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Gross Alpha and Beta Radioactivity in Soil and Sediment around Selected Mining Sites of Kogi State, Nigeria

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Abstract The mean gross alpha and beta activities in soil and sediment around selected mining sites in Ike Kabba (gold), Ayedayo (feldspar-mica), Obajana (limestone), Itakpe (iron ore) and Okobo (coal) of Kogi State, Nigeria have been studied using Protean Instrument Corporation (PIC) MPC 2000DP. The average activities for gross alpha in soil obtained are 33.52±8.20Bq/kg (gold), 32.2±8.0Bq/kg (feldspar-mica), 12.94±6.88Bq/kg (limestone), 29.16±8.32Bq/kg (iron ore) and 25.92±7.52Bq/kg (coal). The average activities for gross beta in soil obtained are 65.6±11.88Bq/kg (gold), 67.02±11.84 Bq/kg (feldspar-mica) 14.26±9.62Bq/kg (limestone), 49.38±11.74Bq/kg (iron ore) and 69.76±11.88Bq/kg (coal). The average gross alpha activities in sediment ranged from 15.48±6.9 Bq/kg to 35.1±8.35Bq/kg (gold) while the average activities for gross beta ranged from 37.44±10.54Bq/kg to 43.85±10.98Bq/kg (coal). The average activity concentrations of gross alpha and beta in soil and sediment were compared with other literature values and correlations were made to determine direct relationships in the investigated samples.

Keywords: *gross alpha and beta, radioactivity, mining sites, soil, sediment, risk analysis*

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1. Introduction

Gross alpha and beta activity measurements in environmental samples such as soil, sediment and water have received increasing importance in recent years. The significance of this measurement is due to the concern that elevated levels of beta radiation may be a sign of radioactive contamination of the environment that results in exposure of humans [1]. Naturally occurring radio nuclides might be present at enhanced levels in the soil as well as surface and groundwater in areas that are rich in natural nuclides [2].

About 96% of the total radiation dose come from natural sources which exist in various geological formations such as soil, rocks, sediment, water, vegetation and air while 4% is from artificial source [3]. Rocks and soil significantly contribute to indoor and outdoor exposure to environmental radioactivity by gamma radiation emitting from Radium 226, Uranium 238, Thorium 232, Potassium 40 and beta radiation which increase the human health risk [2].

The alpha and beta contributor are members of the uranium and thorium decay series. Radon and two of its disintegration decay products, Polonium 218 and Polonium 214, are sources of alpha radiation. Thoron also has two beta-decay products, Lead 214 and Bismuth 214. Radionuclides from the Thorium 232 and Uranium 238 series are responsible for the majority of the alpha and beta activity concentrations. For beta activity concentration, some contribution could be from Potassium 40 [4].

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 [2].

Low radioactivity in lake and sediments are generally due to presence of uranium in disequilibrium with its daughters. The ocean and sediments serve as important reservoir and redistribution systems for radionuclides [5].

The knowledge of various concentrations in soil serves as a basic indicator of the distribution and accumulation of radioactivity in the environment and provides useful information in the monitoring of environment radioactivity [3].

The specific levels are related to the type of rock from which the soil originates. Higher radioactivity levels are associated with igneous rock such as granite and lower levels in sedimentary rocks although exceptions are recorded in some shales and phosphate rocks to have relatively high content of radionuclides. Among the natural radionuclides, alpha and beta emitters are considered the most important with respect to potential internal radiation exposure to humans particularly through ingestion of food and water [6].

Several gross alpha and beta studies have been carried out in the world in different geological formations [4,7,8] and in Nigeria [9-13] to obtain reference data for natural environmental radioactivity.

Kogi State is a state endowed with various mineral resources such as coal, iron ore, limestone, tin, feldspar, gold and they are primarily farmers [15]. Some wastes from mining sites which are particulate in nature could find their way into nearby rivers and sediments play important role in aquatic radioecology because they accumulate and transport contaminants such as (radioactivity and heavy metal) within the geographical area [8] or dispersed through air into nearby farms. Farm produce such as maize, cassava, yam, rice and cashew are the principal cash crops produced in these environment [15] and they could absorb theses radioactive elements either from the soil or through its leaves. These contaminated crops when eaten by animals or humans get into the body and could be hazardous depending on the type of radioactive element present, the rate of consumption of these food/ water products or the extent to which the food/water have been contaminated [2]. There is need to estimate the radiation hazard due to soil and sediment radionuclides in this selected mining sites due to anthropogenic activities and the possible radiological risks on the mine workers and population.

2. Materials and Methods

2.1. Study Area

The study areas are located in selected mining sites in Obajana of Lokoja local government, Ike of Kabba local government, Okobo of Ankpa local government, Ayedayo/Ayedera of Mopa local government and Itakpe of Okehi local government which is located between longitudes 5̊ 40E and latitudes 7̊ 49E and 6̊ 33N and 8̊ 44N within the central region of Nigeria [16]. Geologically, the area in Fig. 1 belongs to the upper Cretaceous formation of the Anambra Basin with a stratigraphic succession of false bedded sandstone, lower coal measures, and Enugu shale [17]. Minerals such as gold, feldspar, tantalite, limestone, tourmaline, mica, coal, granite, gemstone, marble and iron ore which are mined in artisanal and commercial quantity in Kogi State daily [18,19].

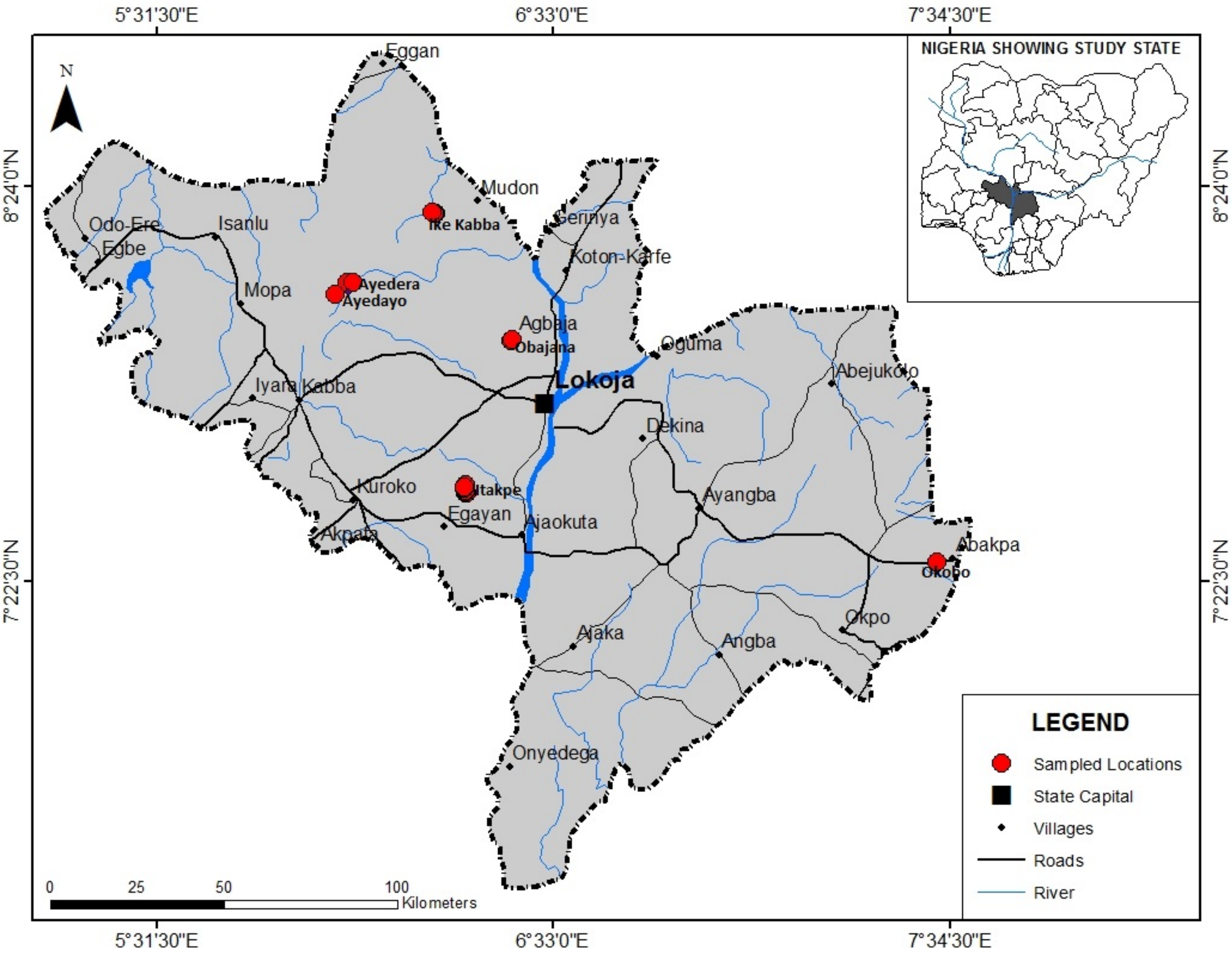

Figure 1. Map of Study Area

2.2. Sample Preparation and Radioactivity Counting

A total of 39 samples were collected; 20 soil samples, 5 soil control samples, 5 mineral samples from host rock samples and 9 sediment samples around selected mining sites of Kogi State, Nigeria. Both soil and sediment samples were placed in a black nylon bag and labelled accordingly.

Two well calibrated radalert 100 and digilert 200 nuclear radiation monitors (S.E. International Incorporation, Summer Town, USA) with a capability of measuring alpha, beta, gamma and x-ray radiation within the temperature range of -10°C to 50°C were used to measure dose rate of selected mining sites 1m above the ground.

The samples were air dried and initially sieved with sieved a 2mm mesh sieve to remove stones and foreign materials. The samples were dried again in an electric oven at a temperature of <80°C overnight until its moisture content was lost [2] and crushed into a fine powder. The samples were weighed and hermetically sealed in Marinelli beaker. The samples were carefully processed following standard.

The samples were analysed for gross alpha and beta activities using Protean Instrument Corporation (PIC) MPC 2000DP available at the Centre for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria. This equipment was calibrated with Sr-90 a beta source and Pu-239 an alpha source. This instrument had a reported calibration results of detector efficiency (alpha=87.95%; beta=42.06%), detector background (alpha =0.50cpm; beta=0.73cpm and detection limit (alpha= 0.21cpm; beta= 0.22cpm). Each sample was counted three times and the mean used in computing the activity. The operational modes used for the counting were the α-only mode for the alpha counting and the β $(+\alpha)$ mode for the beta counting. The count rate of each sample was automatically processed by the computer using the equation 1 [14]

$$C_{(\alpha,\beta)} = B_{(\alpha,\beta)} \times 60T^{-1} \quad (1)$$

Where $C_{(\alpha,\beta)}$ is the count rate (cpm) of the alpha and beta particles, $B_{(\alpha,\beta)}$ is the background count of alpha and beta particles, T is the counting time (2700 secs or 45 mins).

The activity of reach of the samples was calculated using equation 2

$$A_{(\alpha,\beta)} = \left(C_{(\alpha,\beta)} - G_{(\alpha,\beta)}\right) \times \frac{U_{(\alpha,\beta)}}{H_{(\alpha,\beta)} \times S_{(\alpha,\beta)} \times V} \quad (2)$$

where $A_{(\alpha,\beta)}$ is the alpha and beta activity (Bq/kg), $C_{(\alpha,\beta)}$ is the count rate of alpha and beta particle, $G_{(\alpha,\beta)}$ is the background count rate of the alpha or beta particle, U is the unit coefficient of alpha and beta particle (1.67×10^{-2}) conversion factor from cpm to cps (1 cps =1 Bq), $H_{(\alpha,\beta)}$ is the channel efficiency for alpha or beta counting, $S_{(\alpha,\beta)}$ is the sample efficiency for alpha or beta counting and V is the sample mass [14].

3. Results and Discussions

The mean gross alpha and beta activity concentrations for soil and sediment is presented in the Tables below.

Table 1. Result of gross alpha and beta activity concentration of soil samples from mining field (Bq/kg)

SAMPLE CODE	GROSS ALPHA ACTIVITY (Bq/Kg)	GROSS BETA ACTIVITY (Bq/kg)
IKESO1 GOLD	20.6±6.8	26.6±9.1
IKESO2	14.9±7.0	38.4±10.9
IKESO3 (MINERAL ROCK)	39.8±8.7	64.1±12.0
IKESO4	42.3±8.9	75.2±12.6
IKESO5	50.0±9.6	123.7±14.8
MEAN (CONTROL IKESO)	33.52± 8.2(56.6±10.7)	65.6± 11.88(81.0±14.5)
MSO1 FELDSPAR	41.1±8.7	70.7±12.2
MSO2	38.1±8.4	59.4±11.4
MSO3 (MINERAL ROCK)	23.4±7.3	83.3±12.5
MSO4	23±7.2	50.6±10.9
MSO5	35.4±8.4	71.1±12.2
MEAN(CONTROL MSO)	32.2±8.0(32.9±8.2)	67.02±11.84(22.6±9.7)
OBSO1 LIMESTONE	4.0±6.2	18.9±9.9
OBSO2	7.9±5.9	11.6±8.6
OBSO3 (MINERAL ROCK)	8.8±6.6	15.1±9.8
OBSO4	23.4±7.6	6.8±8.9
OBSO5	20.6±8.1	18.9±10.9
MEAN(CONTROL OBSO)	12.94±6.88 (31.0±8.4)	14.26±9.62 (56.9±12.1)
ITASO1 IRON ORE	47.3±11.7	98.9±17.5
ITASO2	24.8±7.7	29.4±10.2
ITASO3 (MINERAL ROCK)	19.9±6.7	33.5±9.5
ITASO4	26.8±8.0	28.6±10.5
ITASO5	27.0±7.5	56.5±11.0
MEAN(CONTROL ITASO)	29.16±8.32 (38.8±8.5)	49.38±11.74 (55.9±11.4)
ANSO1 COAL	37.7±8.2	92.3±12.7
ANSO2	19.1±6.9	56.811.2
ANSO3 (MINERAL ROCK)	16.4±6.8	29.2±9.8
ANSO4	37±8.7	103.9±14.0
ANSO5	19.4±7.0	66.6±11.7
MEAN (CONTROL ANSO)	25.92±7.52 (14.4±6.2)	69.76±11.88 (41.9±9.9)

Table 2. Result of gross alpha and beta activity concentration of sediment samples from mining field (Bq/kg)

SAMPLE CODE	GROSS ALPHA ACTIVITY(Bq/kg)	GROSS BETA ACTIVITY (Bq/kg)
IKSE1 GOLD	15.4±7.0	52.8±11.4
IKSE2	20.4±7.1	27.4±9.6
IKSE3	5.3±6.4	41.4±11.3
IKSE4	15.8±7.0	34.0±10.5
IKSE5	20.5±7.1	31.6±9.9
MEAN FOR GOLD	15.48±6.92	37.44±10.54
ANSE1 COAL	50.0±9.6	33.7±10.9
ANSE2	28.4±7.4	54.9±10.7
ANSE3	19.4±7.3	67.9±12.2
ANSE4	42.6±9.1	18.9±10.1
MEAN FOR COAL	35.1±8.35	43.85±10.98

The gross alpha activities for samples ranged from 14.9±7.0 to 50.0±9.6Bq/kg (gold), 23±7.2 to 41.1±8.7Bq/kg (feldspar-mica), 4.0±8.7 to 23.4±7.6Bq/kg (limestone), 19.9±6.7 to 47.3±11.7Bq/kg (iron ore) and 16.4±7.0 to 37.7±8.2Bq/kg (coal) while the gross beta activities of 26.6±9.1 to 123.7±14.8Bq/kg (gold), 50.6±10.9 to 83.3±12.5Bq/kg (feldspar-mica), 6.8±8.9 to 18.9±12.2Bq/kg (limestone), 28.6±10.5 to 98.9±17.5Bq/kg (iron ore) and 29.2±9.8 to 103.9±14.0Bq/kg (coal).

There is no regulatory standards for radiological contaminants in soils or sediments that can be used for direct comparison with data obtained in this study unlike drinking water [5]. The mean gross alpha and beta result in coal mining field was higher than the soil control value from the host community Okobo while the gross alpha and beta soil control values in other communities namely Ike Kabba, Ayedayo, Obajana and Itakpe was observed to be higher than the mean gross alpha and beta activities in the mining field as shown in Figure 2 – Figure 3. It could be as a result of contamination of the environment from anthropogenic activities.

In this present study, the mean gross alpha and beta activities in soil are lower than the reported values within selected oil producing fields in Rivers State, Nigeria which was attributed to incessant oil spillages in the surveyed area. The values ranged from 152.11±61.67 to 322±121.67 Bq/kg for alpha activity and 311.15±83.3 to 615.5±178.38 Bq/kg for beta activity [20]. The mean gross alpha activity values in this present work agreed favorably with the values recorded from surface soil around steel processing facility and selected mining sites in Benue State Nigeria [2,14] respectively while the gross beta activity obtained in this present work was lower than the values recorded in [2,14] which is as a result of recycling activities of Delta steel company in the area and mining activities in the mineral deposition fields respectively. [21] in their study of gross alpha and beta activity concentrations in sediments in gulf of Izmir (eastern Aegean Sea, Turkey) recorded ranges from 537±77 to 1800±2017Bq/kg and 993±60 to 1842±102Bq/kg for alpha and beta activities respectively which are higher than obtained values in this work. The high values were attributed to geological features of the sea and content of mineral substances.

Figure 4 - Figure 5 shows correlation between alpha and beta activity concentrations and dose rate which were found to be 10% and 0.1% variation respectively at Ike Kabba. Figure 6 - Figure 7 showed 32% and 8% variation for correlation of alpha and beta against dose rate of Apala River in Ike Kabba respectively. These results implies a weak correlation between the dose rate and alpha and beta activity concentrations and it is an indication that the concentrations of gross alpha and beta activities are not linearly related, rather the distribution is scattered. Figure 8 - Figure 9 shows correlation between alpha and beta activity concentrations and dose rate at Ayedayo. There is weak variation of 9% for the alpha activity concentration and a strong variation of 76% for the beta activity concentration. Figure 10 - Figure 11 shows the correlation between alpha and beta activity concentration and dose rate at Obajana. The result showed a weak variation of 27% for the alpha activity concentration and strong variation of 84% for the beta activity concentration. These results suggests that there are higher beta emitting radionuclides than alpha emitters. By measuring dose rate at Itakpe and correlating it with alpha and beta activity concentration as shown in Figure 12- Figure 13, 5% and 4% variation was recorded for alpha and beta activity concentration respectively which is a weak. Figure 14 - Figure 15 shows a weak variation of 19% respectively between alpha and beta activity concentration and dose rate at Okobo.

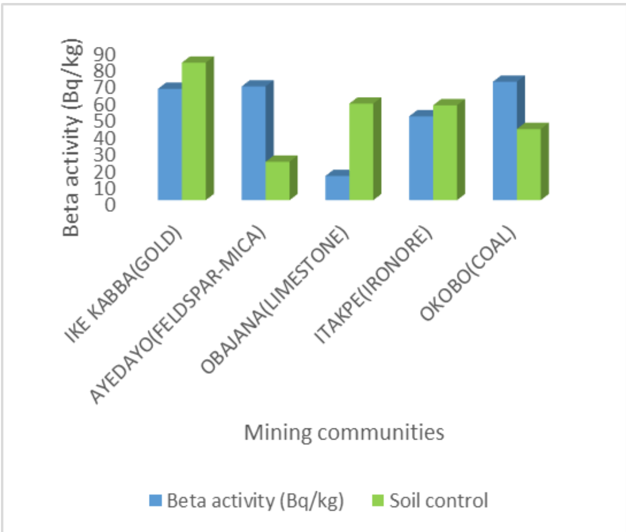

Figure 2. Comparison of mean alpha activity with soil control (Bq/kg)

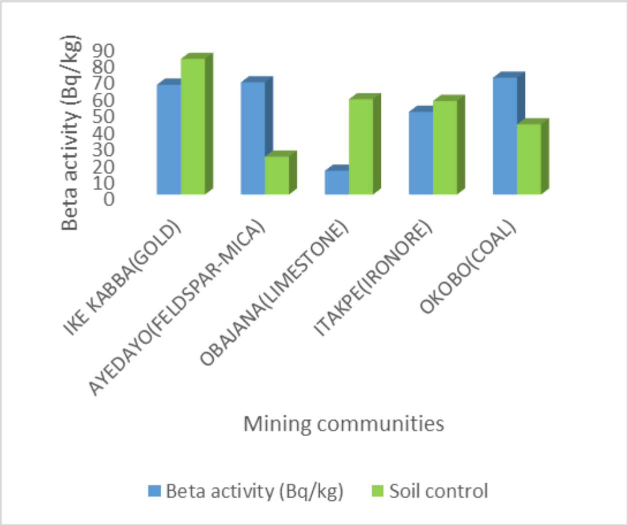

Figure 3. Comparison of mean beta activity with soil control (Bq/kg)

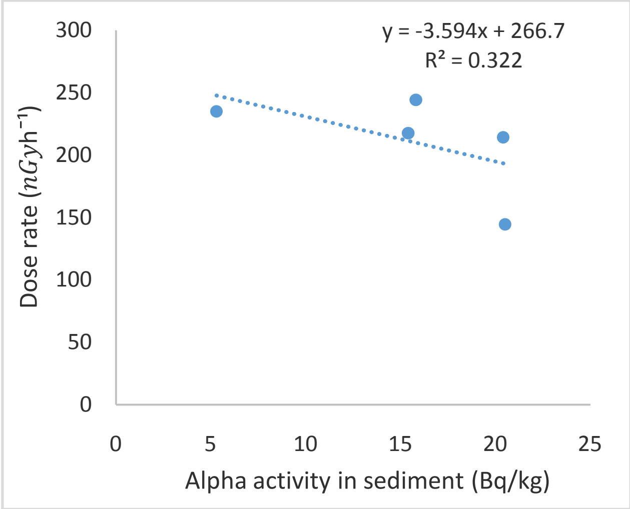

Figure 6. Correlation between gross alpha activity concentration and dose rate in Ike kabba (sediment)

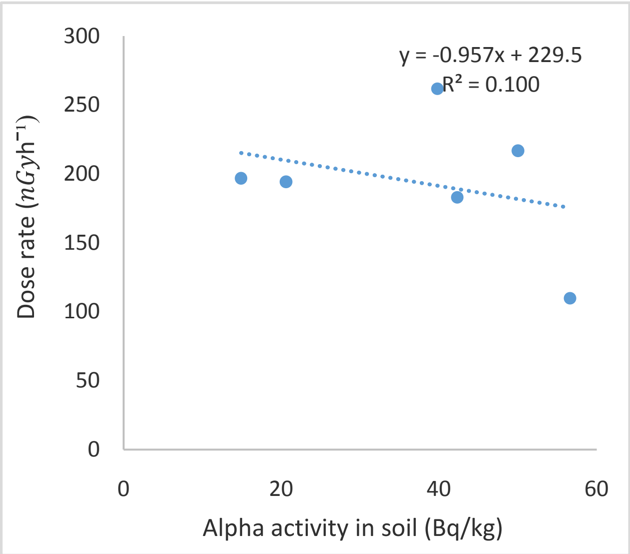

Figure 1. Correlation between gross alpha activity concentration and dose rate in Ike kabba

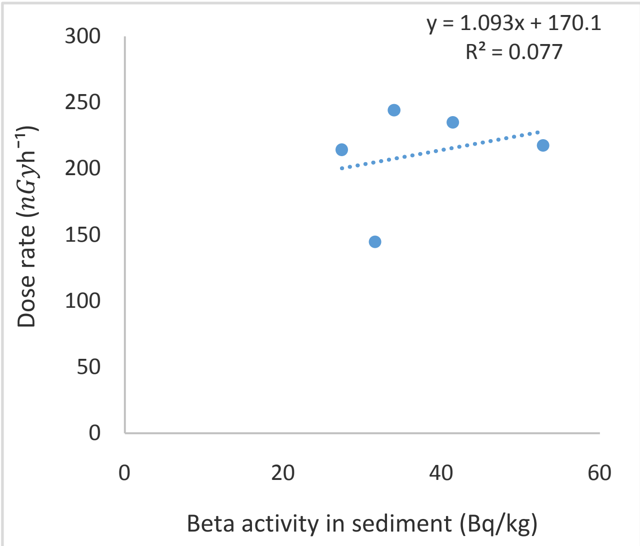

Figure 7. Correlation between gross beta activity concentration and dose rate in Ike Kabba (sediment)

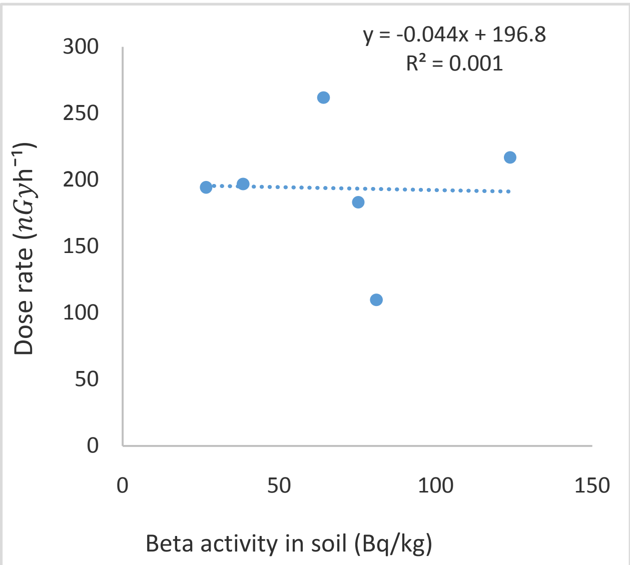

Figure 5. Correlation between gross beta activity concentration and dose rate in Ike Kabba

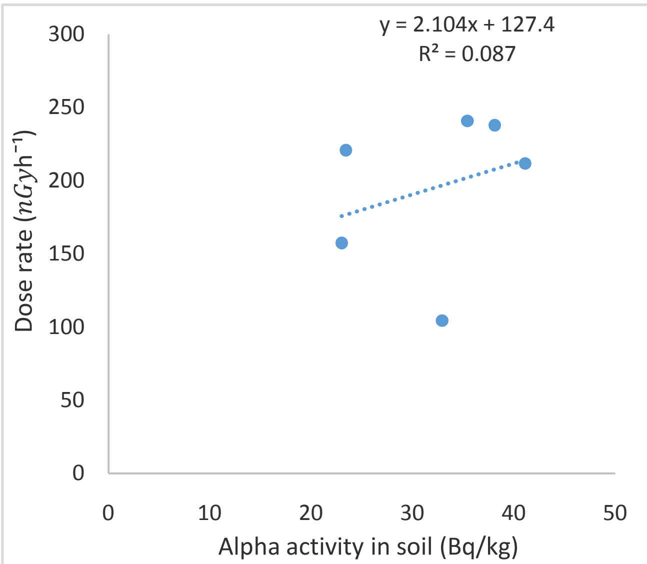

Figure 8. Correlation between gross alpha activity concentration and dose rate in Ayedayo

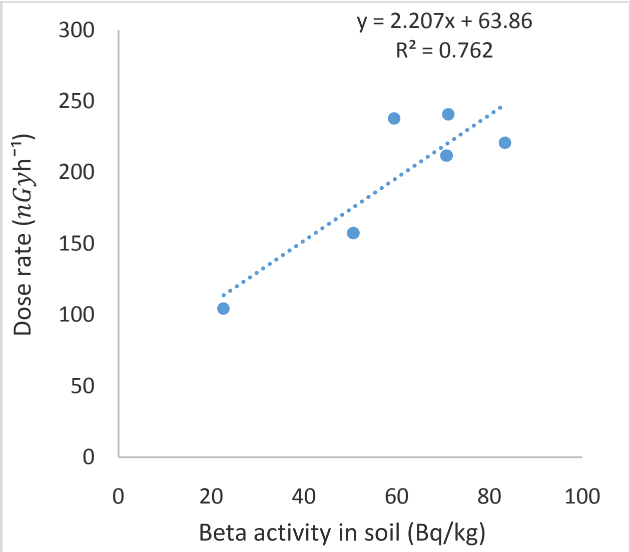

Figure 2. Correlation between gross beta activity concentration and dose rate in Ayedayo

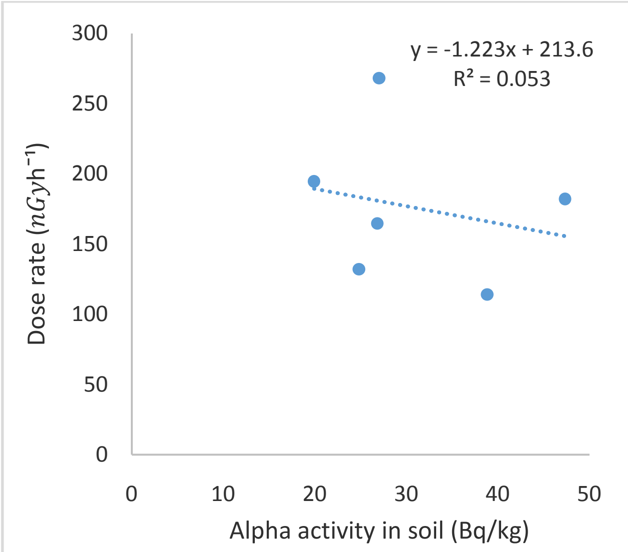

Figure 12. Correlation between gross Alpha activity concentration and dose rate in Itakpe

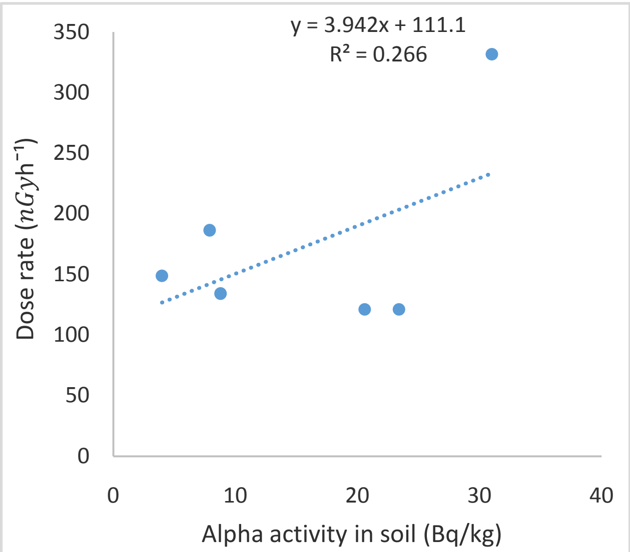

Figure 10. Correlation between gross alpha activity concentration and dose rate in Obajana

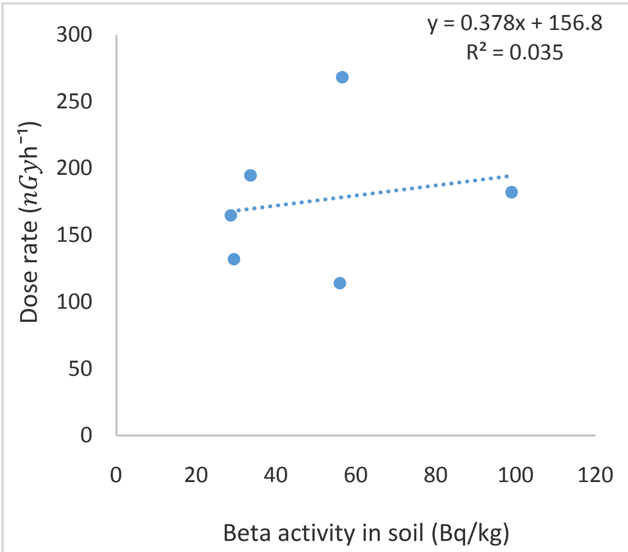

Figure 13. Correlation between gross beta activity concentration and dose rate in Itakpe

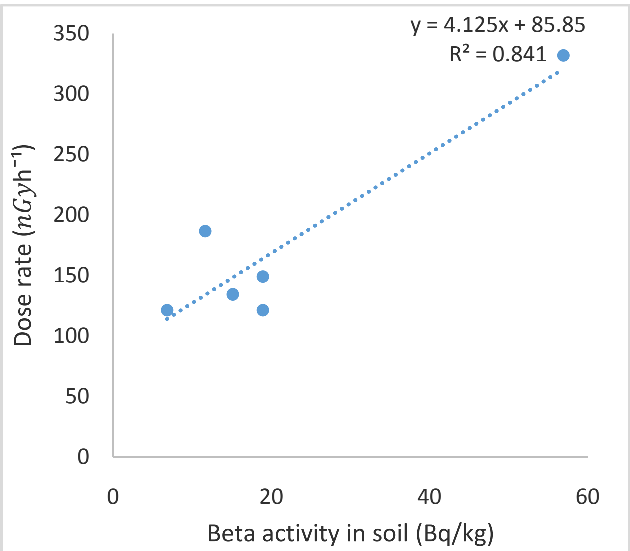

Figure 11. Correlation between gross beta activity concentration and dose rate in Obajana

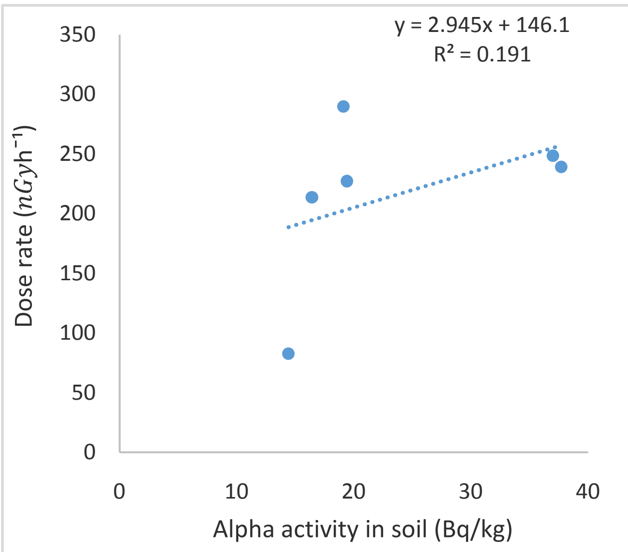

Figure 14. Correlation between gross alpha activity concentration and dose rate in Okobo

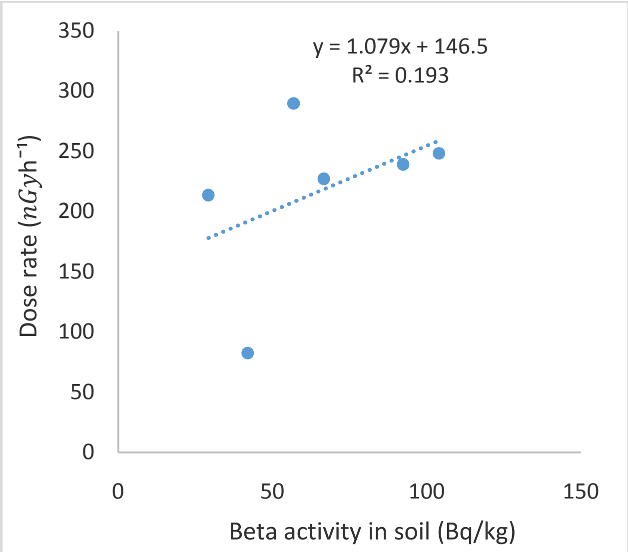

Figure 15. Correlation between gross beta activity concentration and dose rate in Okobo

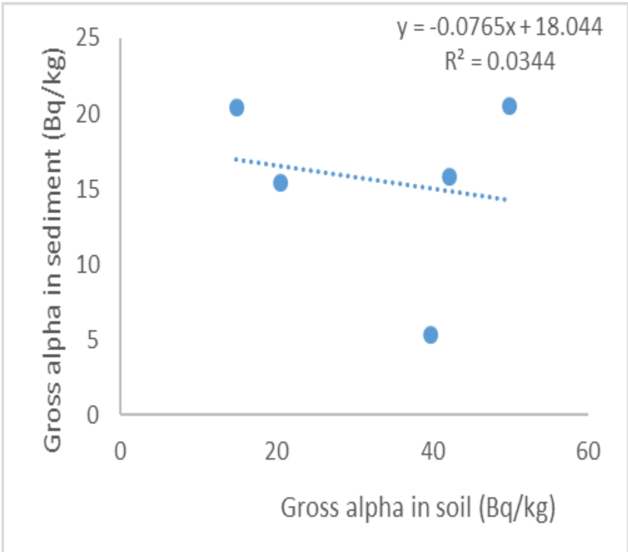

Figure 16. Correlation between gross alpha activities in soil (Ike Kabba) and sediment (Apala River) samples

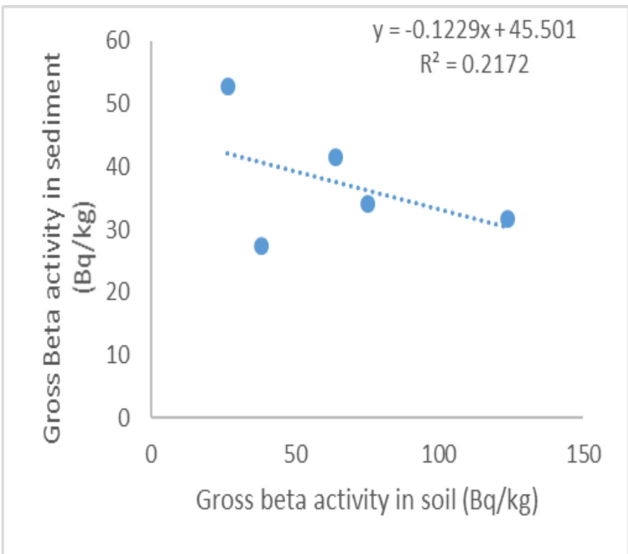

Figure 17. Correlation between gross beta activities in soil (Ike Kabba) and sediment (Apala River) samples

There exist a poor linear correlation between gross alpha and beta activities in the soil and sediment with 3% and 2% variation in gross alpha and beta activities respectively as shown in Fig. 16-17. This shows dissimilar radionuclides might be responsible for the contamination of the sediment and soil at gold mining sites.

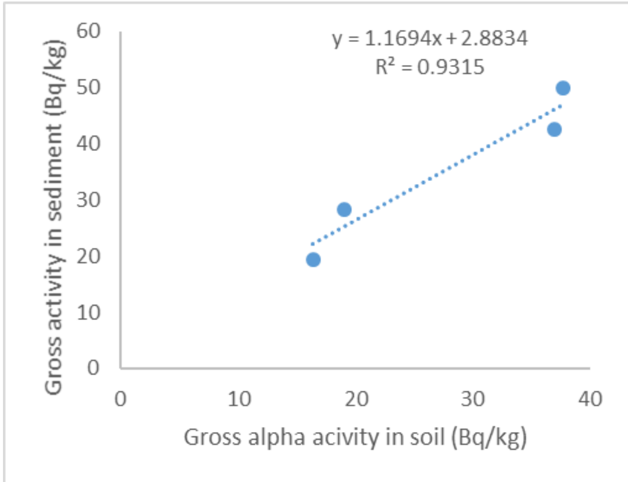

Figure 18. Correlation between gross alpha activities in soil (Okobo) and sediment (Okobo River) samples

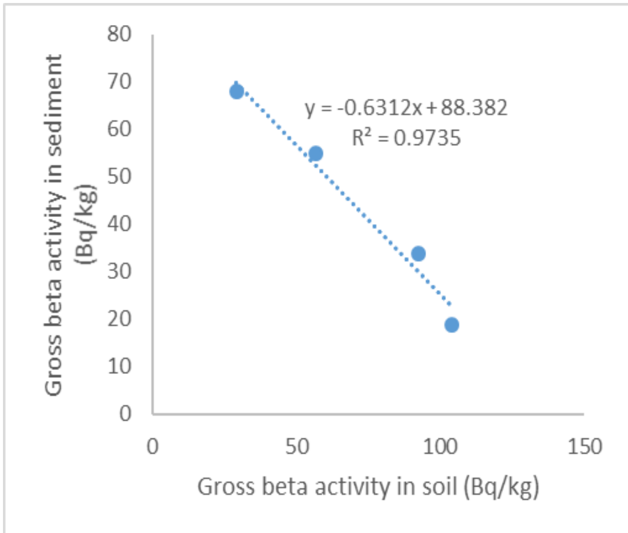

Figure 19. Correlation between gross beta activities in soil (Okobo) and sediment (Okobo River) samples

There exist a strong correlation between gross alpha and beta activities in soil and sediments as shown in Fig. 18-19 with 93% and 97% of the variation in the gross alpha and beta activities respectively at coal mining sites at Okobo. This suggests that there is similar contamination of soil and sediment from physical weathering of mineral rocks into soil and mining activities around the river.

4. Conclusion

The mean gross alpha and beta in surface soil and sediment were measured and correlation between soil sand sediment determined. There exist variations in the gross alpha and beta activities within the various selected mining fields. The soils and sediments exhibited low gross alpha and beta activities when compared to the soil and sediments from northern and southern part of Nigeria. This work shows non perturbation of the environment by these mining activities and the workers may be radiologically safe.

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