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GROSS ALPHA AND BETA RADIOACTIVITY IN CRUDE OIL-CONTAMINATED SEDIMENTS OF SOUTHERN DELTA STATE, NIGERIA

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ABSTRACT

This research work aims at estimating the potential level of gross alpha and beta concentrations in sediments geographical region of Southern, Delta State, Nigeria via gas-filled proportional counter (Protean Instrument Corporation MPC 2000DP). Thirty sediment samples were collected from the river bed and analyzed and the mean obtained results ranged from BDL to 27.56±2.62 Bq/kg and 173.5±229 Bq/kg to 3853.0 Bq/kg with average value of 9.689±3.95 Bq/kg and 1479.7±256.6 Bq/kg respectively. It was practically clear that gross beta activities values generally exceeded alpha activities values in all the samples which implies that beta emitter may be the dominant radionuclide in the area. When the obtained results were compared with the control values (3.212±0.64 Bq/kg for alpha and 82.9±13.26 Bq/kg for beta), it was observed that the obtained results exceeded that of control results, since there is no standard for gross alpha and beta activities. The obtained high values of gross alpha and beta activities could possibly be attributed to area geological formation, hydrocarbon waste effluent discharge into the environment and waste released from marine operations. However, sediment may be use for construction provided appropriate modern scientific solidification/stabilization (S/S) treatment will be done to the hydrocarbon and marine waste before being discharged into the environment. It is a matter of concern to residents of the studied communities to use sediment for construction. Hence government agency responsible for enforcing environment and radiological policies should do so to ensure compliance by all shareholders.

Keywords: Sediments, Hydrocarbon waste, Contamination, Gross alpha and beta, Delta State

INTRODUCTION

Sediment dredged from riverbeds contains a mixture of natural radionuclides, collectively known as naturally occurring radioactive materials (NORMs). These radionuclides emit alpha, beta, and gamma radiation, to which humans are exposed daily (Hanfi et al., 2021; Lin et al., 2015; Esi et al., 2018). The NORMs can increase in building sediments as a result of human activities (artificial) waste released into the environment from oil and gas operation waste, medical waste, nuclear weapons tests and nuclear power plant accidents which also increases the exposure dose absorbed by human beings (Le et al., 2010; Kabdyrakova et al., 2018; Agbalagba and Esi, 2023; Avwiri and Esi, 2015). The radionuclides parameters such as Uranium-238 and Thorium-232 family contribute to majority of alpha and beta activity concentrations found in the environment (Ovuomarie-kevin et al., 2023; Lee et al., 2014). The health implication of the emitted alpha and beta particles (radioisotopes and their progeny) comes to human beings directly or indirectly due to external and internal exposure (Hanfi et al., 2021; Al-sewaidan, 2019; Khandaker, 2012). Alpha and beta particles are emitted from unstable nuclei during radioactive decay, producing decay products. The emitted alpha particles may be dangerous to human beings through absorption by skin injuries, inhalation and swallowed, while beta particles may cause skin burns when it come in contact with the skin. The most significant implication of beta particles is when it is been ingested (Chanki and Hee, 2021; Arogunjo et al., 2004; Suresh et al., 2011; Harb, 2008). Past studies on sediment gross alpha and beta radioactivity in crude oil-contaminated areas include (Agbalagba et al., 2021; Iwetan et al., 2015; Agbalagba et al., 2020; Ijabor et al., 2024; Yümün et al., 2022; Ovuomarie-kevin et al., 2023). The exploration and production activities may have radiologically impacted the river sediment via waste discharged and indiscriminate dumping of radiological hazardous waste in the environment. Other oil activities that may also impact river sediment include oil spill, used drilling mud and sludge deposit and released produce water that may mobilized radionuclides and their decay daughter. These practices may increase the concentrations level of radioactivity in sediment if not adequate control by appropriate authorities and agencies. It is of great concern to residents utilizing this dredged sediment for construction due to potential health implications. To date, there is limited scientific literature on gross alpha and beta activity concentrations in the area. Hence, there is need to estimate the activity concentrations level of sediment in Southern Delta State, Nigeria to ascertain the safety level.

MATERIALS AND METHODS

Investigated area Description

The investigated area is rich in hydrocarbon deposits and is among the highest producers of hydrocarbon products in the country. The area has latitudes northward from 5°24' to 5°0.35' and longitudes eastward from 5°64' to 5°0.55' in Nigeria. The area has elevation of 3.0 m exceeding sea height and bounded by Atlantic Ocean in the south as shown in Fig. 1. The area is swampy with vegetated mangrove tree, freshwater swamp forest, rainforests and it has a flat tidal and flood plains that fall between the high and low tides. The major occupations of the residents are fishing, farming and caving.

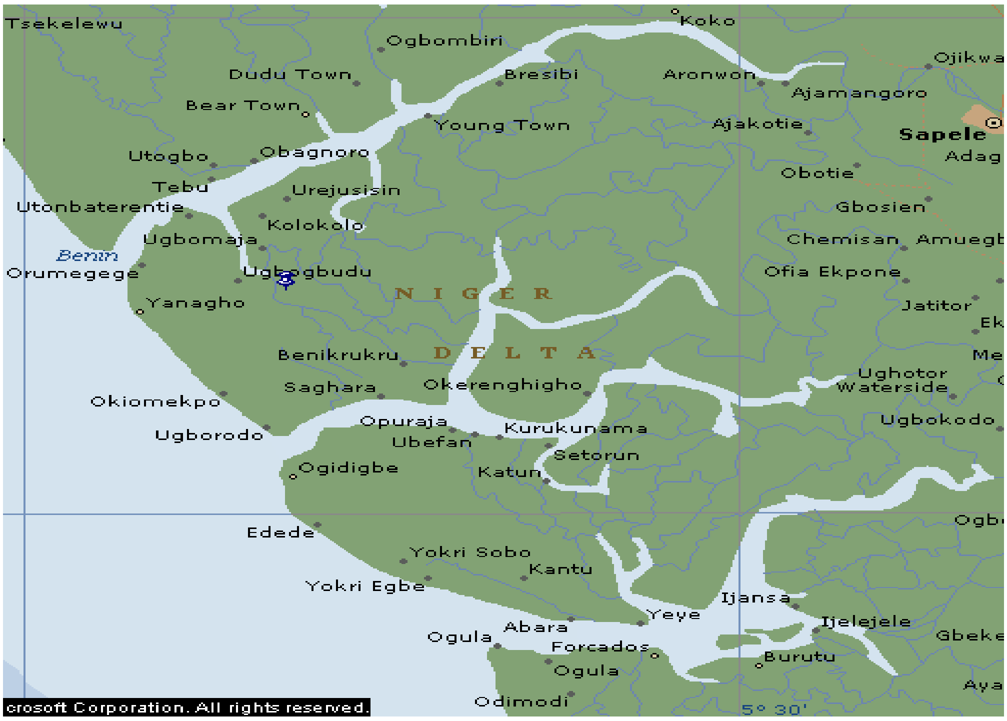

Figure 1: The investigated area map

Sampling and Preparation

Thirty sediment samples were collected from the riverbed, with three samples per community across fifteen communities. These communities were studied due to their closeness to hydrocarbon facilities such as oil wells, field stations and oil terminal. These samples were collected at the riverbed with depth of about 1.5m to 4.5m, with the aid of sampling grab which was acid sterilized, detergent clear and rinsed with distilled water. They were sealed in black polythene bags, labeled to prevent cross-contamination, and transported to the laboratory for instrumental analysis at Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaira, Nigeria. The samples were stored in a controlled environment within the laboratory for same days to prevent contamination. The sediment samples were air-dried for several days before being subjected to oven-dried at 80°C to remove moisture. The dried samples were grinded with mortar and pestle to a powder form and then sieved through a stainless steel sieve (diameter 3mm). The sieved powder samples were than pelletized using hydraulic compressor machine and kept in desiccators waiting for gross alpha and beta counting (analysis) via gas-filled proportional counter for a period sixty minutes (one hour).

Figure 2: Photo of gas-filled proportional counter with Sample

Gross alpha and beta analysis and Computation

The instrument (equipment) was calibrated to obtained adequate curve using alpha source of Pu-239 and beta source of Sr-90 (Avwiri *et al.*, 2016). It was reported that the instrument had initial detector efficiency calibration values of 87.95% for alpha and 42.06% for beta, while the background reading values of the detector are 0.30 and 0.43 cpm for alpha and beta respectively. The obtained efficiency calibration values, producer specifications and similar research literature work are same. The instrument had 0.21 and 0.22 cpm as detection limit for alpha and beta respectively. The instrument was set at high voltage 1650V to 1700V; thereafter 25 cycles of 180secs per cycle were used for counting samples. Before samples counting, blank samples were counted three times to ensure accuracy (quality control). Computing the alpha and beta activity, each sample undergoes counting for three consecutive times and the average results were recorded in count/min. The operational method deployed during counting was α-mode and the β (+α) mode for alpha and beta counting respectively (Avwiri and Agbalagba, 2007). The computer without human intervention processed each sample's count rate automatically by means of the equation 1 below.

$$\text{Rate } \alpha/\beta \text{ (count/sec)} = \frac{Raw\ \alpha/\beta\ count\ 60}{count\ time\ (sec)} \quad (1)$$

Where C = activity concentration in Bequerel per Kilogram (Bq/ kg). Equation 2 was used to compute activity concentration

Activity

$$\frac{\alpha/\beta = Rate\ \beta\ Background\ \beta x\ \beta unit\ Coefficient}{channel\ \alpha/\beta\ coefficient\ x\ samplr\ coefficient\ x\ sample\ volume} \quad (2)$$

α/β radioactivity (Bq/g)

$$= \frac{\alpha/\beta\ count\ tate\ (cpm) - BKG\ count\ rate\ (cpm)}{sample\ eff.*sample\ size.*detector\ eff}\ x0.0167 \quad (3)$$

RESULTS AND DISCUSSION

The computed activity concentrations mean results of fifteen Communities studied are as presented in Table 1.

Table 1: The activity concentrations mean results of Gross Alpha and Beta in studied Sediments

S/No	Communities	AlphaActivity (Bq/kg)	Beta Activity (Bq/kg)
1	Burutu	BDL	767.9±241
2	Yeye	8.938±4.21	1247.0±222
3	Ogulagha	3.368±3.21	876.4±236
4	Forcados	12.23±5.77	1642.0±304
5	Odimodi	10.33±4.87	3049.0±268
6	Okenrenkoko	4.087±389	2084.0±294
7	Kunukunuma	4.767±3.55	173.5±229
8	Benikurukuru	7.693±4.49	823.9±268
9	Oporoza	11.23±6.55	2801.0±403
10	Okpele-Ama	3.316±3.16	1235.0±235
11	Koko	15.11±2.18	595.7±185
12	Agigborodo	10.36±5.37	1194.0±300
13	Tebu	23.43±6.65	1167.0±246
14	Tisum	27.56±2.62	686.6±193
15	Kolokolo	2.916±2.78	3853.0±225
Mean		9.689±3.95	1479.7±256.6
Control		3.212±0.64	82.9±13.26

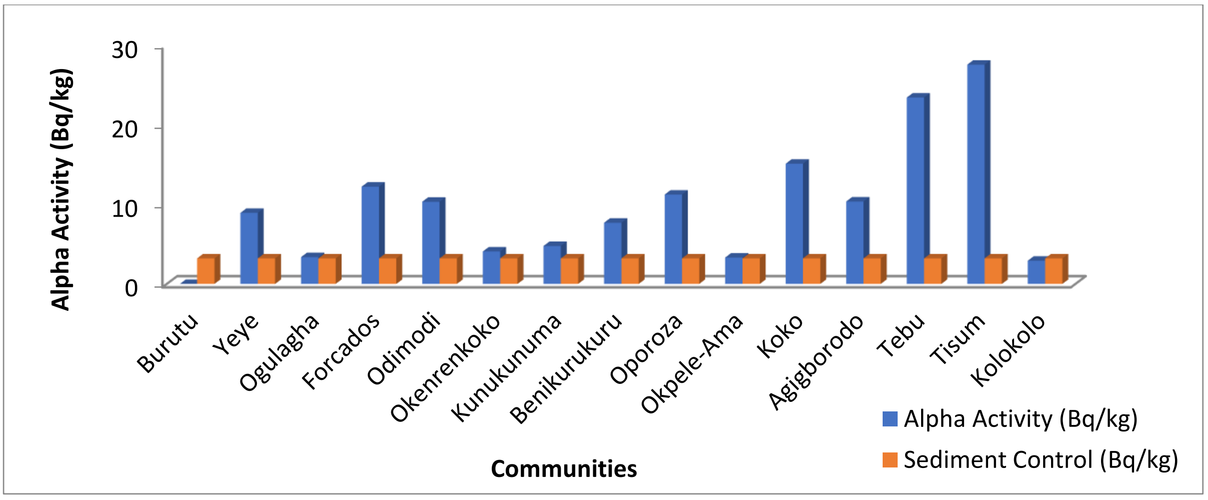

Figure 3: Mean relationship between alpha activity and Sediment Control

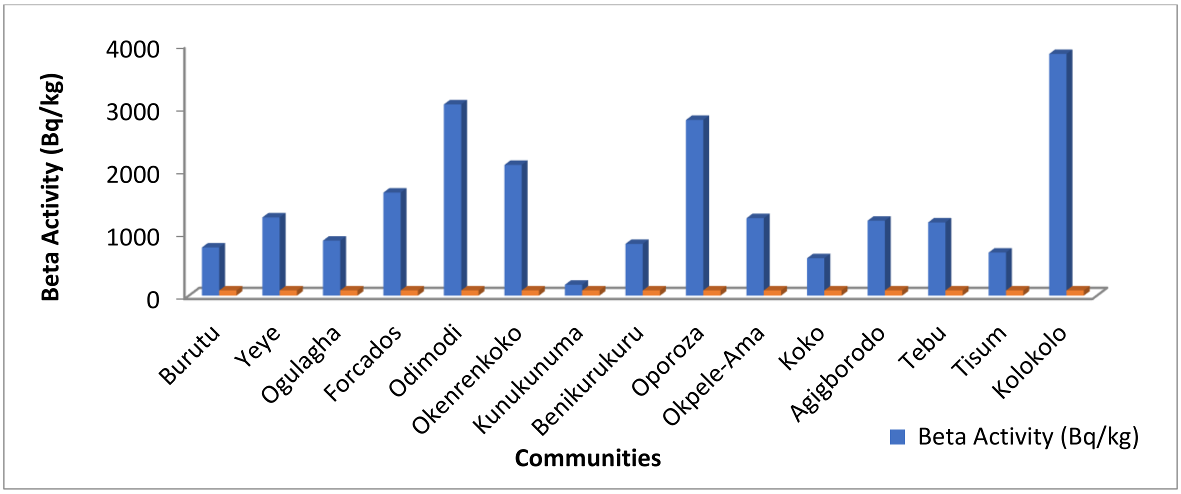

Figure 4: Mean relationship between beta activity and Sediment Control

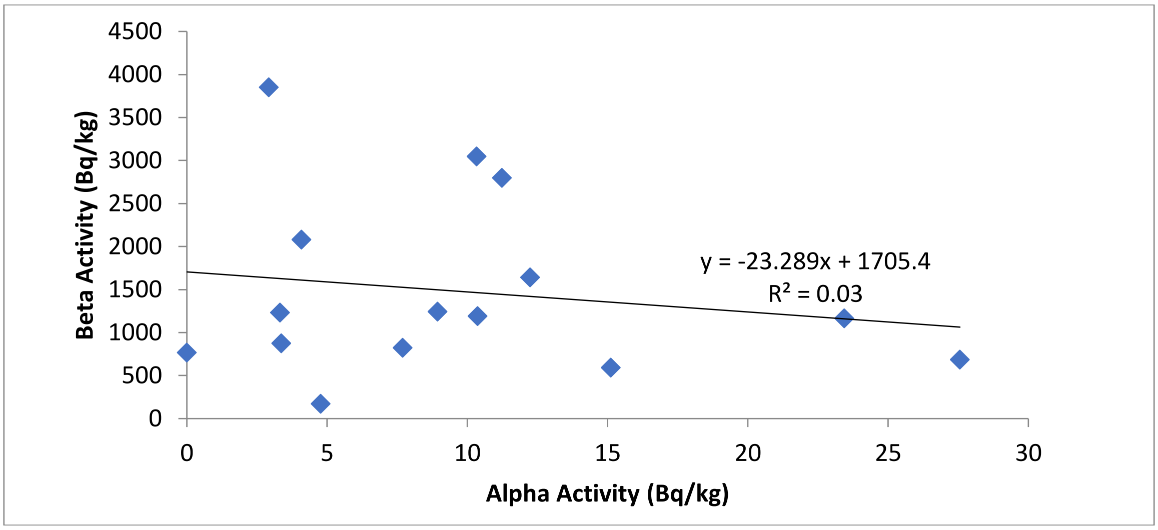

Figure 5: Relationship between alpha and beta activity

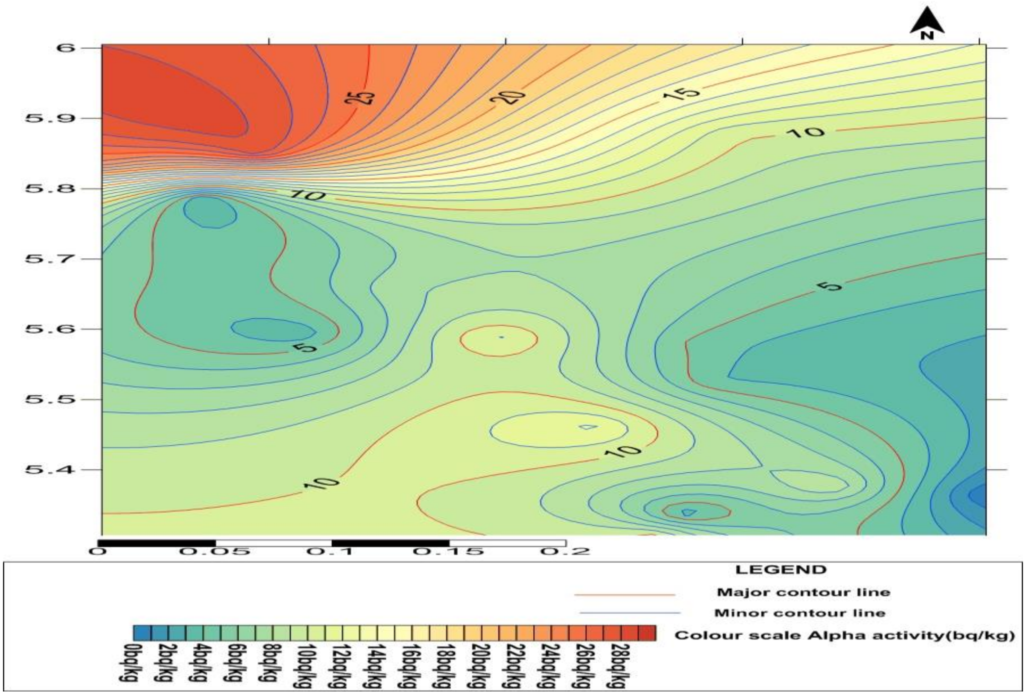

Figure 6: Contour map showing concentrations area of gross alpha activity

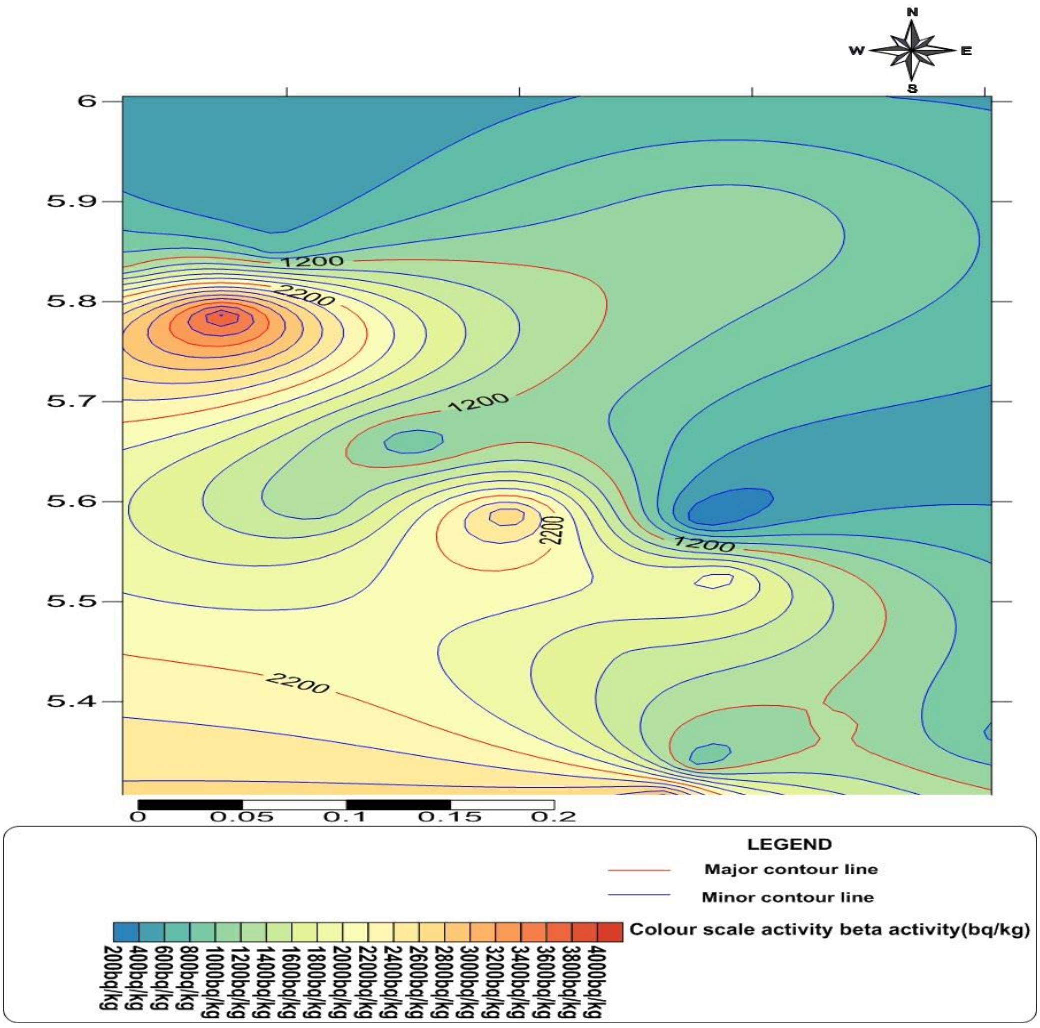

Figure 7: Contour map showing concentrations area of gross beta activity

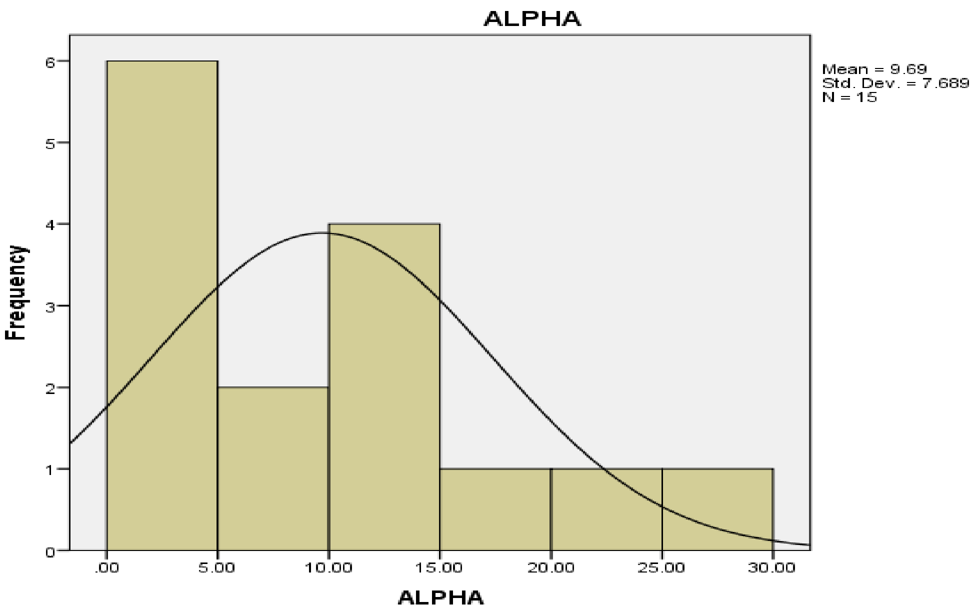

Figure 8: Histogram showing gross alpha frequency distribution

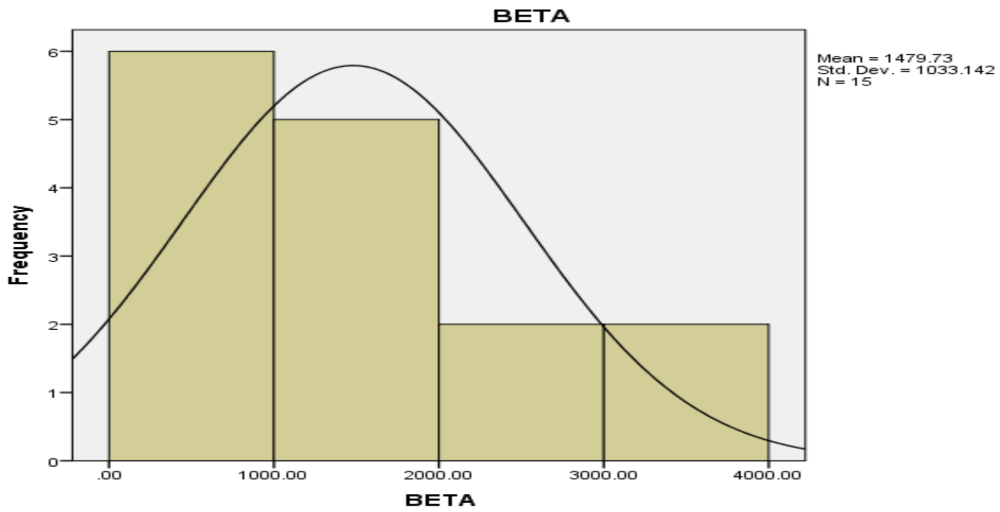

Figure 9: Histogram showing gross beta frequency distribution

The studied sediment gross alpha activities concentrations have is mean results ranged between BDL at Burutu community to 27.56±2.62 Bq/kg at Tisum Community with average value of 9.689±3.95 Bq/kg and that of gross beta activities concentrations ranged between 173.5±229 Bq/kg at Kunukunuma Community to 3853.0 Bq/kg at Kolokolo Community with average value of 1479.7±256.6 Bq/kg. The control values for gross alpha and beta activities are 3.212±0.64Bq/kg and 82.9±13.26Bq/kg respectively. From the results, it shows that the mean activity concentration values of gross beta generally exceeded that of gross alpha in all the samples which implies that beta emitter may be the dominant radionuclide in the area. Since there are no regulatory standard limits for activity concentration of gross alpha and beta for sediments, the obtained values was compared against control values and it was observed to be higher than the control values as presented in Fig 3 and Fig 4. The obtained mean gross Alpha and Beta activities concentrations values were compared with scientific reported, and it was observed that the obtained values exceeded the reported values in same selected countries around the world (Ovuomarie-kevin *et al.*, 2023; Biswas *et al.*, 2015; Aytas *et al.*, 2012; Hanfi *et al.*, 2021; Yümün *et al.*, 2022; Mgbukwu *et al.*, 2019; Kam *et al.*, 2017). The obtained high values of gross alpha and beta activities could possibly be attributed to the ecological formation of the area, hydrocarbon waste effluent discharge into the environment, released from marine operations. The linear correlation between activity concentrations of gross alpha and beta shows a poor linear relationship between them with linear correlation coefficients and equations (R^2) 0.03 and y = -23.289x+1705.4 respectively as presented in Fig 5. Consequently, the level of contamination in sediment may be as a result of disparate of present radionuclides. The contour maps as presented in Fig 6 and Fig 7 shows the dense and the less dense concentrations distribution lines area with a normal distribution bell shape and hence reveal log-normal model by means of multimodality level of gross alpha and beta activity of sediments in the studied area. It revealed the variation distribution which goes beyond geological formations but revealing the high level of contamination in the dense contour lines area. Fig 8 and Fig 9 shows the histograms frequency distributions of sediments which indicates the bell-shaped degree of multi-modality and the feature of radioactive laden minerals in sediment which may be the sources alpha and beta activity concentrations. The obtained high gross alpha and beta activity concentrations may be as results of hydrocarbon waste discharge overtime into the environment.

CONCLUSION

The sediment samples were collected from river bed and were estimated for gross alpha and beta activity concentrations in crude oil polluted environment in Southern, Nigeria. The research shows that the mean activities concentration of gross beta exceeded that of gross alpha, which is an indication that beta emitter may be the dominant radionuclide in the area. The obtained results of gross alpha and beta activity concentrations were observed exceed the gross alpha and beta activity concentrations control results. This suggests that the sediment may have been impacted by the indiscriminate discharge of hydrocarbon waste in the environment. Although there is radioactive contamination of sediment resultant from indiscriminate discharged of hydrocarbon waste into environment, sediment may be use for construction provided appropriate treatment will be done to the hydrocarbon waste before being discharge into the environment. It is a significant concern that requires attention from both government and shareholders to enforce compliance of environment policies, to avoid radioactive contaminations of sediment. These results (data) will serve as baseline data for government and shareholders for future research work

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