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Radiogenic Characterisation of Wastes and Soil around Cassiterite Mine Sites in Plateau State, Nigeria

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ABSTRACT

The radiation levels in mine wastes and soil of cassiterite mine sites from Rayfield, Gero, Sabongida Kanar, Kuru Jantar, Bisichi and Barkin Ladi, Plateau State, Nigeria had been assessed. Samples of mine wastes were collected from the aforementioned mine sites while soil samples were collected from farmlands in the vicinity of the mines. The annual effective doses recorded in all the soil and mine waste samples collected were above the 1mS/yr for general public limit set by the International Commission for Radiological Protection (ICRP). Inhabitants in close proximity to the mines should also be dissuaded as this can expose them to high concentrations of radiations. The present use of mine tailings for baking and frying as well as for plastering of houses should be discontinued as these could result in exposure to radiation from the Naturally Occurring Radioactive Materials (NORMs).

Keywords: *Radiation, Radiological Incidents Naturally Occurring Radioactive Materials, Tailings*

1. INTRODUCTION

Radioactivity is the spontaneous nuclear disintegration and the emission of one or more of the three types of radiation (alpha - α, beta - β or gamma - γ) from unstable nuclei. Over eighty (80) radionuclides can be found in the earth crust and these can be attributed to primordial and cosmogenic sources enhanced by anthropogenic activities such as mining operations (Ike, 2010). Primordial radionuclides (^{238}U, ^{232}Th, ^{226}Ra, ^{40}K and their progeny) which are found in rocks and minerals are the major sources of radioactivity on the earth (Szabo, 1993). Radioactivity in the body mostly comes from these primordial elements which emanate from soils and rocks and are inhaled by humans together with their decay products. Particles inhaled stick to the linings of the lungs thereby causing radiation damage to the cells which can eventually lead to cancer. Radiation can also be taken up by plants and animals thus causing most foodstuffs to be replete with measurable amounts of natural radioactivity and are thereby passed onto humans by ingestion through the food chain. Exposure to radiations is a major source of health hazards as it could result into leukemia, chromosomal breakage, bone necrosis, bone cancer, mutation of genes and cataract of the eye lens (Paul, *et al*, 1979; Chacket, 1981). The effects of radiation can be into somatic (effects on the irradiated person) or hereditary. It is because of this that the International Commission on Radiological Protection (ICRP) sets an annual effective dose limit of 1 mSv / yr in 1990.

Tin mining flourished in the study area from the beginning of the twentieth century to the early 1980s and left behind a post mining environment scarred by numerous mine ponds surrounded by heaps of mine wastes and a devastated landscape (Adiukwu-Brown, 1999; Funtua, 2001; Mallo, 2007; Gyang and Ashano, 2010). Tin and columbite were found associated with radioactive minerals such as monazite and wolframite. The radioactive accessory minerals to the cassiterite deposit which are in concentrated form due to the extraction of the non-radioactive components (tin and columbite) are abandoned in many previous mining sites in the study area. It was discovered in the course of this research that the mine wastes (overburden and tailings) in the study area were being used for building construction, as foundry sand for steel casting, road fill for road maintenance, for frying groundnuts and as recreational facilities in Jos wild life park for sand bathing by children. It is therefore necessary to determine the annual effective dose rate of the radiation in the mine wastes and soil of the study area.

2. MATERIALS AND METHODS

2.1. Soil and Mine Wastes Sampling and Analyses

Simple randomized sampling method was used to collect representative samples of mine wastes and soil samples from all the location of the study area into sample bags from the upper layer (0-15cm depth) of sampling field using a soil auger (Davies, 1998). About 1kg of sample was collected from each sampling point, and carefully packed in a polythene bag, sealed and labelled accordingly. The samples were collected from mine dumps, mine pits, grazing fields, and farms within the impacted land of the study area. The (GPS) locations of sampling points were recorded in the field note book and located on the map. Samples of soil and mine wastes were analysed in accordance with the provisions of International Atomic Energy Agency, IAEA (1996) as well as (UNSCEAR, 2000; Kessaratikoon and Awaekechi, 2008; Masok *et al.* 2015)using the sodium iodide (NaI) radiation detector. The count rate in count per second (cps) which were calculated for ^{40}K, ^{226}Ra, ^{232}Th were converted to specific activity (Ac) in Bq/kg which were further converted to absorbed dose rate in Gy/hr and finally converted to annual effective dose in mS/yr. Each computed annual effective dose was compared with the International Commission on Radiation Protection, ICRP (2012) recommended annual dose limit of 1mSv for general public.

2.2. Determination of the Distribution of Annual Effective Dose Rate in Mine Waste and Soil Samples

Polynomial regression models were generated. This was achieved by plotting the spatial distribution of the annual effective dose in soil and mine waste samples and specific activity of alpha and beta in water samples using Surfer 12 software. A section line was drawn to pass across all contour intervals to obtain a representative model. The edges of the section line were digitized. The grid was then sliced to obtain the coordinates as well as the parameter values of the edges and all points the section line passed through. The resultant differences between the coordinates of all points and the reference point were converted to distances and the parameter values were plotted against distances. Samples labels R, G, S, K, B and BL indicated samples collected from Rayfield, Gero, Sabongida kanar, Kuru Jantar, Bisichi and BarkinLadi respectively.

2.3. Data Analyses

Analysis of variance (ANOVA) was carried on the data using Minitab 17 Software. Tukey test was used for subsequent post Hoc Tests at 5% level of significance.

3. RESULTS AND DISCUSSION

3.1. Summary of Annual Effective Dose Rate in Mine Waste and Soil Samples

Figure 1 shows the Box plot of mean annual effective dose for mine waste and soil samples collected from the study area while Figure 2 shows the difference of means of annual effective dose for mine waste and soil samples collected from the study area. The mean annual effective dose for mine waste and soil samples collected from the study area were 7.6 $\pm$ 1.6 mS/yr and 1.9 $\pm$ 0.4 mS/yr respectively. These values are higher than the mean value of the control as well as the recommended and maximum permissible limits of 1mS/yr set by ICRP (2012) for non-radiation workers. There were however significant differences between the mean annual effective dose of the mine samples and that of the soil samples. There were no significant differences between the mean value of the soil samples and the control.

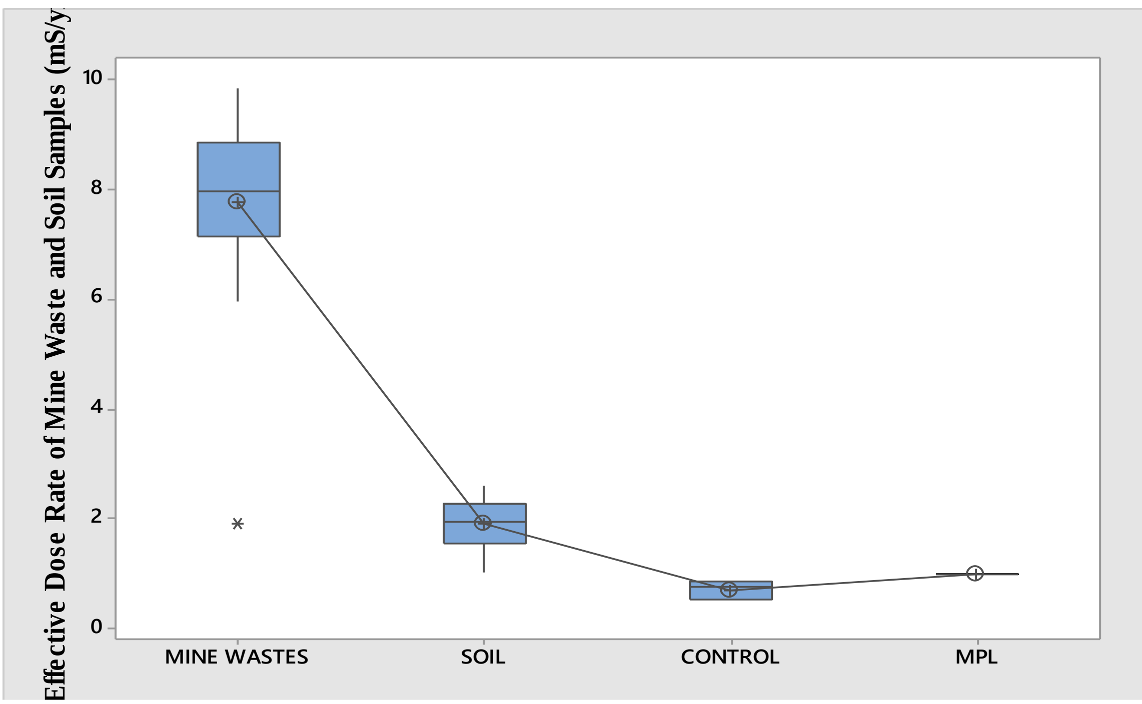

Figure 1: Box Plot of the Annual Effective Dose (Ed) of Mine Waste and Soil Samples in the Study Area (mS/yr)

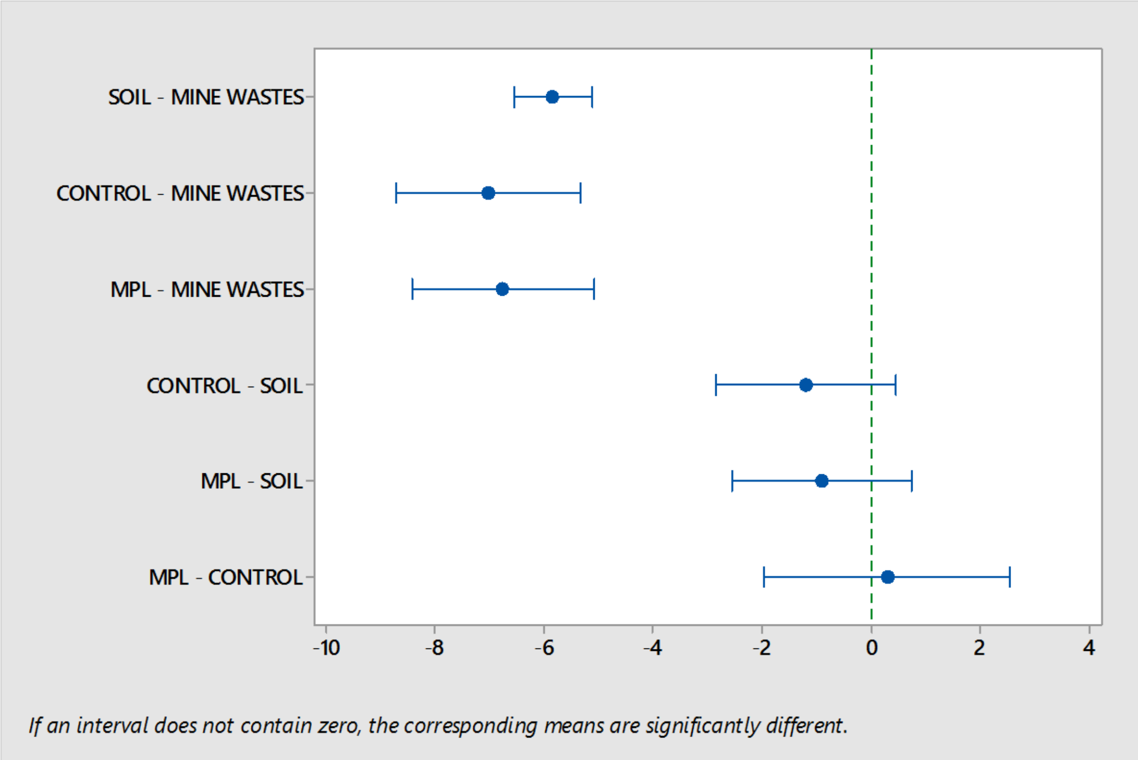

Figure 2: Difference of Means of the Annual Effective Dose (Ed) of Mine Waste and Soil Samples in the Study Area (mS/yr)

3.2. Distribution of the Annual Effective Dose Rate in Mine Waste and Soil Samples

Figure 3 shows the distribution of the annual effective dose in mine waste and soil samples from the study area. The mean annual effective dose in the mine waste samples from Rayfield was 7.9 $\pm$ 0.3. The annual effective dose in the soil samples from Rayfield ranged from 0.9 – 6.9 mS/yr, with a mean value of 4.1 mS/yr. The annual effective doses recorded in 1100 m from the mine were above the 1 mS/yr acceptable limt for general public limit set by the International Commission for Radiological Protection (ICRP, 1990). The mean annual effective dose in the mine waste samples from Gero was 7.6 $\pm$ 0.9. The annual effective dose in the soil samples from Gero ranged from 2.7 – 5.9 mS/yr, with a mean value of 4.1 mS/yr. The annual effective doses recorded in all the sampling points were above the 1 mS/yr maximum permissible limit for general public limit set by the International Commission for Radiological Protection (ICRP, 1990). The mean annual effective dose in the mine waste samples from Sabongida Kanar was 7.5 $\pm$ 0.9. The annual effective dose in the soil samples from Sabonigida Kanar ranged from 0.5 – 4.8 mS/yr, with a mean value of 2.6 mS/yr. The annual effective doses recorded in 620 m from the reference point in the mine were above the 1 mS/yr maximum permissible limit for general public limit set by the International Commission for Radiological Protection (ICRP, 1990). The mean annual effective dose in the mine waste samples from Kuru Janatr was 8.6 $\pm$ 0.7. The annual effective dose in the soil samples from Kuru Jantar ranged from 1.9 – 6.7 mS/yr, with a mean value of 3.8 mS/yr. The annual effective doses recorded in all sampling points were above the 1 mS/yr maximum permissible limit for general public limit set by the International Commission for Radiological Protection (ICRP, 1990). The mean annual effective dose in the mine waste samples from Bisichi was 7.7 $\pm$ 0.9. The annual effective dose in the soil samples from Bisichi ranged from 1.8 – 6.1 mS/yr, with a mean value of 4.3 mS/yr. The annual effective doses recorded in all sampling points were above the 1mS/yr maximum permissible limit for general public limit set by the International Commission for Radiological Protection (ICRP, 1990). The mean annual effective dose in the mine waste samples from Barkin Ladi was 8.3 + 0.8. The annual effective dose in the soil samples from Barkin Ladi ranged from 1.6 – 6.9 mS/yr, with a mean value of 3.6 mS/yr. The annual effective doses in all sampling points were above the 1 mS/yr maximum permissible limit for general public limit set by the International Commission for Radiological Protection (ICRP, 1990). The effective dose rate decreased as distances away from the mine acreage increased in all the locations of the study area. It is therefore clear that the mines were the sources of the radiation. There were significant differences between the mean annual effective dose values of the mine waste samples and those of the soil samples and the control samples. There were however no significant differences between mean annual effective dose values of soil samples and those of the control samples. The effective dose rate, E_d, (mS/yr) in mine wastes and the soil around the Rayfield, Gero, Sabongida Kanar, Kuru Jantar, Bisichi and Barkin Ladi mines distance, x (m) are expressed by Equations 1 – 6 respectively:

$$\text{Ed} = 7x10^{-6} - 0.0173x + 11.288, \quad (R^2{=}0.86; \quad p - value = 1.7x\ 10^{-52}) \text{ ------------------------ } (1)$$

$$\text{Ed} = -0.0042x + 5.764, \ (R^2{=}0.92; p - value = 1.0x\ 10^{-46}) \text{ ------------------------------------ } (2)$$

$$\text{Ed} = 6\text{x}10^{-6}x^2{+}0.0135x + 7.4606, \ (R^2{=}0.94; \ p - value = 3.3\ x\ 10^{-27}) \text{ ------------------------ } (3)$$

$$\text{Ed} = 4\text{x}10^{-5}x^2{-}0.0333x + 8.3927, \ (R^2{=}0.97; \ p - value = 1.1x\ 10^{-27}) \text{ ------------------------ } (4)$$

$$\text{Ed} = -10^{-7}x^3\text{- } 0.0002x^2 + 0.0477x + 6.6861, (R^2{=}0.84; p - value = 1.4x\ 10^{-37}) \text{ ---------- } (5)$$

$$\text{Ed} = 3\text{x}10^{-6}x^2{-}0.0099\ x + 9.0539, \ (R^2{=}0.98; \ p - value = 5.3\ x\ 10^{-38}) \text{ ---------------------- } (6)$$

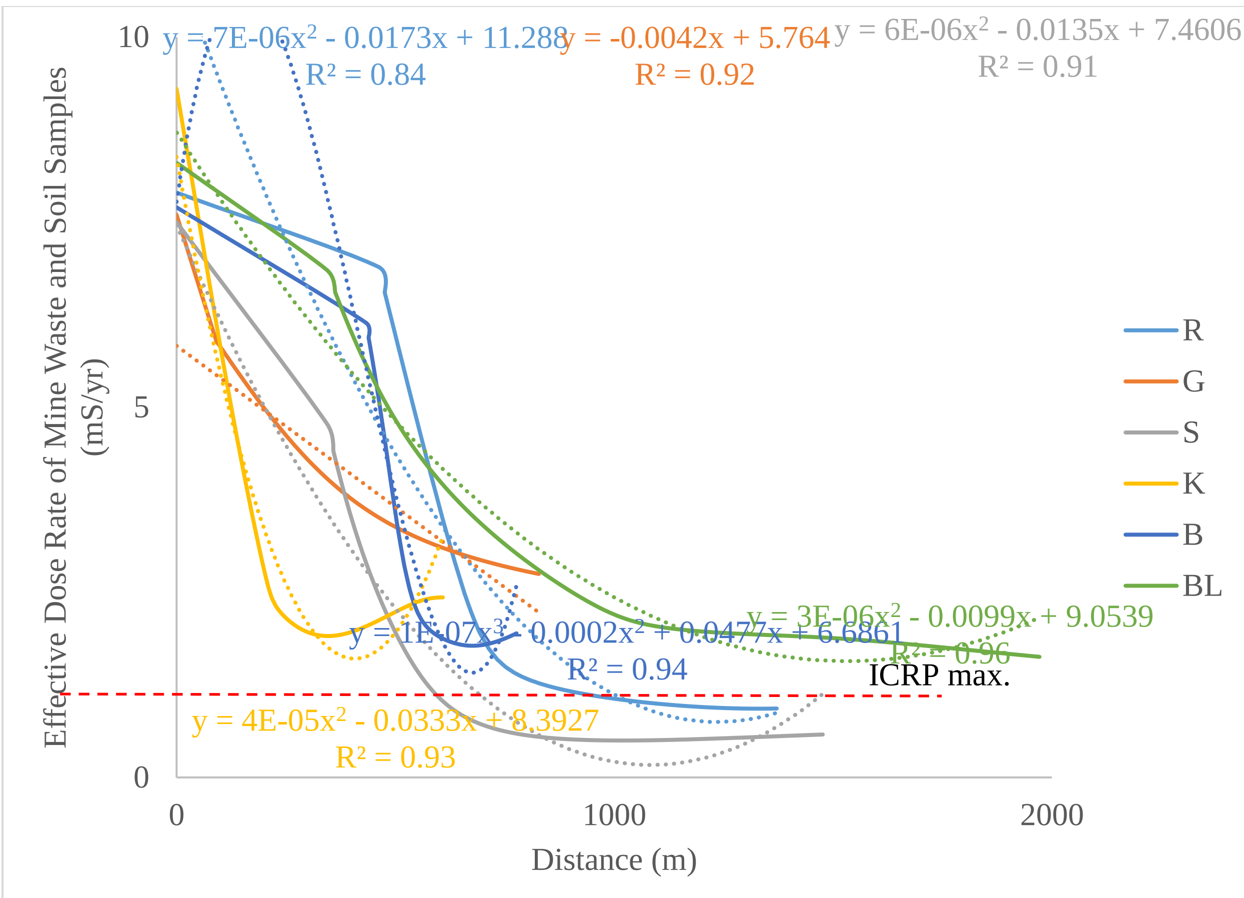

Figure 3: Annual Effective Dose (Ed) of Mine Waste and Soil Samples in the Study Area (mS/yr)

4. CONCLUSION

The effective dose rate for soil samples collected from the study area were also beyond the acceptable limit of 1mSv/yr. Therefore, most areas and inhabitants are prone to radiation hazards. These natural radionuclides liberated by mining activities may make the inhabitants susceptible to chronic diseases such as cancer of the kidney, colon and lungs. It was discovered that radiation reduced as distances from the mine increased for all samples collected from all the locations of the study area.

It is suggested that the mine wastes in the study area be properly controlled and confined away from the public so as not to expose those living and working in the area to radiological incidents. The present use of mine tailings for baking and frying as well as for plastering of houses should be discontinued as these could result in exposure to radiation from the Naturally Occurring Radioactive Materials (NORMs). In habitants in close proximity to the mines should also be dissuaded as this expose them to high concentrations of radiations.

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