may be higher than the safe limit due to various contributory sources of ionizing radiation such as radionuclides from rocks, effluents, sand, and radon gas that emanates from caves and this can be of health detriment to the miners. Measurements of ambient dose rates in four selected mining sites have been investigated. Gamma absorbed dose rates were measured in air onsite at Komu, Sepenteri, Gbedu, and Eluku mining sites in Oke-Ogun areas of Oyo State, Nigeria using GammaRAE II dosimeter. Radiation dose to risk software was used to estimate the cancer risk for the period the miners spent onsite. The measured mean dose rate at the sites falls within the range of (19-240) nSv/y and the estimated annual dose rate, cumulative dose, and cancer risk fall within the range of (37-314) µSv/y, (4.0 −11.1) mSv and (0.5 − 4.5) E-04 respectively. The upper limits of the range for the radiological parameters are all above the safe limit. The health implication of that is that increased work activities at these mining sites may over the years have a negative health effect on the miners. The exposure time of workers can be reduced through proper planning of working shifts for the miners.

Keywords: Measurement, Ambient Dose Rates, Tantalite,

INTRODUCTION

Work activities involving naturally occurring radioactive materials (NORMS) are potential sources of radiation exposure to workers and members of the public (IAEA, 1996; EC, 1996; UNSCEAR, 2000; Van der Steen and Van Weers, 2004). The practice of mining involves surface and underground mining and both methods are employed by the artisan miners that are into the business of exploring God-given resources in the nation. Also, artisan miners employ crude methods in the process of assessing these resources thereby disturbing the equilibrium of the naturally occurring radioactive materials (NORM). These result in gradual disintegration of the radionuclide in soil layers and rocks concealing the natural resources thereby emitting gamma rays into the ambient environment of the mining sites. This again will result in increase in radionuclide concentrations in the products, by-products or residues (IAEA, 2011) and this may be another level of exposure to the miners. Furthermore, the work activities in the mining of tantalite a known radioactive material of high economic value because of its diversified uses entails digging or harvesting the tantalite from the concealing rocks which further results in the release of gamma radiation into the ambient environment in the mining sites. The continuity of the mining activities at these sites over the years and any other possible sources of ionizing radiation in the environment may pose a risk to the miners as exposure pathways such as inhalation of dust particles due to the work activities at the sites cannot be ruled out as well. Hence, it becomes necessary to carry out an assessment of the dose rate in the mine air to ascertain if they are beyond the permissible limit recommended by appropriate regulatory authorities. To the best of the knowledge of the author, no study has been reported on the measurement of the dose rates in the study areas. The study is aimed at measuring the ambient and estimating the corresponding cancer risk associated with the measured dose rates in the mine air at selected tantalite mining sites in Oke-Ogun, Oyo State, Nigeria, and the result will contribute to the existing body of knowledge in the field of study.

MATERIALS AND METHOD

Description of the Study Area

The study locations are Komu (KO), Sepenteri (SP), Gbedu (GB), and Eluku (EL) villages in Itesiwaju, Saki East, Iwajowa , and Saki Local Government areas, respectively all in Oke-Ogun, Oyo State, Nigeria. Oke-Ogun (Lat 80 00'00"N-80 39'00" N and Long 20 56'00"E-30 46'00"E) is a populated place in Oyo State with a population 1.4 million according to 2006 national population census. It is located at an elevation of 188 meters above sea level as shown in Fig. 1 (Oke-Ogun, Map). Fig. 2 shows the geological map of the area.

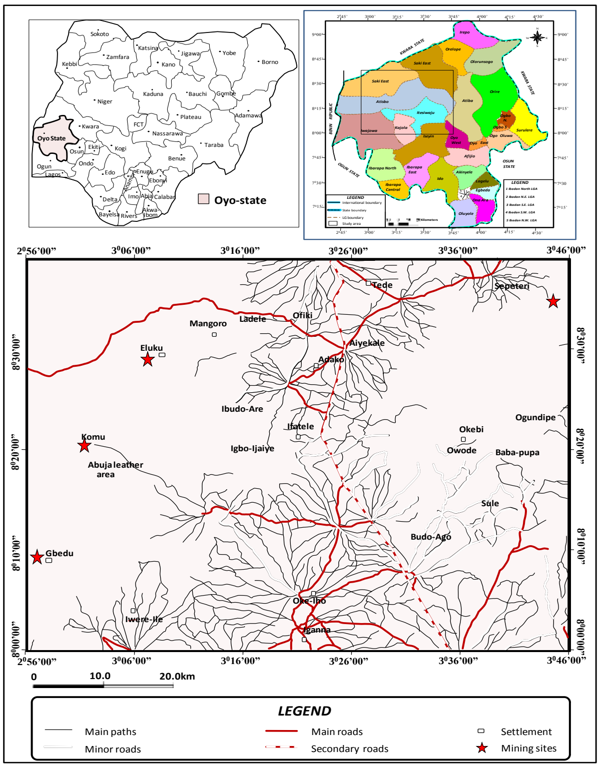

Figure 1: The Location Map for Oke-Ogun, Oyo State

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(Source: Researchgate.net)

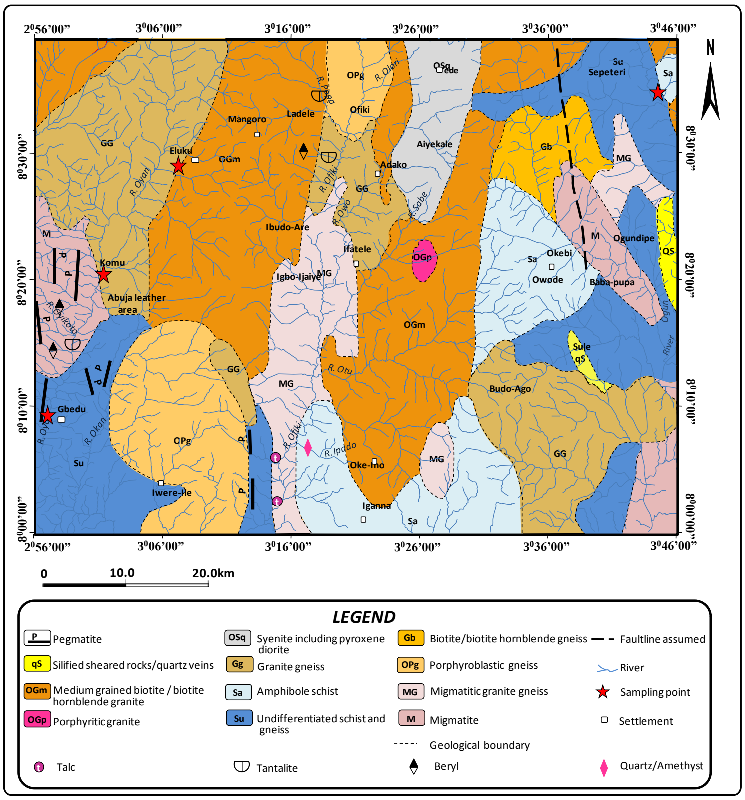

Figure 2: Geological Map of the study area.

(Source: Researchgate.net)

In-Situ Measurement of Dose Rate inside and outside Caves/Open Pits

Dose rate measurements inside and outside the caves/open pits were carried out using a dosimeter; Gamma RAEIIR 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. The dose equivalent range (DER) for ^{137}Cs is 0.01- 40 µSv/h and accuracy of ±30%. Fig. 3 show the picture of the GammaRAEIIR

Figure 3: Gamma RAEIIR Dosimeter.

Radiation Dose to Risk Software

This software determines the health risk from a given radiation dose. For individuals, the dose can be entered as a dose, or as dose rate plus occupancy information. The parameters needed for the estimation are entered into the input interface. These parameters have reasonable initial values which can be modified as needed. The software was used to estimate the excess lifetime cancer risk, annual effective dose, cumulative dose of the artisan miners with an assumed retirement age of 35 years for all the sites. The stay time of the workers at the EL site is 8 hours per day for 317 days/y that is 253 6h/y (all the weekdays except Sundays). Similarly, the stay time for KO is 5 hours per day (1585 h/y), for SP site, the stay time of workers is 8 hours per day (with two shift duties of 4 hours per shift) for 317 days (1268 h/y) and the stay time of artisan miners for GB site is 5 hours per day for 317 days (1585 h/y). The stay time of all the workers at the sites is entered in the appropriate colon on the interface of the software and pressing "Calculate" on the interface gives the result in the result colon.

Validity of Radiation Dose to Risk Converter Software

According to UNSCEAR, (1993) and Taskin et al. (2009), the conventional equations used to estimate two radiological parameters viz; annual effective dose and excess lifetime cancer risk given by equations 1 and equation 2 were used to ascertain the validity of the software by selecting a measured value of Dose rate (80 nSv/h) for 365.25 h/y and using a conversion factor of 0.7 Sv/Gy for the estimation of annual dose and a public risk factor of 0.05 for the estimation of excess lifetime cancer risk and comparing the results with the values estimated with the radon dose to risk converter software. The values of the two methods in estimating the radiological parameters gave the same value for exposure to ionizing radiation over the same period as presented in Table 1.

Annual Effective Dose

The annual effective dose H_e was calculated using equation (1) where H_e is the annual effective dose rate in $mSvy^{-1}$ and D is the value of absorbed dose rate calculated, T is the occupancy time ($T = f \times 24 \times 365.25h\ y^{-1}$) and f is the occupancy

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factor with the value of 0.3 because the miners spend 8 hours out of 24 hours at the mining site for outdoor measurement and F_o is the conversion factor (0.7 $SvGy^{-1}$) UNSCEAR, 1993. Dose conversion factors are used to convert radioactivity taken into the body to radiation dose.

$$H_e = DTF_o \qquad (1)$$

Life Time cancer Risk

Lifetime Cancer Risk (ELCR) was calculated using equation (2):

$$ELCR = AEDE \times D \times L \times RF \qquad (2)$$

Where AEDE, DL, and RF are the annual effective dose equivalent, duration of Life (70 years), and risk factor (S/v) of fatal cancer risk per Sievert respectively. For stochastic effects, ICRP 60 adopted 0.05 for the public (Taskin, *et al.*, 2009).

Table 1: Comparison of values of radiological parameters estimated using Radiation dose to Risk Converter software and conventional equations.

S/N	Method for estimating Radiological parameters	Dose Rate (nSv/hr)	Annual Effective Dose (µSv/y)	Excess Life Time Cancer Risk (%)
1	Conventional equation	80	29.22	0.010
2	Radiation Dose to Risk Software	80	29.22	0.010

Source: UNESCEAR, 1993 and Radiation Dose to Risk Software (Uranium Wise Project)

RESULT AND DISCUSSIONS

As indicated in Tables 2 and 3, for the KO mining site, the mean dose rates measured outside the pits falls within the range of (69 – 101) nSv/h with the mean of 88 nSv/h and the dose rate measured inside the pits is within the range of (209 – 231) nSv/h and the mean value of 222 nSv/h. The estimated annual effective dose inside and outside the pits are within the range of (169– 314) µSv/y with a mean of 241.92 µSv/y. The cumulative dose estimated for inside and outside the pit falls within the range of (4.0 – 12.0) mSv with a mean of 7.74 mSv. The excess lifetime cancer risk estimated for both inside and outside falls within the range of (1.75 – 4.5) × 10^{-4} with the mean of 3.08×10^{-4} and (1.3 – 2.1) × 10^{-4}. The value inside the pit is higher than the permissible limit of 2.9× 10^{-4}, (UNESCEAR, 2000).

Secondly, for the SP mining site, the mean dose rate measured outside the pits falls within the range of (79 – 101) nSv/h with the mean of 86 nSv/h while the dose rate measured inside the pit falls within the range of (89 – 101) nSv/h with a mean of 96 nSv/h and this is greater than the world average value of 42 nSv/y. The estimated annual effective dose for inside and outside the pits is within the range of (131 – 139) µSv/y with a mean of 135.48 µSv/y. Also, the estimated cumulative dose and cancer risk falls within the range of (4.0-4.9) mSv with a mean of 4.58 mSv and (1.70 – 1.93) × 10^{-4}. with a mean of 1.82 × 10^{-4}., respectively. There is a need for the artisan miners working at SP to spend less time working at the mining site thereby reducing their time of exposure to ionizing radiation from the work scenarios at the site. This may also suggest the shift duties that are operational at the site.

Table 2: Measured Dose Rate (nSv/h) inside and outside the Pits at the selected Mining sites Using Dose to Risk Software

S/N	Dose rate outside the Pits (nSv/h)				Dose Rate inside the Pits (nSv/h)			
	KO	**SP**	**GB**	**EL**	**KO**	**SP**	**GB**	**EL**
1	100	80	40	50	220	100	90	80
2	80	100	30	40	230	90	90	50
3	70	80	20	50	220	90	90	50
4	100	80	20	40	210	100	90	40
5	90	90	20	40	230	100	80	40
Mean	**88**	**86**	**26**	**44**	**222**	**96**	**88**	**52**

The estimated annual dose rate for both inside and outside the pits seems to be close. This can be because SP mining site is an open pit with little or no atmospheric condition variation.

Thirdly, GB mining site, the mean dose rate measured outside and inside the pits falls within the range of (19 – 41) nSv/h with the mean of 26 nSv/h and (79 – 91) nSv/h with a mean of 88 nSv/h. The estimated annual effective dose is within and outside the pits falls the range of (37–127) µSv/y with a mean of 82.06 µSv/y. The estimated cumulative dose estimated for this period falls within the range of (1.3 – 4.5) mSv with the mean of 2.85 mSv. The excess lifetime cancer risk for both within and outside the pits falls within the range of (0.5 – 1.77) × 10^{-4} with the mean of 1.14 ×10^{-4}. This value is lower than the permissible limit of 2.9 × $10^{-4.}$

Table 3: Estimated Average Radiological parameters for selected Mining sites Using Radiation Dose to Risk Software

SITES ID	Annual Effective Dose (µSv/y)		Cumulative Dose (mSv)		Excess Life Time Cancer Risk (10^{-4})	
	Inside Pit	**Outside Pit**	**Inside Pit**	**Outside Pit**	**Inside Pit**	**Outside Pit**
KO	313.92	169.92	11.08	4.44	4.44	1.76
SP	138.48	132.48	4.84	4.33	1.92	1.72
GB	126.72	37.44	4.44	1.31	1.76	0.52
EL	119.80	101.38	4.19	3.55	1.68	1.42

Finally, for the EL mining site, the mean dose rate measured outside the pits falls within the range of (39 – 51) nSv/h with the mean of 44 nSv/h while the measured dose rate inside `the pit falls within a range of (39 – 79) nSv/h with a mean of 52 nSv/h . The estimated annual effective dose rates are within and outside the pit falls within the range of (102.0 – 119.0) µSv/y with a mean of 110. 6 µSv/y for the artisan miners that worked for 8 hours per day with two shift duties for a day cumulating to 2536 hours per year and for an assumed official age of retirement of 35 years. The cumulative dose estimated for this period falls within the range of (3.5 – 4.3) mSv with the mean of 3.87 mSv. The excess lifetime cancer risk estimated for the cumulative dose falls within the range of (1.4 – 1.7) $\times 10^{-4}$ with the mean of 1.55×10^{-4}. This value is lower than the permissible limit of 2.9×10^{-4}.

The mean dose rates and the estimated mean annual effective doses for mining site SP (86 nSv/h and 135.48 µSv/y), EL (44 nSv/h and 110.359 µSv/y), and KO (88 nSv/h and 241.92 µSv/y) are all greater than the values in the works of Innocent *et al.,* (2014), (41nSv/h and 0.000073 µSv/y) and Odumo (2009), (29.4 nSv/h and 4.2 µSv/y). However, the measured dose rates of mining site GB (26 nSv/h) are less than that of Innocent *et al,* (2014) with a value of 41.3 nSv/h and Odumo (2009) with a value of 29.4 nSv/h. This is also lower than the work of Kasoga *et al.,* (2015) in Uranium mine in Tanzania, where the dose rates due to the naturally occurring radionuclide in Uranium at the mine has a mean value of 320 nSv /h. The maximum value measured for their study was about thirty times the world average of 42 nSv /h. The dose rates value from the work of Louis *et al.,* 2018 (23 – 83) µSv/h with a mean of 158 µSv/h) is greater than to be is greater than the all the values for the study. The dose rates values from study of Abba *et al.,* 2017 is greater than the values from all the mining sites with a range of 40 nSv/h – 1265 nSv/h and a mean of 250 nSv/h. Eyakifama and Tchilabalo, 2021 reported absorbed dose rate of 84 nSv/h for Phosphate miming sie in Togo which is quite close to the highest dose rate reported at Ko miming site for the study. This may be due to the radioactive potential in tantalite and Phosphate.

In open mines, dose rate values are of close range and same atmospheric condition; the histogram revealed that the dose rates distribution is negatively skewed to the left with the value -0.052 ± 0.512 and kurtosis value of -1.540 ± 0.992 (Figure 4). The distribution is almost normal. This explains the effect of good ventilation of open mines. Radiation doses from any source of radioactive material in the pit are not allowed to accumulate to a level that can be of detrimental health effect to the miners.

In caves or underground mines, the dose distribution is positively skewed with a value of 0.945 ±0.512 with a kurtosis value of -0.633 ± 0.992 (Figure 5). This explains the dose distribution in caves where the ventilation is poor. Accumulation of dose from radioactive materials tends to build up such that at high dose, it can pose a threat to artisan miners working in the caves.

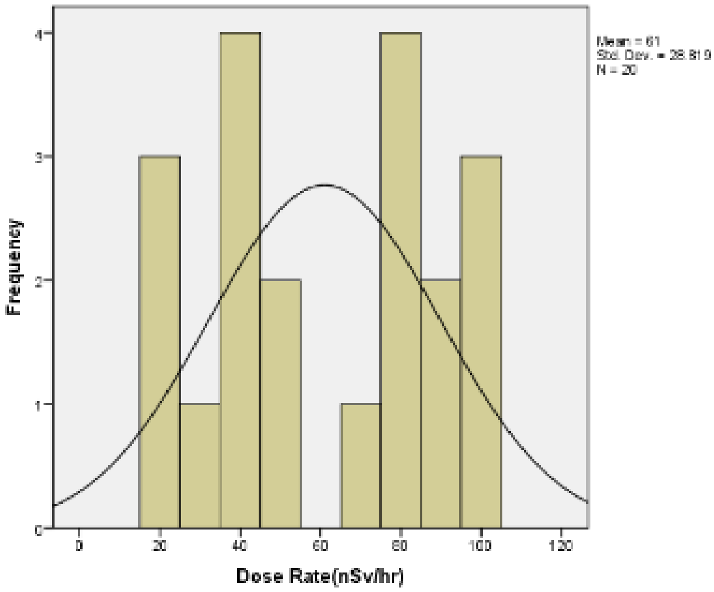

Figure 4: Histogram for Dose Rate (nSv/h) for all the open mines in the Study

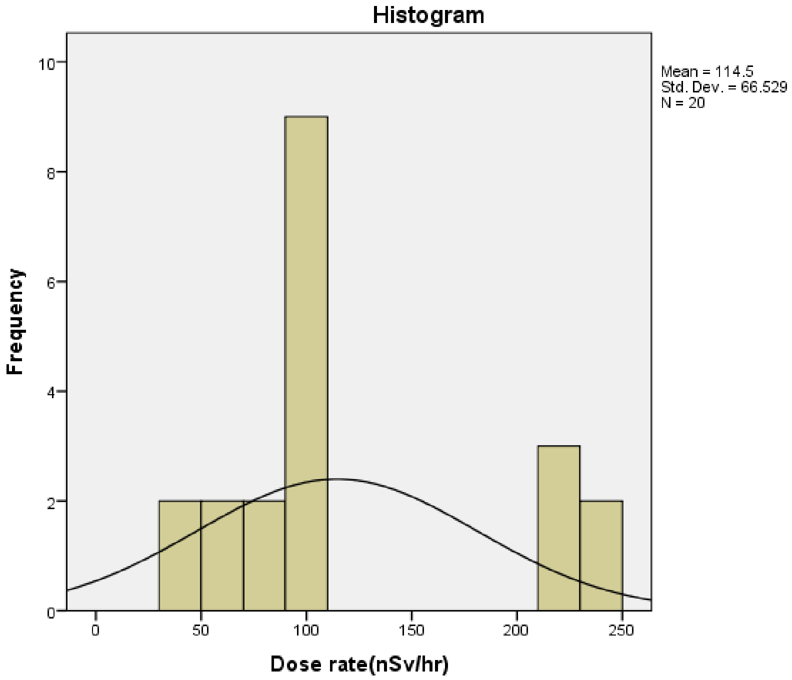

Figure 5: Histogram for Dose Rate (n h) for all the underground mines in the Study

Results of Statistical Analysis of Data for the Study

The ANOVA analysis and Multiple Comparison of Post Hoc Test for dos ates inside the pits at the mining sites for the study are shown in Tables 5 and 6

Table 5: Analysis of Variance for Dose Rates (nSv/h) inside the pits for all the sites

Source of Variation	Sum of Square	Df	Mean Square	F	Sig.
Between-group	83780.0	3	27926.667	272.455	0.000
Within-group	1640.0	16	102.500		
Total	85420.0	19			

From table 5, there is a significant difference between dose rates measured inside the pits for all the mining sites since p = 0.000., hence Turkey post hoc test further gives the details of the significant difference in the dose rates measured outside the pits for all the sites. Table 6 present the multiple comparison of post hoc test for dose rates inside the pits at the mining sites. There is a statistically significant difference in the mean dose rates measurements at KO, EL and SP (*p* = 0.000). Also, there is statistically significant difference between the measured dose rates at SP, KO and EL (*p* = 0.000) but there is no statistically significant difference in mean dose rates measures at SP and GB (*p* = 0.989). Also, there is significant difference between the dose rates at GB miming site and KO and EL mining sites (*p* = 0.000) but there is no significant difference in the dose rates measurement at GB site and SP site (*p* = 0.989). Finally, there are significant difference in the dose rates measured at EL, KO, SP and GB sites (*p* = 0.000)

Table 6: Multiple Comparison of Post Hoc Test for Dose rates inside the pits at the mining sites

Locations		Mean Difference (i-j)	Std Error	Sig	95 % Confidence Interval	
					L.B	U.B
KO	SP	132.000	6.403	.000	113.68	150.32
	GB	134.000	6.403	.000	115.68	152.32
	EL	170.000	6.403	.000	151.68	188.32
SP	KO	-132.000	6.403	.000	**-150.32**	-113.68
	GB	2.000	6.403	.989	-16.32	20.32
	EL	38.000	6.403	.000	19.68	56.32
GB	KO	-134.000	6.403	.000	-152.32	-115.68
	SP	-2.000	6.403	.989	-20.32	16.32
	EL	36.000	6.403	.000	-17.68	54.32
EL	KO	-170.000	6.403	.000	-188.32	-115.68
	SP	-38.000	6.403	.000	-56.32	-19.68
	GB	-36.000	6.403	.000	-54.32	-17.68

***The mean difference is significant at the 0.05 level**

Table 7: Analysis of variance of Dose Rate (nSv/h) outside the pits for all the selected mining sites

Source of Variation	Sum of Square	Df	Mean Square	F	Sig.
Between-group	14340.00	3	4780.00	53.111	0.000
Within-group	144.00	16	90.00		
Total	15780	19			

From Table 7, there is a significant difference between dose rates measured outside the pits for all the mining sites (*p* = 0.000). Turkey's Post hoc test gives the further details on the significant difference in the mean of the measured dose rates outside the pits. Table 8 presents the Turkey's Post Hoc test for the mean dose rates (nSV/h) outside the pits of the selected mining sites. There is no significant difference in the mean dose rates measured outside the pit at KO and SP mining site. This can be explained by the fact that KO and SP are in same column (4) in the table. GB and EL are in different columns (2 and 3); hence, it was interpreted to have a significant difference between their mean dose rates.

Analysis of Variance of dose rates (nSv/hr) inside and outside the pits and Duncan Post Hoc test for dose rates inside and outside the pits at the sites are presented in tables 9– 10.

Table 8: Turkey's Post Hoc Test for the mean dose rate (nSv/hr) outside the pits of the selected mining sites

Mining Sites	N	Subset for alpha=0.05		
		1	2	3
GB	5	26		
EL	5		44	
SP	5			86
KO	5			86

Table 9: Analysis of Variance of Dose Rate (nSv/hr) inside and outside the pits for all the mining sites.

Source of Variance	Type III Sum of Square	Df	Mean of Square	F	Sig.
Model	434112.500[a]	5	86822.500	93.826	.000
Inside and Outside Pits	23522.500	1	23522.500	25.420	.000
Mining Sites	84787.500	3	28262.500	30.542	.000
Errors	32387.500	35	925.357		
Total	466500.00	40			

a. **R squared = 0.0931 (adjusted R value = 0.921)**

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From table 9, the difference in mean of dose rates measured inside and outside the pits where the tantalite is mined is significant at *p* = 0.05. From the ANOVA table 9, it shows that the mean dose rates inside and outside the pits at the selected mining sites are significantly different at *p* = 0.000 which is less than 0.05. Duncan Post Hoc test further gave the details of the significant difference of the mean measurement inside and outside the pits at all the mining sites. The mean dose rates measurement in and outside the pits where Tantalite is mined at EL and GB is not significantly different while the mean dose rates measurement in and outside the pit at SP and KO is significantly different as explained in Table 10

Table 10: Duncan Post Hoc test for Dose Rate inside and outside the Pits at the Sites

Villages	No of Data	Sub Set (Mean)		
		1	2	3
EL	10	48		
GB	10	57		
SP	10		91	
KO	10			165

CONCLUSION

The ambient dose rates measured across the mining sites in the study reveals that the radiological parameters measured and estimated for SP, EL, and KO (86, 44, 88) nSv/h mining sites are above the world average (42 nSv/h) for the dose rates except that of Gb site with a value of 26 nSv/h. The dose rates inside the pits for the underground mines such as that of KO are significantly different from that outside the pit. The estimated cumulative dose for the time of stay of workers at KO site (5 hrs/day which is equal to 1589h/y) is quite high (11 mSv) with an attending cancer risk of 4.44×10^{-4} which is above the safe limit of 2.9×10^{-4}. The workers mining in the underground mines can spend less hours or adopt shifting of duty plan in order to reduce their exposure to ionizing radiation from NORM in the soil / rocks/ tantalite at the sites. Protective materials such as nose masks and gloves can be used by the artisan miners so as to reduce exposure to radiation through inadvertent inhalation of dust from rocks/ soils and external irradiation respectively. Surface mining sites such as that of GB, SP and EL seems to pose no health risk to the miners due to low values of radiological parameters estimated for the sites (26 nSv/h for dose rates of GB outside the pit and cancer risk values of 1.76×10^{-4}, 1.68×10^{-4} and 1.92×10^{-4} for GB, EL and SP respectively. These values are lower than the safe limit of 2.9×10^{-4}. More employed youth of the in these sites can be employed as administrative staff at the sites thereby to an extent reduce the teeming unemployment rate in the nation.

REFERENCES

EC, 1996. Laying Down the Basic Safety Standards for Protection of the Workers and the General Public against the Dangers arising from

Ionizing Radiation *Journal of European Union* 13(2):1-73.

Eyakifama. H., Tchilabalo E. P. 2021. Assessment of radiological hazards in the phosphate mining area of Kpogame, Togo. Case study in chemical and environmental enginnering. Vol 3, pp 1-9.

IAEA, 1996. International Basic Safety Standards for Protection Against Ionizing Radiation and for the Protection of Radiation Sources. Safety series No 115(Vienna: International Atomic Energy Agency).

IAEA, 2011. Exposure of the Public from Large Deposits of Mineral Residues. International Atomic Energy Agency, VIENNA, 2011. IAEA -TECDOC-1660.

Kasoga, K .F., Mwalongo, D. A., Sawe, S F., Nyaruba, M. M. and Dammalapati, U, 2015.Ambient Gamma Dose Rate Measuremen at Manyoni Uranium deposits, Singida, Tanzania. A Proceeding od South Africa Institute of Physics, South Africa pp1-7

Louis N. E, Joseph E. N N, Masahiro H, Daniel B. S, Naofumi A, Rosalie K H, Moïse G. K. N, and Shinji.T. 2018. Air Absorbed Dose Rate Measurements and External Dose Assessment by Car-Borne Survey in the Gold Mining Areas of Betare-Oya, Eastern Cameroon. Jpn. J. Health Phys.53 (1), 200 - 209 (2018)

Odumo, B.O. 2009. Radiological Survey and Elemental analysis in Gold Mining belt, Southern Nyanza, Kenya. M.Sc Thesis, University of Nairobi.

Oke-Ogun. (Online). http://www.getamap.net/maps/nigeria/oyo/okeogun/(26 April, 2015)

Taskin, H., Karavus, M., Ay, P., Topuzoglu, A., Hindiroglu, S., and Karahan, G. 2009. Radionuclide Concentrations in Soil and Life time Cancer rRsk due to the Gamma Radioactivity in Kirklareli, Turkey. *Journal of Environmental Radioactivity* 100:49-53.

UNESCEAR, 1993. Report to the General Assembly, with Scientific Annexes, New York United Nations Scientific Committee on the Effects of Atomic Radiation,1993.

UNSCEAR, 2000. Radiological Protection Bulletin, United Nations Scientific Committee on the Effects of Atomic Radiation, New York. pp224.

Van der Steen, J. and Van Weers, A.W. 2004. Radiation Protection in NORM industries 11*th* International Congress of the International Radiation Protection Association IRPA 11 Madrid. Spain