Assessment of Radiation at Tin Mining Sites, In Jos South Local Government Area of Plateau State, Nigeria.

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Abstract— Mining has been identified as one of the potential sources of exposure to Naturally Occurring Radioactive Materials (NORM), as well as higher activity concentrations of primordial radionuclides in the topsoil of mining sites and their environs. This research focused on the assessment of radiation at tin mining sites in Jos North Local Government Area, Plateau State, Nigeria. Eleven sample sites were considered and measured using the hand held Geiger counter for radiation and temperature. GPS was also used to measure location and map out sample sites. GIS analysis, Wilcoxon signed rank test and spearman rank correlation coefficient were used to analyzed data obtained from field. Results showed that, samples sites measured in March have a higher mean value of 0.3227μSvh^{-1} than those measured in July with a mean value of 0.2545μSvh^{-1}. Diurnal analysis showed that there was no significant variation with the time of day radiation readings were taken using Wilcoxon Signed Ranks Test, although annual radiation projection reveals that all sample site measurement are higher than the ICRP 2007 recommendation with up to 5mSvy^{-1} for the highest measured radiation readings of 0.72 μSvh^{-1}. The study also proves that there is a significant relationship between the amount of emitted radiation and temperature. This research recommends that, the public should be made aware and most especially miners, to the dangers associated to radiation exposure as a result of mining and other manmade sources.

Dose: a measured level of radiation. **μSv**: microsievert. **mSv:** millisievert. **Gy:** Gray, unit of ionizing radiation. **CPEP:** Contemporary Physics Education Project. **PHE:** Public Health England. **Exposure pathways**: the physical course through which humans are contact radiation.

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1 Introduction

According to the Nigeria Extractive Industries Transparency Initiatives (NEITI) audit report on the solid minerals industry 2007-2010, over N2.21 billion was paid as royalty by operating companies, N51.4 billion as taxes by some companies/major players in the industry. This indicates the lucrative nature of mining solid minerals in the country. Mining is associated with by products which might be radioactive, and emits waves which might be harmful to the miners, users of these by products for construction of houses, or even the prolong exposure to it. Ionizing radiation has many practical uses in medicine, research, construction, but present a health hazard if used improperly.

According to Canadian Nuclear safety Commission[1] there are three main types of radioactive decay, these are: Alpha decay, Beta decay and Gamma decay**:** This takes place when there is residual energy in the nucleus following alpha or beta decay, or after neutron capture (a type of nuclear reaction) in a nuclear reactor. The sources of these radiations according to the United Nations Scientific Committee on the Effects of Atomic Radiation [2] include exposure from cosmic radiation, exposure from terrestrial radiation, exposure through inhalation, exposure through ingestion: trace amounts of radioactive minerals are naturally found in the contents of food and drinking water. For instance, vegetables are typically cultivated in soil and ground water which contains radioactive minerals.

Most of the radiation doses that are received by members of the public and by radiation workers both routinely and in accidents are what are commonly referred to as “low doses” [3]. There is no precise definition of “low” but it would include doses below, for example, 10 mSv per year. Radiation doses above 3 Gy (300 rad) can be fatal and doses above 6 Gy (600 rad) are almost certain to be fatal, with death occurring within several months (in shorter times at higher doses). Radiation that causes genetic damage, which directly damages the reproductive organs, and therefore affects any offspring that individual may have after the damage has occurred. Radiation damage is done to genes and chromosomes, which can be passed on to future generations [4]. Studies of survivors of the Hiroshima and Nagasaki bombings and of the Chernobyl survivors in Ukraine have shown that there are increased rates of stillbirths, miscarriages, and infant death [5].

According to Ibrahima, Aliyub, Najibc and Hamza [6], radiation exposure associated with tin mining sites around Toro area in Bauchi State were above the safety limit recommended for the public by International Commission on Radiological Protection (ICRP). Similarly, Wapwera, Ayanbimpe and Odit [7] observed the traces of X-ray, beta-ray and gamma-ray as well as the heavy metals such as Lead, Arsenic , cadmium, chromium and nikel which exceeded the international standards around abandoned mine in Jos plateau. Aigbedion [8] conducted a research in Jos-Plateau State about the mysterious deaths of tin miners who used most of the byproducts of tin mining for construction and attributed their deaths to high level of radiation released by monazites-rich sand used for building the houses the deceased lived in. This present research is therefore geared towards assessing the level of radiation emission at selected tin mining site in Jos South Local Government Area of Plateau State. In order to achieve this, the research will strive to:

- Measure and analyse the amount of emitted radiation in the various towns in Jos South local Government Area, Plateau State.
- analyze seasonal radiation and temperature variations at the mined sites
- Proffer possible ways in reducing radiological hazards.

2 Study Area

Jos south local government area in Plateau State, Nigeria is located on coordinate 9^0 46N to 9^0.76N and $8^0$48'E to 8^0.80E.It has a total land area of about 5,104km^2 (1,971 sq mi) see figure 1 and 2. According to the 2006 population census Jos South has a population of 306,716 and a density of 604/km^2. It is the second most populated local government area in the state after Jos North. The major mineral resources found in the study area are tin ore, cassiterite (Sn02), columbite and calcium carbonate (CaC0$_3$). The area extent of devastated arable land by open-cast tin mining is estimated at 316km^2, which comprises of mine spoils, pits, paddocks, and site of abandoned equipment, mining scar, tailing, mine dumps and ponds, especially along the river valleys [9]. Balogun [10] pointed out that the Jos Plateau mining region covers an area of approximately 3,670km^2, about 43% of the total land area of Jos Plateau.

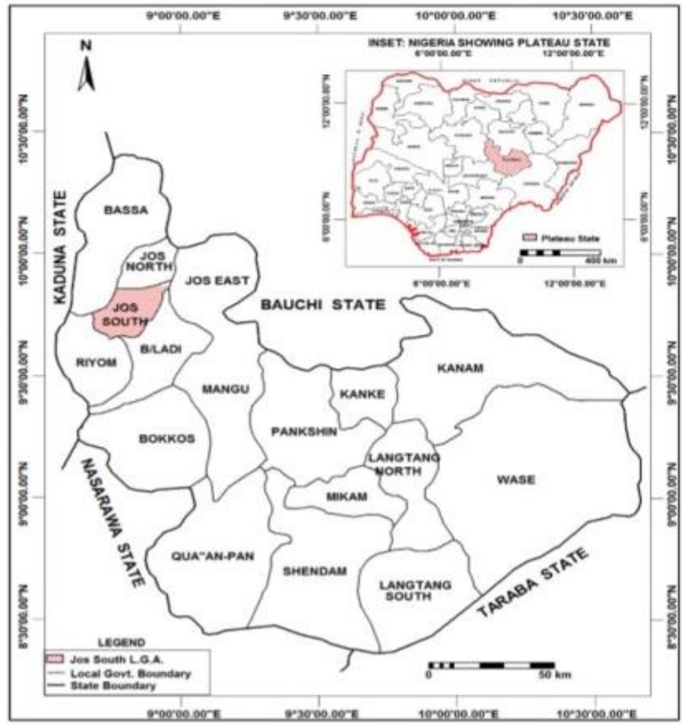
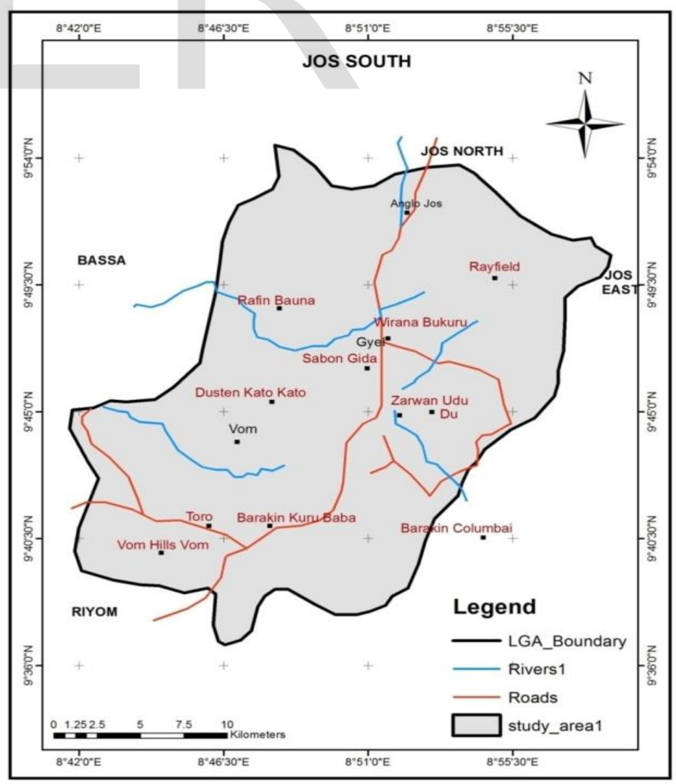


Figure 1: Map of Nigeria Showing Plateau State and Study Area (Jos South)



Source: Plateau state Geographic Information Site, 2016.

Figure 2: Map of Jos South showing towns in study area.
Source: Plateau state Geographic Information Site, 2016.

3 Material and Methods

Data on the amount or level of radiation was collected in situ using an instrument called the Geiger counter (RadEye G gamma survey meter), the instrument was also used to measure the temperature as at when radiation readings were taken. Samples each were measured from Guratopp, Rayfield, Turu, Giring, Bukuru, Du and Zawan, to cover the Jos South Local Government Area, these samples was collected around February/March and then June/July and subjected to further statistical test to show variability.

Field data collected from sampled site were organized and input into excel with their coordinate, then ArcGis was used to extract the excel file and then georeferenced before interpolating the data, in order to produce a map for both radiation and temperature base on the data obtain from the field. Frequency tables, charts and maps, were also used to present the analyzed data. The Wilcoxon signed-rank test was used to show variation using the median between dry season and wet season. Since the sample size are equal and the two groups of observation are on the same population, the most appropriate statistical tool to use was the Wilcoxon signed-rank test, also the Wilcoxon signed-rank test was used to test the diurnal variability of radiation. The formula for the Wilcoxon signed-rank test is given as

$$z = \frac{R - \mu_R}{\sigma_R}$$

$$\mu_R = \frac{n_1(n_1 + n_2 + 1)}{2}$$

$$\sigma_R = \sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}}$$

Where
R= sum of ranks for smaller sample size (n_1)
n_1= smaller of the sample size
n_2= larger of sample size

To further analyse the data collected to show if there is relationship between emitted radiation and temperature the spearman rank correlation coefficient was used to measure the
strength of the link between the paired x (emitted radiation)and y (temperature) values of the sample data collected. Where d^2 =difference between the two ranks of each observation, n = number of observations and R= Spearman's arnk correlation coefficient

$$(R^2) = 1 - \frac{6\sum d^2}{n^3 - n}$$

4 Literature Review

Mining the earth of minerals has result in diverse environmental hazards, ecological disturbance and disturbance of flora and fauna, pollution of air, land and water, instability of soil and rock masses, landscape degradation and radiation. In recent years little attention is given to radiation because its effect is not immediate. In a research conducted by Wapwera, Ayanbimpe and Odit [7], deaths of tin miners within Jos, were attributed to the use of mining by products for building, In the developed countries such as members of the European Union (11), each member country is obliged to identify work activities that cannot be ignored from the radiological protection point of view. This action has increased the awareness of the potential problems enormously, and most of the EU member states have now implemented regulations dedicated to natural sources of exposure [11]. Recently there are a lot of reports on natural occurring radioactive materials (NORM) with respect to occupational and public exposure situations that have been published recently [12], [13], [14] that have all contributed significantly to the recognition of the radiological consequences and risk associated with NORM. On the average, the annual global effective dose due to exposure to NORM has been estimated to be 2.4 millisievert (mSv) with a typical range between 1-10 mSv [15].

However, specific individuals residing near installations releasing radioactive materials into the environment may be subjected to higher exposures. It should be noted that, should some of the sites with high levels of radioactive residues be inhabited or re-inhabited, the settlers would incur radiation exposures that would be higher than the global average level of natural exposures [15]. This is a contrary case as Gbarato, Osimobi and Avwiri [16] measured the Background Gamma Radiation Level of Udi, Enugu-South And Ezeagu Lgas Of Enugu State, the results of the background ionizing radiation measurements from the measurement points around each of the solid mineral sites studied shows that the exposure dose rate ranged from 0.010 mR/hr to 0.025 mR/hr with an average of 0.014 mR/hr at location 1 (Amagu-Umuene), 0.012 mR/hr to 0.022 mR/hr with an average of 0.0165mR/hr at the location 2 (Ogulogo-olo) and 0.011 mR/hr to 0.022 mR/hr with an average of 0.0153 mR/hr at location 3 which are populated region in the south east of Nigeria.

The level of radiological hazards associated with the activities of tin mining and milling in most cases are detrimental to physiology of the human for instance,

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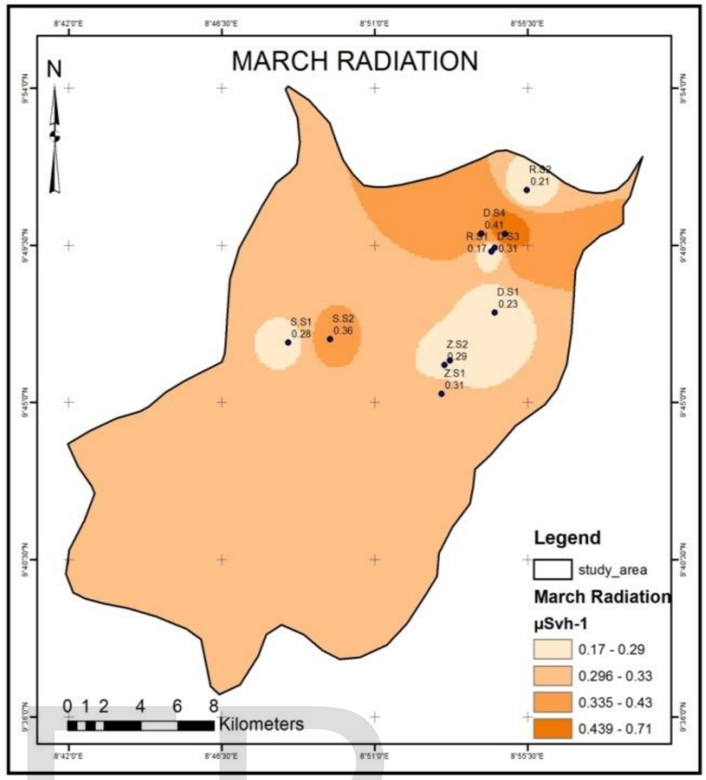
measurement of Radionuclides in processed tin mine tailings in Jos using NaI(TI) detector by Mangset and Sheyin [17] shows that the mean activity concentration ranged from 364Bq/kg-27930Bq/kg in the tailings. Similarly HPGe detector used to measure the radioactivity in mine tailings in Jos, revealed that 226Ra (radium) have mean activity concentration ranged between 51.36Bq/kg – 512.24Bq/kg while 232Th (thorium) mean concentrations ranged between 378.02Bq/kg – 2635.78Bq/kg [18]. These measurements show high radionuclide readings within the Jos Plateau.

These high readings were also observed by Usikalu M.R, Anoka O.C and Balogun F.A [18], who measured radioactivity of the Jos Tin Mine Tailing in Northern Nigeria, discovered that the activities of ^{226}Ra and^{232}Th are much higher than the recommended average limit given by UNSCEAR in the mining sites and even at 500 m away from the mining site. At 1 Km away from the mining site the activity measured is within the limit for normal background. The ratio of activity of Thorium to Radium is greater by factor of 5 in all the samples in the mining site and 500 m away which should be about unity. The mean absorbed doses (1828.66, 252.08 and 171.07 nGyh-1) for Site1, Site2 and 500m from mining site respectively in air are equally high compared with (51 nGyh-1). Also, the estimated effective dose equivalents are much higher than the recommended limit except for 1 Km from the mining site. Lastly Wapwera, Ayanbimpe and Odita [7], researched on abandoned mines in Jos Plateau Tin-Mining Region, they recorded traces of X-ray, beta-ray and gamma-ray as well as the heavy metals such as Pb, As, Cu, Cr and Ni which exceeded the international standards. This is particularly significant as people use the contaminated soils as building materials for their homes as well as for farming and food production. The inhabitants of the area are often without any knowledge about the perils of the contaminated soils, water as well as air which is serious long-term human catastrophe. Drawing from international experience, the paper argues that it is possible to develop housing in former tin-mining areas but requires careful remediation and engagement by the public and private sector.

5 Result and Discussion

The results of assessment of radiation measured at selected tin mining sites in Jos south local government area is presented figure 3 and 5, Geographic information system was used to depict radiation and temperature data obtained from the month of March and July, the used of interpolation model to depict these data gives a clearer view on the variation of data obtained from this two month which are presented

Figure 3: Map of March Radiation Measured



Source: Field Work 2019

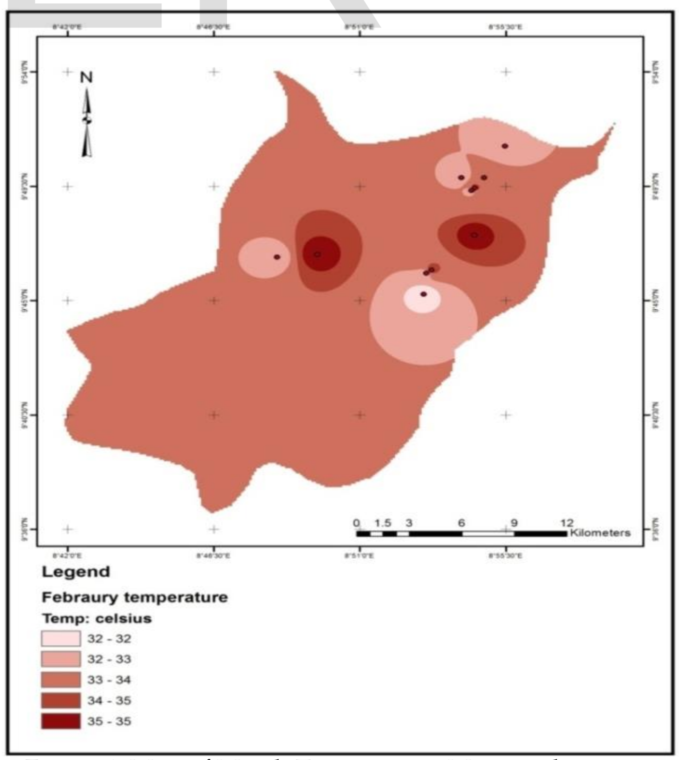


Figure 4: Map of March Temperature Measured.
Source: Field Work 2019

Figure 3 shows that the mean value of radiation readings collected in March is 0.3227 μSvh-1. The highest reading of radiation was 0.72 μSvh-1 which is located at Rayfield, while the lowest was 0.17 μSvh-1 which may be regarded as NORM. These values indicate that at 0.72 μSvh-1 if calculated for a year would be about 6307.2 μSvy-1 which is above 3.0 mSv/year global average annual dose per person from all sources of radiation in the environment [19]. The highest point was located at Rayfield North of Jos South; this might be due to the high presence of Uranium, thorium and/or potassium which are radionuclide in nature as observed by Odusote et al [20]. The March temperature readings as express in figure 4, indicates that the highest and lowest reading on the days when samples were collected was 36^{0}C and 32^{0}C respectively and as observed by Eziashi [21] two distinct season (wet and dry) has a temperature range of 32^{0}C to 18^{0}C respectively, this directly conforms to the measurements as shown in figure 4. The mean temperature is 33.91^{0}C with a standard deviation of 1.375 which indicate that temperature were stable during the periods samples were collected, this may not have huge impact on the radiation readings obtained as at the time temperature readings were taken. From figure 3 and 4, it could be noticed that the region with highest radiation level also recorded a high temperature reading of 34^{0}C which was taken around 1:58pm.

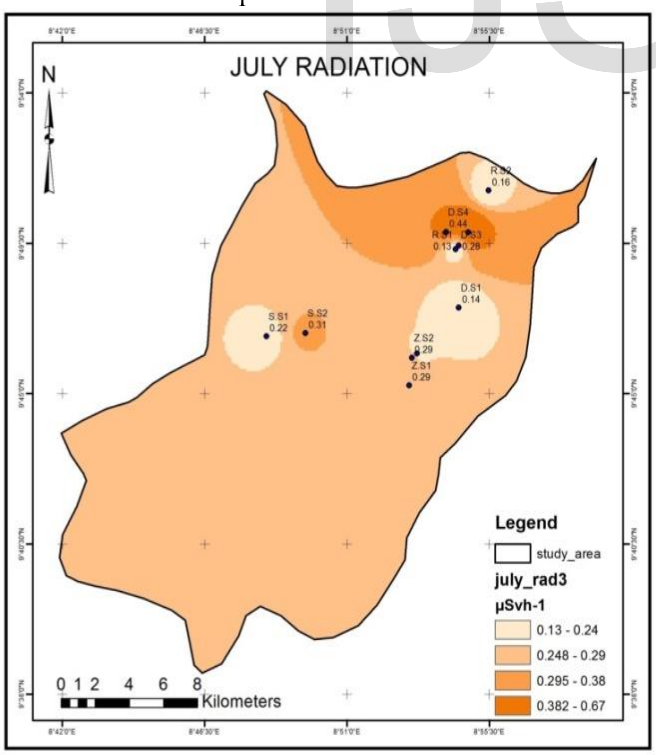


Figure 5: Interpolation Map of July Radiation Measured.
Source: Field Work 2019.

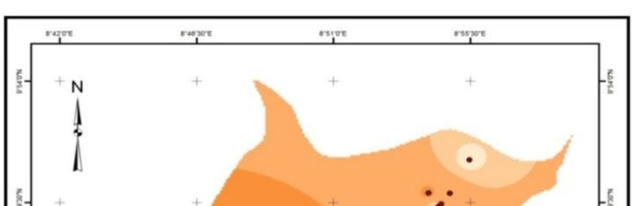


Figure 6: Map of July Temperature Measured.
Source: Field Work 2019.

Figure 5 shows radiation readings collected at various sampling point within Jos South Local Government Area of Plateau State in month of July. The highest recorded radiation reading was 0.67 μSvh-1 (5956.8 μSvy-1) this is also above the annual dosage limit a human is expected to be exposed to according UNSCEAR[19] which is set at 1mSv, while the lowest recorded was 0.13 μSvh-1 (1401.6 μSvy-1). These level of radiation may not really pose an immediate threat to the inhabitants of the regions where high radiation readings are taken according to Ministry of Public Works and Government Services Canada (PWGSC) [22].While the temperature reading for the month of July during the days when samples were collected were relatively colder than that of March as expected, the lowest temperature readings is below 24^{0}C while the highest was above 31^{0}C, with mean of 29.18^{0}C as shown in figure 6, with a standard deviation of 2.750. This reading conforms to the seasonal temperature of Nigeria. The radiation readings were a bit lower than those recorded in March, this may be attributed to the high rainfall which according to Dung-Gwom et al [23] peaks at the month of July and August, therefore readings are expected to be lower due to cloud cover. The mean annual rainfall is between 1347.5mm per annum; this high rainfall washes off the surface of the piled byproduct of tins and reduces the amount of concentrated minerals emitting radiation through leaching. Surface runoff which concentrate these minerals when settled, are later absorbed by plants and consumed by herbivores and passed from animal up the food chain, thereby increasing the radiation intake up the food chain. Muhammed et al [24], observed that high value of uranium obtained in cereals and vegetables can be attributed to the fact that some of the cereals (corn) and vegetables are phytoremediators in a uranium contaminated soil because of their high bioaccumulation of uranium.

6 Seasonal Variation in the Amount of Emitted Radiation

Analysis of seasonal variation in the amount of emitted radiation, using readings from month of March and July is presented in figure 7. Among the eleven (11) sample points measured, only one (1) sample point was radioactively alarming as shown in figure 7 and projected in figure 8, which is located at Rayfield, just behind the Golf club, which lies on latitude 9° 49' 50"N and longitude 8° 54' 49"E. This point has the highest average reading both in March and July of over 0.65 μSvh^{-1}.

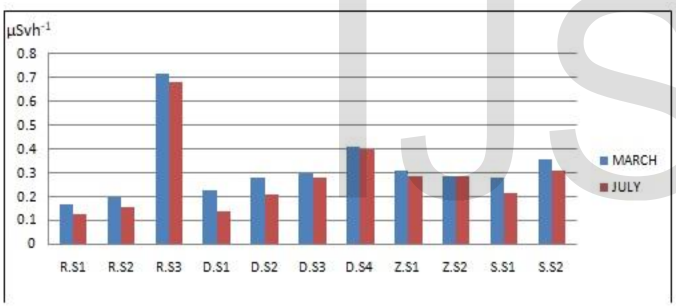


Figure 7: Chart Representation of March and July Radiation.
Source: Field Work 2019.

In a study conducted by Ekong *et al* (2019), radiation measurements obtained were from 0.041 ± 0.002 - 0.045 ± 0.002 μSv/hr with overall mean of 0.042 ± 002 μSv/hr which indicate an increase in the exposures to background ionizing radiation which can lead to Excess Life Cancer Risk at 0.05 × 10^{-3}. An increase in the background ionizing radiation means a possibility of an increase in the cancer patient within the same environment, based on the Excess Life Cancer Risk at 0.05 × 10^{-}, the radiation readings in figure 7 shows that readings far exceed those observed by Ekong et al [26] and the world radiation measurement mean of 0.2 μSv/hr, which indicate a possibility in the increase of cancer patients with the environs over time.

8 Annual Projected Radiation Readings at Sample Sites against ICRP Standard.

Figure 8: Chart Representation of Annual Estimated Radiation for March and July.
Source: Field Work 2019.

It was estimated that the inhabitants of these regions are exposed to an average annual radiation dose of 3.7 mSvy^{-1} and up to 6.3 mSvy^{-1} in dry season and 5.9 mSvy^{-1} in rainy season, with a mean of 2843.02 μSvy^{-1} for the month of March and 2476.62 μSvy^{-1} for July as shown in figure 8. These values are higher than the study by Sadiq *et al* [25] who reported values of 1.04 to 1.75mSv/yr and 0.24 to 0.44mSv/yr for indoor and outdoor radiation at Akwanga, Nigeria respectively.

7 Statistical Analysis of Seasonal Variation of Radiation.

Table 1. Statistical Analysis of March and July radiation

			∝= .05		
RadiationMonths (units = μSvh^{-1})		descriptions	(, p=0.005, z= -2.814, *Significant)		
	N	Mean	Std. Deviation	Minimum	Maximum
March Radiation	11	0.3227	0.14806	0.17	0.72
July radiation	11	0.2545	0.15839	0.1	0.68
	Wilcoxon signed Ranks test				
			N	Mean Rank	sum of Ranks
July radiation/March Radiation		Negative	10	5.5	55
		Positive	0	0	0
		Ties	1		
		Total	11		
		Test output.			
July radiation – March Radiation					
		Z	-2.814		
		Asymp. Sig.(2-tailed)	0.005		

Source: field work 2019

The result of the Wilcoxon test is depicted in table 1, the z-values is -2.814 and since the alpha level is set at 95% that is 0.05 and the p-value of 0.005 is less than the alpha level, therefore it can be concluded that there is a significant variation in the amount of emitted radiation between March and July readings obtained. In a similar study, Akpootu et al [27] observed that radiation peaks were observed around February, March and April while the minimum was recorded around June and October; this explains maximum incident solar radiation during the dry season than wet season.

Table 2: Correlations between Radiation and Temperature Readings for both March and July

			Radiation	Temperature
Spearman's rho	Radiation	Correlation Coefficient	1	.482*
		Sig. (2-Tailed)	-	0.023
		N	22	22
	Temperature	Correlation Coefficient	.482*	1
		Sig. (2-Tailed)	-	0.023
		N	22	22

Source: Field Work 2019.

From the statistical analysis presented in table 2, a spearman's correlation was run to assess the relationship between temperature and radiation using a small sample 22 observations within Jos South Local Government Area of plateau State. There was weak positive correlation between temperature and radiation which was statistically significant, r_s= 0.482, and P = 0.023 which is less than the alpha level of 0.05. At P≤0.05 level of significance. The result of the analysis indicated that there is significant relationship between temperature and the amount of emitted radiation, this is also evident in a solar radiation study in Akure, where for the diurnal variations showed that the solar radiation values rose steadily from dawn and attained their peaks between 12:00 hLT and 14:00 hLT after which the values fall to a minimum in the late afternoon and evening periods at about 18:30 hLT [27].

9 Conclusion

The study was motivated by the fact that these region are prone to mining activities which are not monitored or done in a manner that put the environment into consideration, also the region is known as heavy minerals mining area with operations dating back to the 19th century, and most of the piled up byproducts emits radiation. The potential exposure of the population in the study area was assessed by estimating the annual effective doses at various sites; this was done by multiplying the hours within a day by days within a year, and by the recorded emission dose per hour. The highest recorded dosage was measured at Rayfield 0.72 μSvh^{-1} (6307.2 μSvy^{-1}). The research therefore concluded that residents around mine dumps should be enlighten on the disadvantage of using the mine dump sand for building construction since accumulated radiation turn to affect the health of the residents negatively. Further research such be encouraged on the health implication of cultivating vegetables close to mine dumps for easy access to water from mine ponds.

10 REFERENCE

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