Gross Alpha and Beta Radioactivity in Surface Water and Soil from Lead and Zinc Mining Area and their Radiological Risks in Wase Local Government Area, Plateau State, Nigeria

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D.O.I: 10.56201/ijasmt.v8.no2.2022.pg51.62

ABSTRACT

Radionuclides are naturally found throughout all environments. They are present in varying amounts in air, water, plants animals, soil and water. In this study ten (10) water samples and fifteen (15) soil samples from Zinc and Lead mining areas in Kampani Zurak village, Wase LGA of Plateau state were collected using standard methods. The samples were analyzed for gross alpha and beta activities using MPC – 2000-DP. The results obtained showed that the gross alpha activities in water ranged from (0.005 ± 0.004 – 0.456 ± 0.019) Bq/l with a mean value of 0.1059 ± 0.0087 Bq/l while the gross beta activities for the water samples ranged from (0.290± 0.009- 1.450 ± 0.047) Bq/l with a mean value of 0.723 ± 0.1335Bq/l. The gross alpha activities in soil samples ranged from (0.003± 0.001- 0.737 ± 0.132) Bq/g with a mean value of 0.1876 ± 0.0301 Bq/g and the gross beta activities ranged from (0.003± 0.004- 3.615 ± 0.003) Bq/g with a mean value of 0.3961 ± 0.0099 Bq/g. The committed effected doses for adults ranged from (0.001- 0.092) mS_V/yr with a mean value of 0.0216mS_V/yr while for children it ranged from (0.001-0.137) mS_V/yr with a mean value of 0.0316mS_V/yr. The committed effective doses to children and adults were compared with the WHO's standard limit of 0.1mSv/yr. The results indicated that location 3 had relatively high dose to children while other locations are within the standard limits. From the results obtained, 40% of the water and soil samples analyzed had their activity above the WHO's Standard Limits. This implies that the general public in the studied areas where their values are above the accepted limit may be exposed to radiation health risks.

Keywords: *Gross alpha; gross beta; mining area; committed effective dose; mining ponds.*

INTRODUCTION

Humans are exposed naturally to ionizing radiation from a number of sources which include cosmic rays and natural radionuclides in air, food and drinking water. Water is essential to life as the air breath by humans. Natural water is not completely free of radioactive isotopes due to the presence of beta and alpha emitters from the natural decay series of uranium, thorium and actinium and other isotopes such as ^{40}K (Ferdous, Rahman, & Begun, 2012).

Natural occurring radioactive materials (NORM) are frequently found in surface water supplies in Plateau State, Nigeria as a result of the natural geology of the area and the mechanized tin mining activities that has taken place in the area (Mangset, Yakubu, & Izam, 2009). Tin mining has a very long history in the Jos Plateau. It started in 1904 and by the mind-1920s more cassiterites (tin ores) discoveries had been made which resulted in more mechanized extraction techniques to meet the high demands of tin by 1960s-1970s. This in turn results in high generation of radioactive wastes (tailings) (James, & Edefatano, 2010). The activities of human and natural phenomena constantly pollute the source of water and affect water quality. Water pollution arises as a result of waste and sewage disposal into the environment and rivers by industries, hospitals and use of materials such as fertilizers by farmers. These disposed materials often contain radionuclides (Onoja, 2004). Human activities such as a mining, milling and processing of uranium ores and mineral sands, smelting of metallifererous ores, manufacture of fertilizer, drilling, transportation, processing and burning of fossil fuels have raised the concentrations of naturally occurring radioactive materials in the environment (Avwrri, & Ebeniro, 1998, Foland, Kirland & Vinnikoor, 1995, Pujol & Sanchez – Cabeza, 2000). In developing coutnries like Nigeria, lack of good drinking water is one of the serious threats to the human health as a result of that, rivers, streams, well and borehole waters are often used as supplement for the scarce pipe-borne water for drinking and domestic activities without any treatment (Shittu, Chifu, Abdulssalam & Hafeez, 2016). The dumping of large amount of waste materials in sites without adequate soil protection measures result in soil as well as surface and groundwater pollution (Eikel boom, Ruwiel & Gunmans 2001, Namasivayam, Adhika & Suba, 2001). Enhanced levels of these naturally occurring radionuclides might be present in the soil as well as surface and groundwater in areas that are rich in natural radionuclides. The soil acts as a source of transfers of radionuclides through the food chain depending on their chemical properties and the uptake process by the roots to plants and animals (Jabbar et al, 2010). Lead and Zinc are being mined extensively in Wase Local Government Area of Plateau State. The aim of this study is to assess the exposure of the host community to artificial and enhanced natural radioactivity in the environment by determining the gross alpha and beta activity in water and soil samples from different locations of mining area and estimate the committed effective dose to adults and children.

The study Area.

The area of sample collection is bounded between longitude $8^{0}51E$ to $8^{0}53E$ and latitude $9^{0}52N$ to $9^{0}58N$.

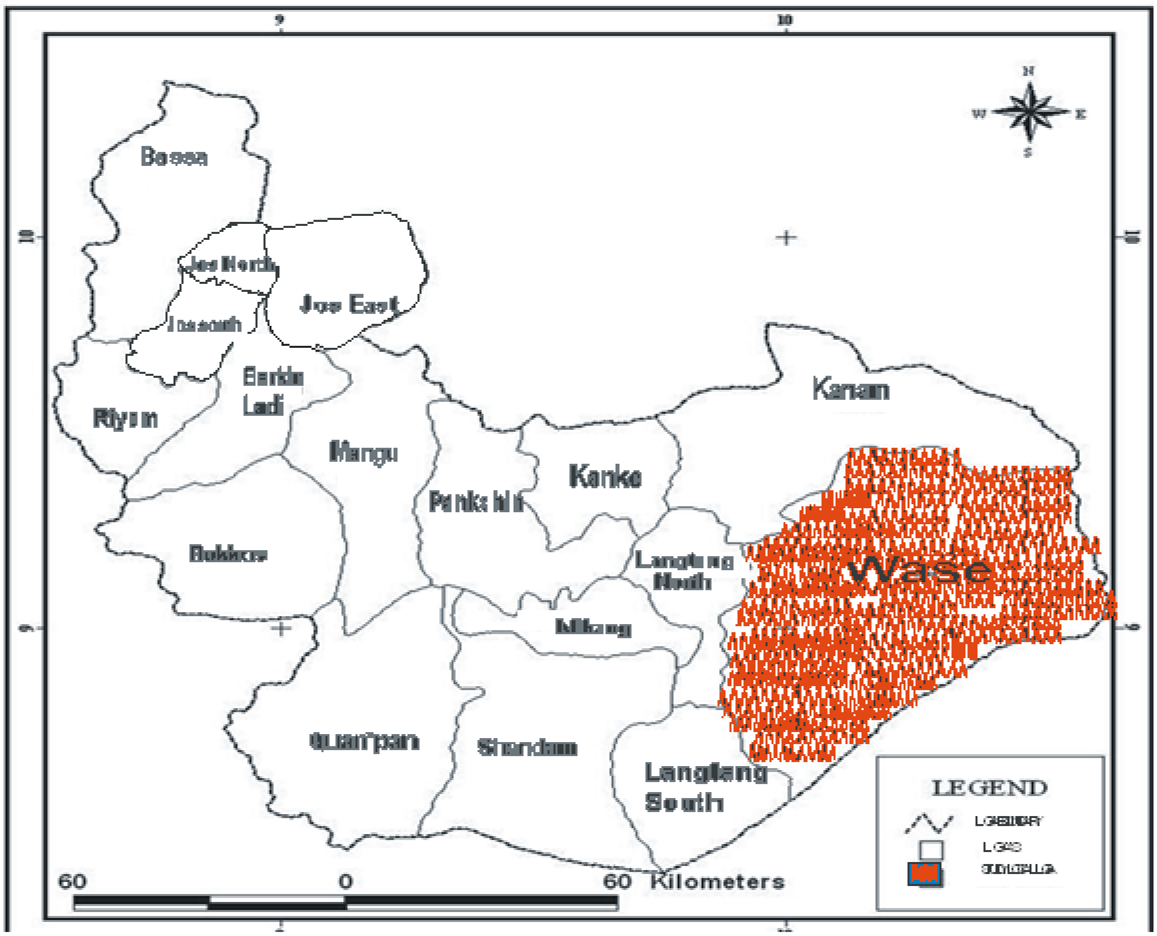

Figure 1: Map of the study Area

MATERIALS AND METHOD

Gas-flow Detector Dual Phosphor (counting system), Beakers (100-1500) ml, Graduated Measuring Cylinder, Ceramic Petri-dishes, Planchets, Spatulars, stirring rod, needle with syringe, cotton wool, detergent, hot plates, Infrared radiator, Analytical weighing Balance, Glass desiccator, Vinyl acetate, acetone and distilled or deionized water. In order to measure the gross Alpha and gross Beta radioactivity in waters, ten (10) water samples were collected randomly from different locations (the Zinc and Lead mining area of Kampani Zurak village). The choice of sampling locations was based on population density and accessibility. An Extrex garmin Globa18

Positioning System (GPS meter) was used to obtain coordinates and locations of the sampling points. The sample container was rinsed two times with the water being collected, to minimize contamination from original content of the sample container. Then 2 litres ($2.0 \times 10^{-3} m^3$) of water was collected such that an air space of about 1% of container capacity was left for thermal expansion. About 10ml of nitric acid were added to the samples (for preservation) immediately after collection. The sample was tightly covered, labelled and kept until analyses.

Soil Sample Collection

A total of Fifteen (15) soil samples were collected by random sampling method from the mine sites using Fifteen (15) pairs of surgical gloves to avoid contamination with each sample collected. The soil samples collected were tightly packed in nylon and labelled reflecting location and kept until analyses.

Water Sample Preparation

All apparatus- beakers, petri-dishes, planchet, spatulars, stirring rods, and syringes were washed and rinsed properly with distilled water and acetone respectively. A little quantity of the sample to be analyzed was used to rinse the beakers twice to ensure that cross contamination was avoided. 1000ml of the sample was measured and transfer into the beaker and placed on the hot plate. The hotplate was then switch on from the mains supply and the temperature controlled to below $100^{o}C$ to prevent the water sample from boiling in order to achieved the required residue. When the sample volume was substantially reduced to about 50ml, it was then transferred to an empty weighed petri-dish. The petri-dish with its contain were place on the hot plated for surface evaporation and drying to obtain the required residue. The weight of the petri-dish and the residue was measured again. The weight of the residue obtained from 1000ml of the sample evaporated was gotten by subtracting the weight of empty dish from the weight of the residue and the dish. The weight of residue require for measurement was 77mg (0.077g) and the weight exceeded this value according to literature only the 77mg of the residue was used for analysis. The residue i.e., 77mg (0.077g) was transferred into a sterilized planchette and weighed on the analytical balance.

Soil Sample Preparation

The soil samples were grounded manually with an agate mortar and pestle to obtain a homogenous powder to grain size of about 125µm. Pellets of 19mm diameter were prepared from 0.3g powder mixed with three (3) drops of organic liquid binder (toluene) and pressed at 10tons hydraulic press. After which was mounted on the counter for measurements.

Counting Analysis

The counting equipment is automated. The protocol involves entering present time, counting voltage and number of counting cycles. Also are the counter characteristics (efficiency and background) volume of sample used and sampling efficiency specified. Results were displayed as a raw count (count/min), count rate, activity and standard deviation. (Akpa T.C., Mallam S.P., Ibeanu I.G. & Onoja. 2004). The calculation formula for count rate activity and other parameters for a given sample are shown below

a) Count rate

$$\text{Rate } (\alpha+\beta) = \frac{rate(\alpha,\beta)count}{count - time} \quad (1)$$

b) Activity

$$\text{Activity } (\alpha,\beta) = \frac{rate(\alpha,\beta) - Bgd\ (\alpha,\beta)}{sample\ efficiency \times channel\ efficiency \times 100} \quad (2)$$

Estimation of Committed Effective Dose

The committed dose is based on the risk of radiation induced effects and the use of the International Commission on Radiological Protection (ICRP) metabolic model that provides relevant conversion factors to calculate effective doses from the total activity concentration of radionuclides measured.

The Committed Effective Dose (CED) over one year was calculated using formula (Fasae, 2013)

$$CED = IACX\ 365 \quad (3)$$

where I is the daily water consumption in one day, A is the alpha activity in Bq/L and C is the dose conversion factor for ingestion. For an adult, C = 2.8 X 10^{-4} msvBq^{-1}, while for children's C = 1.5 X 10^{-3} msvBq^{-1} for a given gross alpha and beta.

RESULTS AND DISCUSSION

The results of this study are shown and discussed below:

Table 1:The gross alpha and beta radioactivity in water in Kampani Zurak mining area of Wase L.G.A

S/No	Sample ID	Elevation (m)	Geographical coordinate	Alpha (∝) activity (Bq/L)	Beta (β) activity (Bq/L)
1.	Point 1	196	N 09^o 14'26.0'' E 010^{o}34'24.8''	0.092 ± 0.009	0.708± 0.023
2.	Point 2	182	N 09^o 14'25.0'' E 010^{o}34'18.2''	0.005 ± 0.004	0.352± 0.011
3.	Point 3	192	N 09^o 14'23.0'' E 010^{o}34'19.3''	0.456 ± 0.019	1.450± 0.047
4.	Point 4	190	N 09^o 13'47.4'' E 010^{o}34'21.5''	0.107 ± 0.004	0.290± 0.009
5.	Point 5	203	N 09^o 13'53.4'' E 010^{o}34'17.5''	0.041 ± 0.005	0.430± 0.014

6.	Point 6	215	N 09^o 13’53.2’’ E 010^{o}34’19.3’’	0.145 ± 0.007	0.619± 0.018
7.	Point 7	187	N 09^o 13’33.4’’ E 010^{o}34’52.5’’	0.128 ± 0.004	0.380± 0.012
8.	Point 8	189	N 09^o 14’32.5’’ E 010^{o}34’55.5’’	0.068 ± 0.027	1.270± 0.870
9.	Point 9	176	N 09^o 14’21.0’’ E 010^{o}34’25.2’’	0.011 ± 0.006	0.758± 0.247
10.	Point 10	172	N 09^o 14’35.0’’ E 010^{o}34’42.0’’	0.006 ± 0.002	0.973± 0.084
Average				0.1059 ± 0.0087	0.723 ± 0.1335
WHO Limits				0.1	1.0

Table 2

The gross alpha and beta radioactivity in soil in Kampani Zurak mining area of Wase L.G.A

S/No	Sample ID	Elevation (m)	Geographical coordinate	Alpha (∝) activity (Bq/g)	Beta (β) activity (Bq/g)
1.	Point 1	196	N 09^o 14’26.0’’ E 010^{o}34’24.8’’	0.268 ± 0.02	0.072 ± 0.004
2.	Point 2	182	N 09^o 14’25.0’’ E 010^{o}34’18.2’’	0.079 ± 0.002	1.170 ± 0.009
3.	Point 3	192	N 09^o 14’23.0’’ E 010^{o}34’19.3’’	0.094 ± 0.002	0.269 ± 0.007
4.	Point 4	190	N 09^o 13’47.4’’ E 010^{o}34’21.5’’	0.072 ± 0.002	0.084 ± 0.005
5.	Point 5	203	N 09^o 13’53.4’’ E 010^{o}34’17.5’’	0.069 ± 0.002	0.003 ± 0.004
6.	Point 6	215	N 09^o 13’53.2’’ E 010^{o}34’19.3’’	0.004 ± 0.001	0.054 ± 0.003
7.	Point 7	187	N 09^o 13’33.4’’ E 010^{o}34’52.5’’	0.156 ± 0.001	0.024 ± 0.003
8.	Point 8	189	N 09^o 14’32.5’’ E 010^{o}34’55.5’’	0.069 ± 0.001	0.027 ± 0.004

9.	Point 9	176	N 09^{o} 14'21.0'' E 010^{o}34'25.2''	0.058 ± 0.001	0.087 0.003
10.	Point 10	172	N 09^{o} 14'35.0'' E 010^{o}34'42.0''	0.012 ± 0.001	0.053 ±0.003
11.	Point 11	209	N 09^{o} 14'51.1'' E 010^{o}34'23.1''	0.737 ± 0.132	0.129 ± 0.003
12.	Point 12	170	N 09^{o} 14'25.4'' E 010^{o}34'52.5''	0.468 ± 0.10	0.125 ± 0.010
13.	Point 13	223	N 09^{o} 14'45.0'' E 010^{o}34'53.1''	0.072 ± 0.001	3.615 ± 0.003
14.	Point 14	210	N 09^{o} 14'25.4'' E 010^{o}34'53.7''	0.653± 0203	0.193 ± 0.003
15.	Point 15	192	N 09^{o} 14'32.1'' E 010^{o}34'43.5''	0.003 ± 0.001	0.037 ± 0.004
Average				0.1876 ± 0.0301	0.3961±0.0099
WHO Limit				0.1	1.0

Table 3:
The estimated effective dose for the water sample of lead and zinc mining area in KampaniZurak

S/No	Sample ID	Dose Limits of Adults (mSv/yr)	Dose Limits of Children (mSv/yr)
1.	Point 1	0.019	0.027
2.	Point 2	0.001	0.001
3.	Point 3	0.093	0.137
4.	Point 4	0.022	0.032
5.	Point 5	0.008	0.012
6.	Point 6	0.030	0.044
7.	Point 7	0.026	0.038
8.	Point 8	0.014	0.020
9.	Point 9	0.002	0.003
10.	Point 10	0.001	0.002

Average	**0.0216**	**0.0316**
WHO Limit	**0.1**	**0.1**

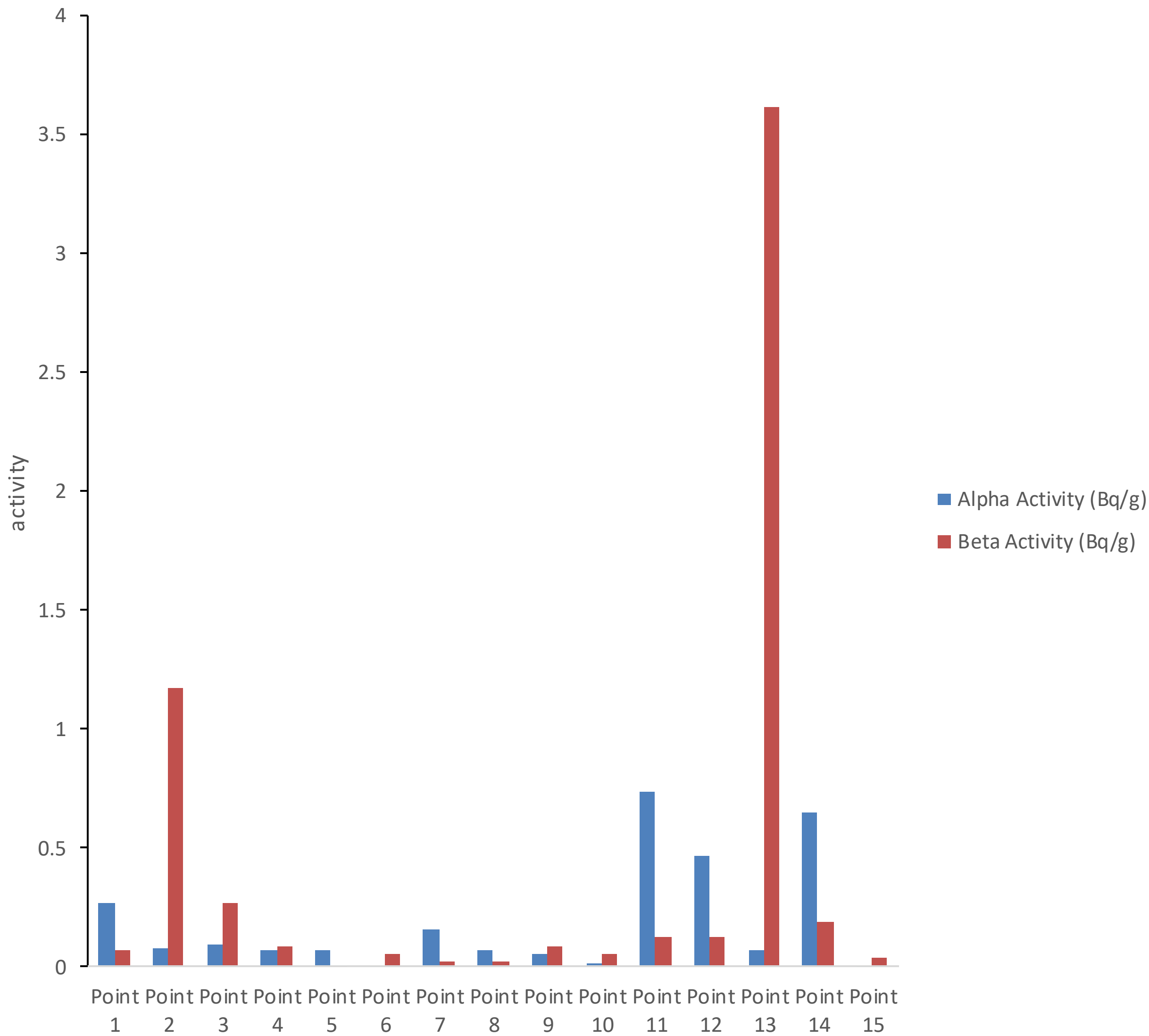

Fig 4 Bar charts representing the gross alpha and gross beta in water of lead and zinc mining area of Kampani Zurak.

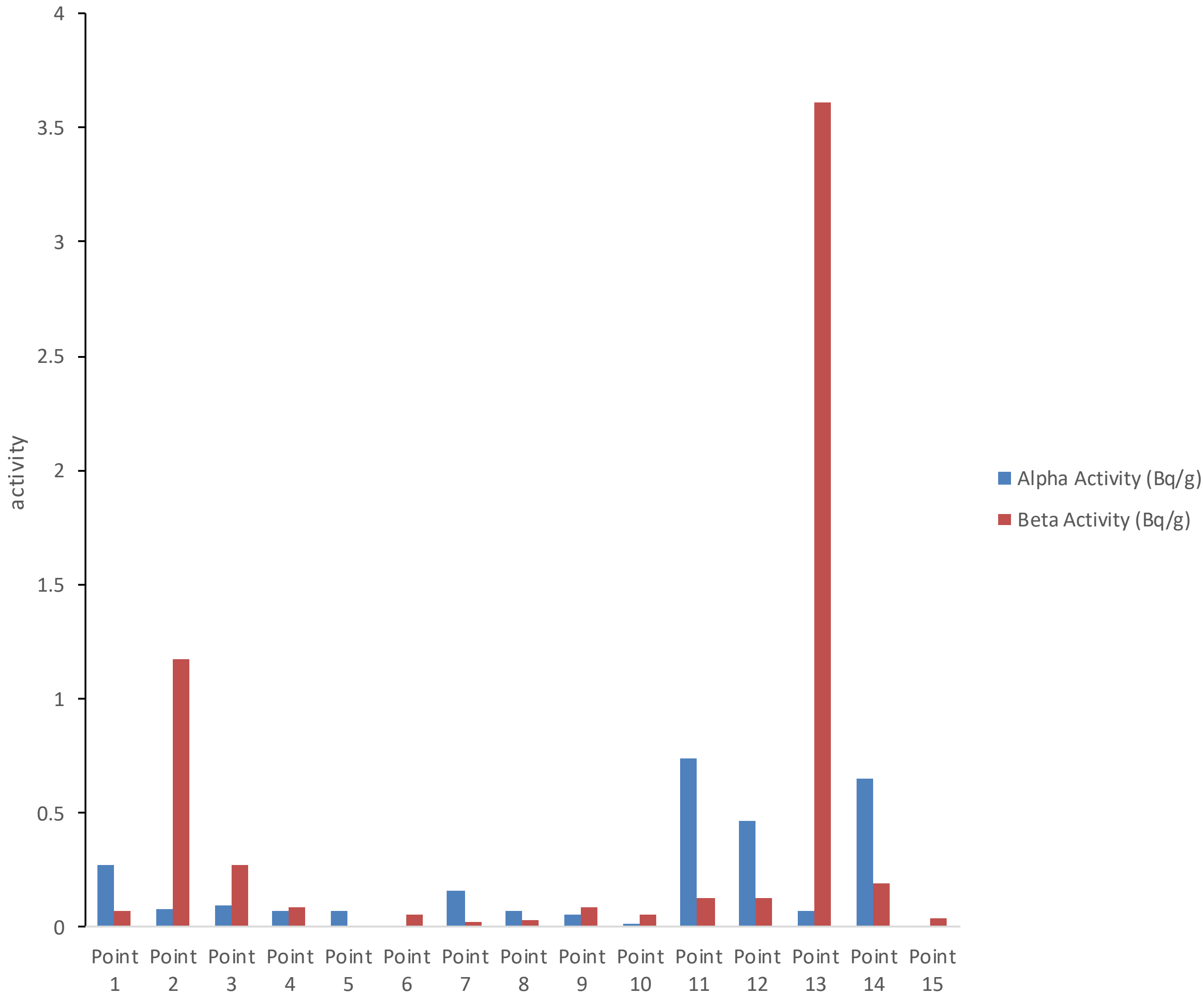

Fig 5 Bar chart representing the gross alpha and gross beta in soil sample of Kampani Zurak.

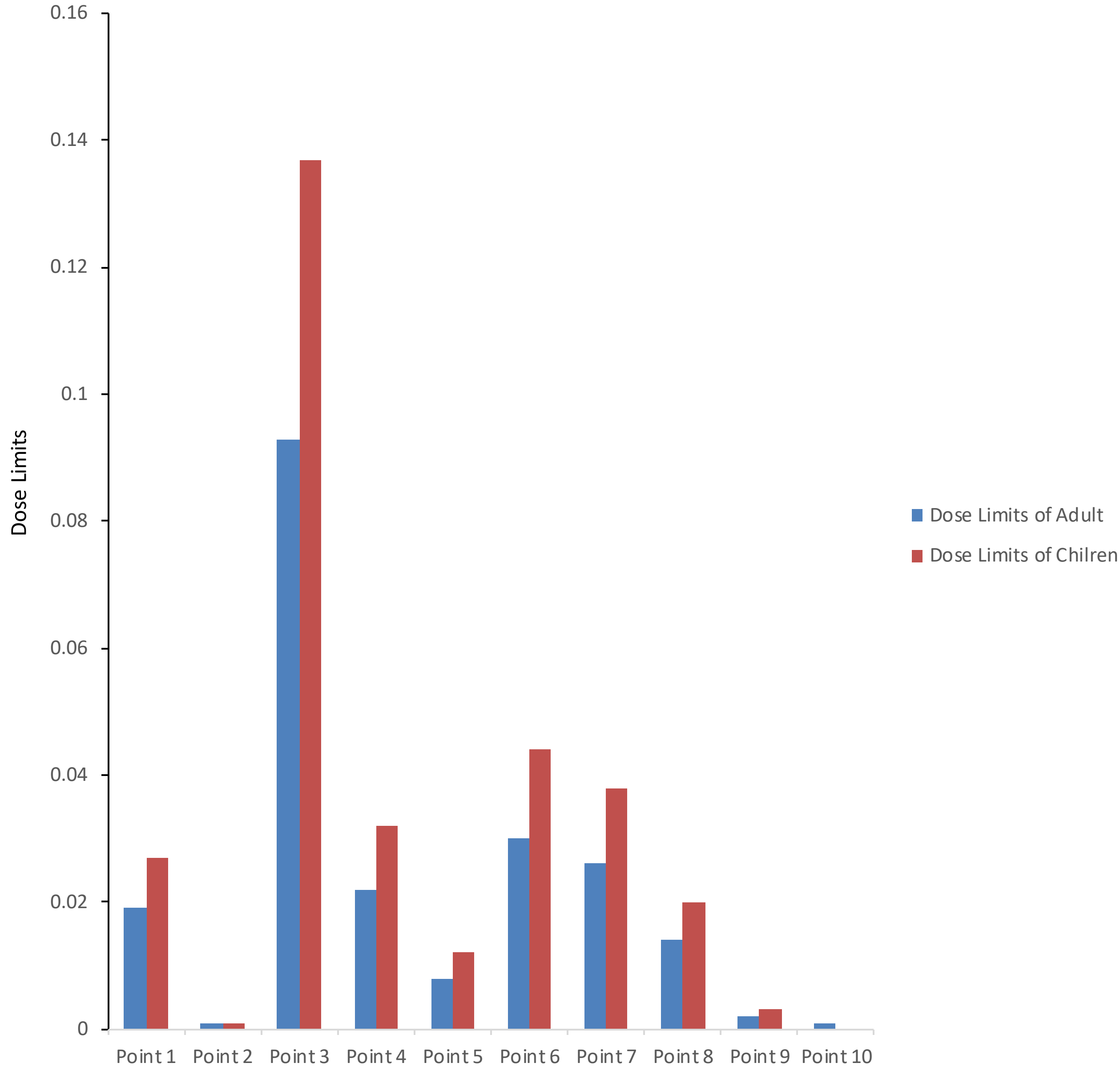

Fig 6 Bar chart representing the estimated effective dose in adults and children in water of lead and zinc mining area of Kampani Zurak

Tables 1 and 2 shows the gross alpha and beta activities in water and soil samples in Kampani Zurak mining area of Wase LGA. Tables 3 and 4 presents the summary of gross alpha and beta activities in water and soil samples respectively in Mining area of Kampani Zurak and table 5 show the estimated effective dose for the water sample of the mining area. From the estimated effective dose for the water, the effective dose for alpha ranged from 0.001mSv/yr to 0.093mSv/yr with the mean of 0.0216mSv/yr for an adult while the values for children ranged from 0.01mSv/yr to 0.137mSv/yr with the mean value of 0.0316mSv/yr.

Gross alpha activity in the water ranges from 0.005 ± 0.004 Bq/L for point 2 to point 3 where the activity is 0.456 ± 0.019 Bq/L with the mean of 0.1059±0.0087 Bq/L The beta activity concentration ranges from 0.290 ± 0.009 Bq/L for point 4 to 1.450 ± 0.047 Bq/L. for point 3 with a mean value of 0.723 ± 0.1335 Bq/L. The alpha activity concentrations in all the water samples examined are within the practical screening level of 0.1 Bq/L except for samples collected from point 3, 6 and 7 which are slightly above it. The average values (gross alpha) of the water were calculated to be 0.1059 ± 0.0087. The beta activity values for two (2) of the ten (10) samples analyzed i.e point three (3) and eight (8) were above the recommended WHO Limit of 1.0 Bq/L. In other words of all the ten (10) water samples analyzed, only two (point 3 and 8) were above the recommended WHO Limit of 1.0 Bq/L and eight (8) were within the screening level. The average beta activity in all the water samples analyzed was calculated to be 0.723 ± 0.1335 which is within the recommended practical screening level of drinking water 1.0 Bq/L sect by WHO (WHO, 2003). This high level of beta activity in the two points may suggest the presence of pollutants of anthropogenic origin as screening for beta activities in the environment is screening for artificial or anthropogenic radionuclides (Ezekiel, *et al.,* 2013). Such pollutants in the lead and zinc mining area could be the mining tailings. Gross alpha activity in the soil ranges from 0.003 ± 0.001Bq/g to 0.737 ± 0.132Bq/g. the beta activity concentration ranges from 0.003 ± 0.004Bq/g to 3.615 ± 0.003Bq/g.

The alpha activity concentrations in all the soil samples examined were within the practical screening level of 0.1 Bq/g except for samples collected from point 1, 7, 11, 12 and 14 which were above the practical screening level of 0.1 Bq/g. The mean gross alpha activity was calculated to be 0.1876 ± 0.0301 which is slightly above the 0.1 Bq/g limit. The high alpha activity could be attributed to the geological formation of the area because of the shale and limestone (Pindiga formation) that are in such area. The beta activity concentrations in all the soil samples examined were within the practical screening level of 1.0 Bq/g except for sample collected from point 2 and 13. The average value (gross beta) of the soils were calculated to be 0.3961 ± 0.0099 less than the 1.0 Bq/g limit set by the WHO.

CONCLUSION

This study measured the gross alpha and gross beta activity concentrations in water and soil and also estimated the committed effective dose in surface water in Zinc and lead mining area of Kampani Zurak in Plateau State. The gross alpha and beta activity concentrations in surface soil and water vary in quantity from one location to the other. The estimated committed effective dose intake for children and Adults also showed variation between the sources. The enhanced radionuclides concentration levels observed in some points/locations can be attributed to the radionuclides exposed during mining. We conclude that the high radioactivity levels observed in some locations in the study area have been influenced by mining activities and the indiscriminate disposal of mine tailings without following laid down regulations for this purpose. It is therefore recommended that areas with very high activity concentrations should not be used for drinking, agricultural or recreational activities by the host communities. Further investigation of the concentrations of the individual radionuclides responsible for the gross activities is recommended.

ACKNOWLEDGEMENTS

The researchers wish to express their appreciation to staff and management of Kampani Zurak, Community Leaders and Staff and Management of Centre for Energy Research and Training, Zaria their cooperation and support during the collection and analysis of the research samples.

REFERENCES

Akpa, T.C. Mallam, S.P Ibeanu, I.G. & Onoja, R.A.(2004). Characteristics of Gross Alpha/Beta Proportional Counter. *Nigerian of Journal of physics*, 16 (1): 13-18.

Avwiri, G.O. & Ebeniro, J.O. (1998). External environmental Radiation in an Industrial Area of Rivers State. *Nigeria Journal of Physics*, 10: 105-107.

Eikelboom, R.T., Ruwiel, E. & Gounmans, J.J.J.M (2001). The Building materials decree. An example of a dutch regulation based on the potential impact of materials on the environment. *Waste management*, 21(3).

Fasae, K.P. (2013). Effective dose due to intake of groundwater in Ado-Ekiti metropolis; the capital city of Ekiti state, south western Nigeria. *Journal of Natural Sciences Research. 3(12).*

Ferdous, M.J. Rahman, M.M & Begum, A. (2012). Gross Alpha and Gross Beta Activities of Tap water Samples from different locations of Dhaka city Sri Lankan. *Journal of Physics* 13(1): 1-8.

James, D.G. & Edefatano C.A.(2010). Effects of mining on water quality and the environment. A case study of parts of the Jos Plateau, *North Central Nigeria Pacific Journal of Science and Technology*, 11 (1): 631 – 639.

Mangset, W.E., Yakubu, I. & Izam M.M (2009). Alpha and Beta radioactivity in mining ponds, wells and stream water in Bisichi. *Journal of Environmental Sciences,*13 (1): 98 -103.

Mangset, W.E., Christopher, L.D., Solomon, A.O., Ike, E.E., Mallam, S.P & Onoja, R.A (2014). Gross Alpha and beta Radioactivity Concentrations and Estimated Committed Effective Dose to the general public due to intake of Groundwater in mining areas of Plateau State, North Central Nigeria". *Advances in physics theories and applications*, 38, 30-38.

Onoja, R.A.(2004). *Survey of Gross Alpha and Beta Radioactivity in well water form Zaria Area*. Unpublished M.Sc Thesis, Ahmadu Bello University, Zaria, Nigeria .

Shittu, A., Chifu, E.N., Abdulssalam, B.S. & Hafeez, Y.H.(2016). Evaluation of Radioactivity concentration in drinking water collected from local wells and boreholes of Dustse town, north west, Nigeria. *International Journal Environmental monitoring and analysis*, 4(1): 6-11.