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Evaluation of gross alpha and gross beta activity levels in soil and sediment samples from different oil spi ll areas in Bayelsa State, Nigeria

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Abstract
The evaluation of gross alpha and gross beta activity levels in soil and sediment samples for different oil spill areas in Bayelsa State, Nigeria have been done with the aid of Protean Instrument Corporation (PIC) MPC 2000DP detector. The result of gross alpha and beta activity concentrations obtained for soil samples in oil spill sites of Bayelsa State ranged between 22.00±1.78 Bq/kg (Otuasega) - 39.40±1.88 Bq/kg (Imiringi) and 37.86±2.72 Bq/kg (Otuasega) - 102.57±3.43 Bq/kg (Imiringi). The gross alpha and beta activity concentrations obtained for sediment samples in oil spill sites of Bayelsa State ranged between 20.30±1.54 (Otuasega) - 142.00±1.82 Bq/kg (Ibelebiri) and 30.60±3.23 (Otuasega) - 83.10±3.93 Bq/kg (Ibelebiri) in oil spill sites. The average activity concentrations of gross alpha and beta in soil and sediment samples were compared with other research works. Correlations were made among the variables (gross alpha and gross beta) to prove the interdependency or direct relationship in the investigated samples. The results of the gross alpha and gross beta activities in both soil and sediment samples were found to be greater than the gross alpha and beta activity for their control samples which indicates some degree of perturbation in the oil spilled sites. Comparisons were made between the average activity concentrations of gross alpha and beta in soil and sediment samples and previous research publications. The interdependency or direct relationship in the analyzed samples were done and correlations were computed between the variables (Gross alpha and gross beta). It was discovered that the results of the gross alpha and gross beta activities in both soil and sediment samples were higher than the gross alpha and beta activity for their control samples, which suggests some degree of disruption in the oil spilled sites.

Keywords: Soil and sediments samples, activity gross alpha, activity gross beta and oil spill

Introduction
Studies have revealed that the earth's radioactivity is caused by both natural sources and human actions in the environment. Since the earth's origin, natural radioactivity has been a part of the coastal environment. The Niger Delta region has a reputation for making a significant economic contribution to Nigeria through its oil and gas resources. The Bayelsa States have large gas and crude oil deposits [1]. The Niger delta's oil and gas business is diverse, encompassing the construction, exploration, and production sectors, among others. Most of these industries heavily rely on the utilization of radioactive materials and radiation generators, which serve as the source of radiation such the alpha, beta, and gamma rays that are frequently present in the petroleum matrix [2]. Petroleum (Also known as crude oil) contains radioactive elements, notably uranium and thorium, as well as hazardous compounds. If handled improperly, this petroleum could leak during production and have a radioactive impact on the environment. Inadvertent releases of crude oil into the environment due to human activity or system failure are known as oil spills. In the Niger Delta region, oil spills have been identified as a significant cause of land and water pollution, and their rise has been linked to both the expansion of the oil industry and the prevalence of aging oil pipelines. Vandalism or equipment malfunction could result in an oil spill. The ecosystem has been degraded and polluted as a result of the use of its abundant hydrocarbon resources. Therefore, it's critical to keep an eye on any crude oil spills that may contain a small amount of naturally occurring radionuclides that, when exposed to the environment, release ionizing radiation. The majority of the alpha and beta activity concentrations are caused by radionuclides from the Thorium-

232 and Uranium-238 family. Potassium K-40 may have some impact on beta activity concentration [3].

Based on the chemical characteristics of radionuclides and how they are absorbed by roots of plants and animals, the soil serves as a source of radionuclide transfers along the food chain [4]. The presence of uranium in a state of disequilibrium with its daughters is typically the cause of low radioactivity in lakes and sediments. Important reservoir and redistribution systems for radionuclides are the ocean and sediments [5]. The importance of measuring gross alpha and beta activity in environmental materials such soil, sediment, and water has grown recently. Understanding the different soil radionuclide concentrations is helpful for monitoring environmental radioactivity since it acts as a basic indicator of the dispersion and accumulation of radioactivity in the environment [6].

Analysis of the gross alpha and beta radiation content in soil and sediment from the Bendimahi River and Van Lake (Turkey) was done by Selçuk and others [7]. In soil samples taken in May and August, the concentrations of gross-alpha and gross-beta activity ranged from 0.800 to 4.277 Bq/g and 0.951 to 11.773 Bq/g, respectively. When Dimovska *et al.* [8] evaluated the radioactivity levels in the soil surrounding the city of Kavadarci in the Republic of Macedonia, they discovered that the average values of gross alpha and gross beta activities were 522±192 and 681±146 Bq/kg, respectively. The analysis's findings revealed a substantial relationship between soil natural radionuclide abundance and geological origin.

The gross alpha and beta activity of a few oil-producing regions in Abia state, Nigeria, was examined by Enyinna and Avwiri [9]. Mean gross beta activity was 48.22 Bq/kg, 28.24 Bq/kg, and 24.33 Bq/kg (soil), according to the data, while mean gross alpha activity was 13.67 Bq/kg, 19.71 Bq/kg, and 14.53 Bq/kg. The results of the soil samples' gross alpha and beta activity are within the range of background radiation that is often present.

In their study of the effects of offshore oil and gas facilities on the environment, Stanislav and Elena [10] demonstrated that produced water from oil and gas production contains naturally occurring radioactive elements (Uranium and thorium) and their offspring. Oil spills, produced water discharged into land and water bodies, harmful chemical discharges, sewage disposal, solid waste generation, petroleum industry, etc. are examples of artificially generated inputs [11].

Oil exploration and exploitation in Bayelsa State, Nigeria has led to the destruction of the ecosystem. It impacts with respect to radioactive sources might be a high level of radionuclide presence in the soil, sediment, and water samples which might lead to serious biological health effect to human. The oil spill in these environments have enable a constant exposure of the environment to these (Radionuclide) radiation elements. According to USEPA [12], the Bayelsa state villages that have experienced oil spills are also dealing with a number of other environmental degradations, including the extinction of aquatic life, loss of biodiversity, and soil fertility. These events may result in the buildup and release of radon gas, the leaching of radionuclide-contaminated sludge into groundwater and other bodies of water, and other things.

Although there are some exceptions in some shales and phosphate, internal radiation exposure to humans, particularly through ingestion of food and water [13], is associated with higher radioactivity levels in igneous rocks like granite and lower levels in sedimentary rocks, rocks also have a relatively high content of radionuclides. The most significant natural radionuclides in terms of possible internal radiation exposure to humans, notably through ingesting food and water, are alpha and beta emitters [13]. The inhabitants of Bayelsa State are largely farmers and the state is rich in mineral resources including gas and crude oil. The state is home to one of the greatest crude oil and natural gas deposits in the nation, which helps the local economy grow but is nonetheless hampered by widespread poverty and pollution from oil spills [14]. Sediments play a crucial role in aquatic radioecology because they accumulate and transport contaminants like radioactivity and heavy metals within the geographical area [15] or disperse them through the air into nearby farms. Oil spills may harbor wastes that are particulate in nature and could end up in nearby rivers. The main cash crops grown under these conditions are farm products including plantains, bananas, yams, rice, and rubber, all of which are susceptible to absorbing radioactive elements from the soil or through the leaves. The main cash crops grown in these regions are grains like maize, cassava, yam, rice, and cashew, which could absorb radioactive elements from the soil or through the leaves. It is necessary to evaluate the radiation levels in soil and sediment samples taken from the chosen oil spill areas as a result of human activity.

Materials and methods

Methods

One of the ancient cities where oil is being explored is Bayelsa State. Started in Nigeria. This activity has continued to the hinterlands in the area. As a consequence, the water, soil and sediment resources situation is now precarious and of great concern to both host communities and Government. Bayelsa States lies between 4o52' N – 6o05'E which is located within the lower delta plain and Yenagoa, is the capital city. The major activity of economic value in the study area is exploration and exploitation of crude petroleum oil. The nearby hinterlands have seen a continuation of this activity. As a result, both the host communities and the government are quite concerned about the current state of the water, soil, and sediment resources. The capital city of Bayelsa State, Yenagoa, is situated inside the lower delta plain between latitudes 4o52'N and 6o05'E. Exploration and extraction of crude oil are the main economic activities in the studied region. Farming and fishing are the main jobs that the inhabitants of Bayelsa State have. The ecology of Nigeria's Niger Delta region, which produces the majority of the country's oil and serves as its economic backbone, has been challenged by the numerous oil exploration and extraction activities taking place there. The ecology of Nigeria, particularly the Niger Delta region, has suffered significant harm as a result of the country's expanding oil sector, population boom, and lax enforcement of environmental laws. Major oil spills contaminate coastal shorelines and severely harm the local ecology of the population that is close to the ocean. The ecosystem has deteriorated as a result, which has led to intense conflict between the local populace and the global oil firms who operate in the area.

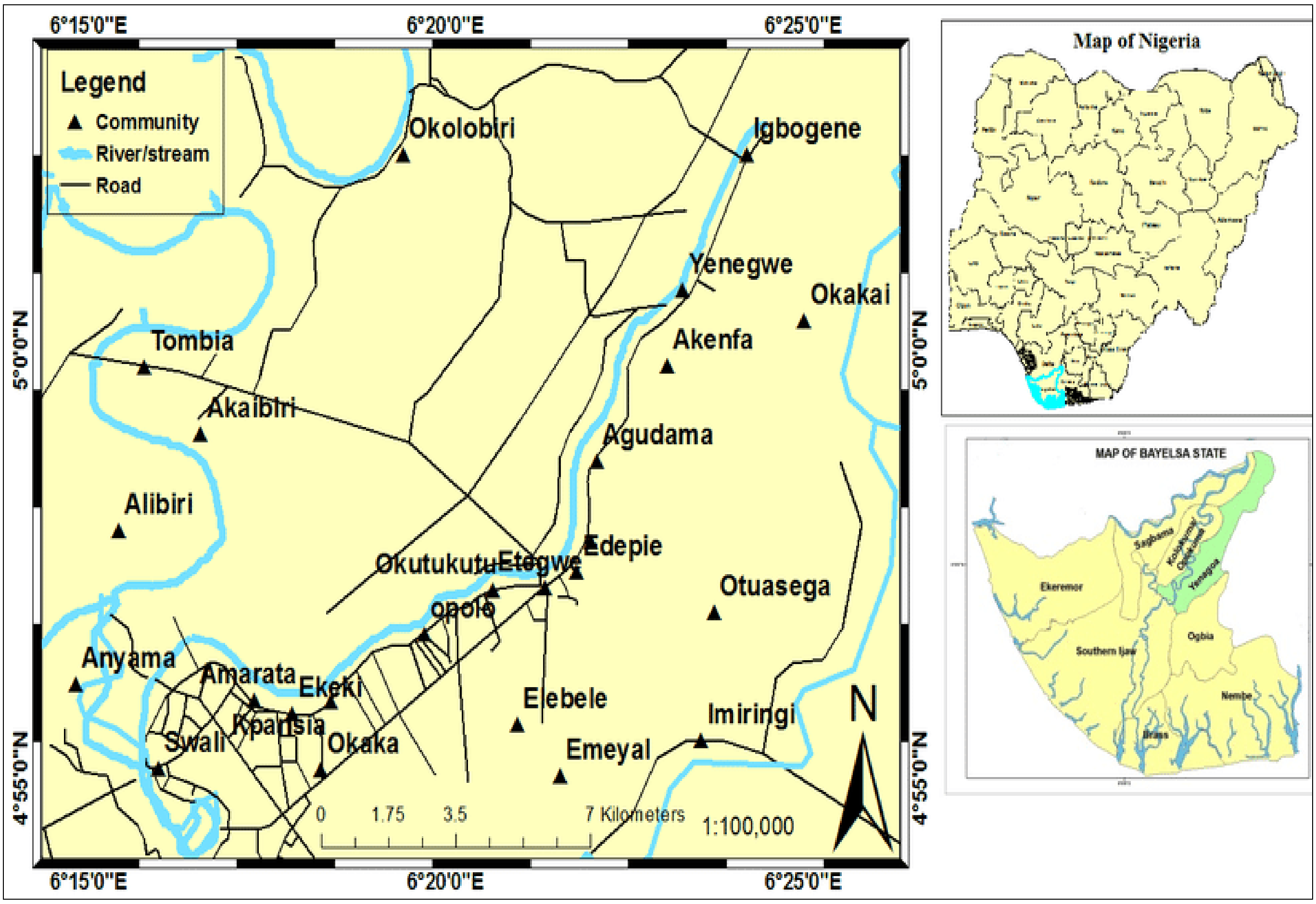

Fig 1: Map of Bayelsa showing the areas under research

Collection of samples and analyzing the radioactivity

Environmental matrices (soil and sediment samples) were collected at oil spill areas in the Bayelsa State towns of Otuasega, Ibelebiri, Imiringi, and Otugwe. 23 samples in all, including 8 soil samples, 15 sediment samples, and 2 control samples for both soil and sediment, were taken. To eliminate stones and other foreign objects, the samples were first sieved with a 2 mm mesh sieve after being air dried. The samples were dried once more overnight at 800C in an electric oven until all moisture was removed, then they were ground into a fine powder. In a Marinelli beaker, the samples were sealed after being weighed. The samples were individually confined in their planchets and stored in desiccators while waiting to be counted, in accordance with International Atomic Energy Agency (IAEA) [16] requirements for gross alpha and beta analyses. Using a Protean Instrument Corporation (PIC) MPC 2000DP type gas-free proportional counter available at the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria, Nigeria, the samples were examined for gross alpha and beta activity. The activity was calculated using the mean after each sample was counted three times. For the counting, the α-only mode for the alpha counting and the β (+α) mode for the beta counting were employed. The computer automatically processed each sample's count rate using the equation below;

$$A_{(\alpha,\beta)} = B_{\alpha,\beta} \times 60/T$$

Where the alpha and beta particle count rates are expressed as *A* (α,β) counts per minute (cpm), raw counts of alpha or beta particles are expressed as B (α,β) (cpm), and counting time is expressed as T (2700 s or 45 min).

Each sample's activity was calculated as follows:

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

Where the alpha and beta activity (Bq/kg) is represented by $C_{(\alpha,\beta)}$, background alpha and beta particle count $G_{(\alpha,\beta)}$, $U_{(\alpha,\beta)}$, unit coefficient of alpha and beta particle (1.67 x 10^{-2}), channel efficiency for alpha or beta counting $H_{(\alpha,\beta)}$, sample efficiency for alpha or beta counting $S_{(\alpha,\beta)}$, and sample mass (V) for alpha or beta counting.

The soil samples' sample efficiency was calculated using;

$$\varepsilon_s = \frac{M_r}{M_i} \times 100$$

where M_i denotes the sample's initial mass in powder form and M_r denotes the recovered mass following pellet formation.

The sample activity's related error was estimated using;

$$E_r = \frac{\left[B + \frac{(10000)^2}{T_{bgd}} \times G_{(\alpha,\beta)}\right]}{100000} \times \frac{U_{(\alpha,\beta)}}{H_{(\alpha,\beta)} \times S_{(\alpha,\beta)} \times V}$$

where B is the alpha or beta particle's raw count., T_{bgd} is the time of the background count.

The instrument reported a calibration results of the following

Sr-90, a beta source, and Pu-239, an alpha source, were

employed as calibration sources.
Detector Efficiency: Alpha =87.95%, Beta = 42.06%
Detection Limit: Alpha = 0.21 cpm, Beta = 0.22 cpm
Background of the detector: Alpha = 0.50 cpm, Beta = 0.73 cpm

Results

The results in the tables below shows the results of the mean gross alpha and beta activity concentration.

Table 1: Shows the mean concentrations of gross alpha and gross beta activity in soil samples from the study locations.

Sample areas	Gross alpha concentration (Bq/Kg)	Gross beta concentration (Bq/Kg)
Otuasega	22.00±1.78	78.00±3.83
lmiringi	39.40±1.88	66.30±3.47
Otuegwe	25.80±1.76	102.57±3.43
Ibelebiri	32.33±1.46	37.86±2.72
Control Soil	14.09±1.92	11.31±3.87

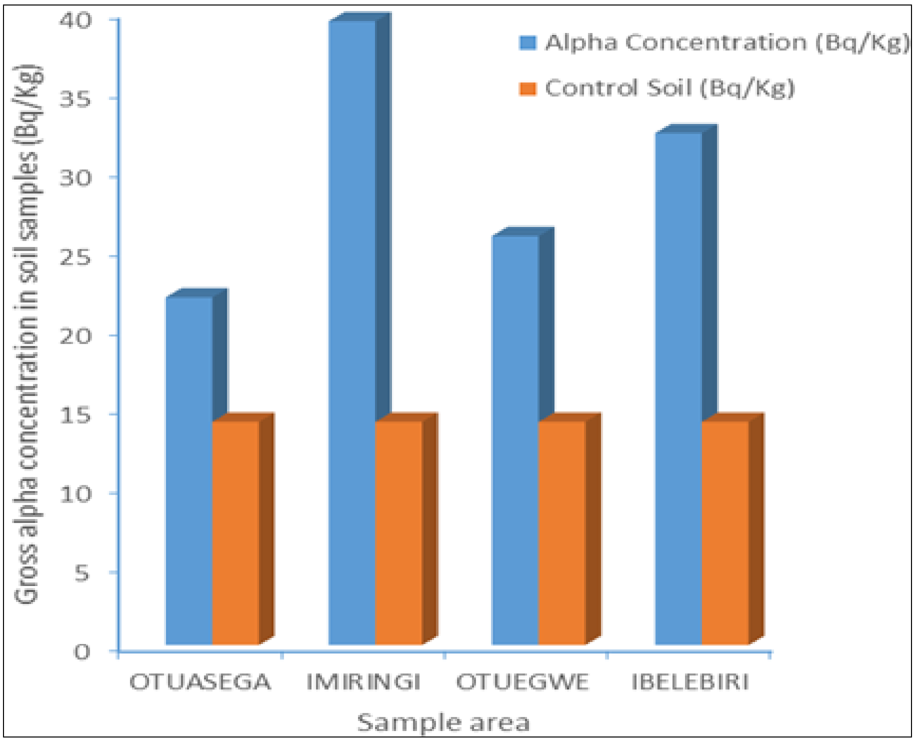

Fig 2: Shows the comparison of concentration of gross alpha activity in soil samples and the control sample in oil spill site in Bayelsa State

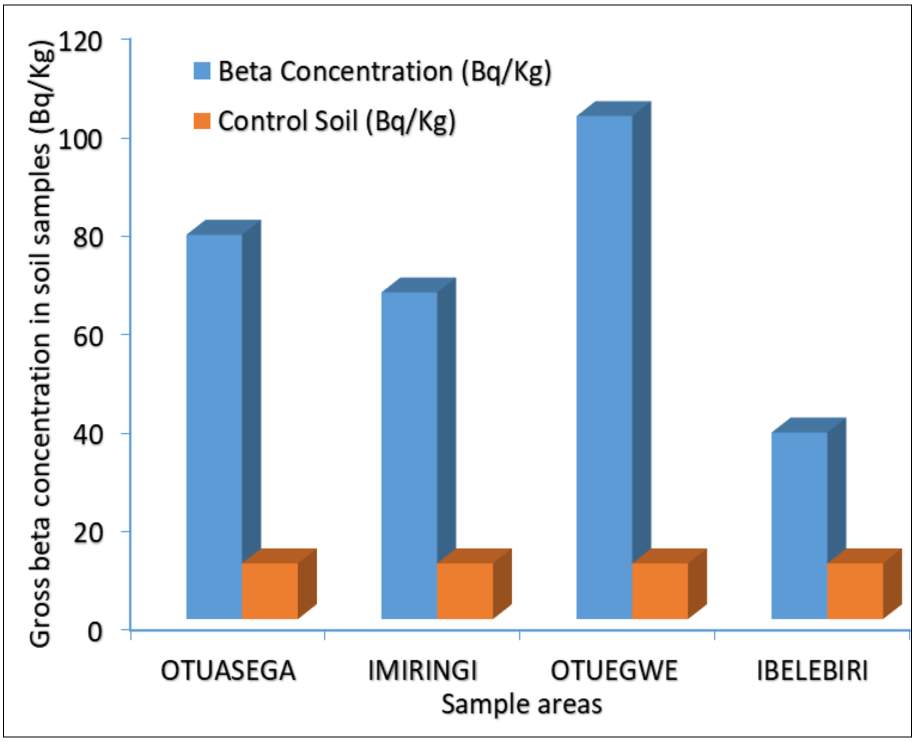

Fig 3: Shows the comparison of concentration of gross beta activity in soil samples with the control sample in oil spill site in Bayelsa State

Table 2: The mean gross alpha and beta activity concentration (Bq/Kg) in sediment samples for the study areas

Sample areas	Alpha concentration (Bq/Kg)	Beta concentration (Bq/Kg)
Ibelebiri	142.00±1.82	83.10±3.93
Otuasega	20.30±1.54	30.60±3.23
Otuegwe	30.40±1.73	76.90±3.56
Imiringi	22.10±1.51	43.80±3.17
Control Sed.	1.95±1.10	19.36±2.58

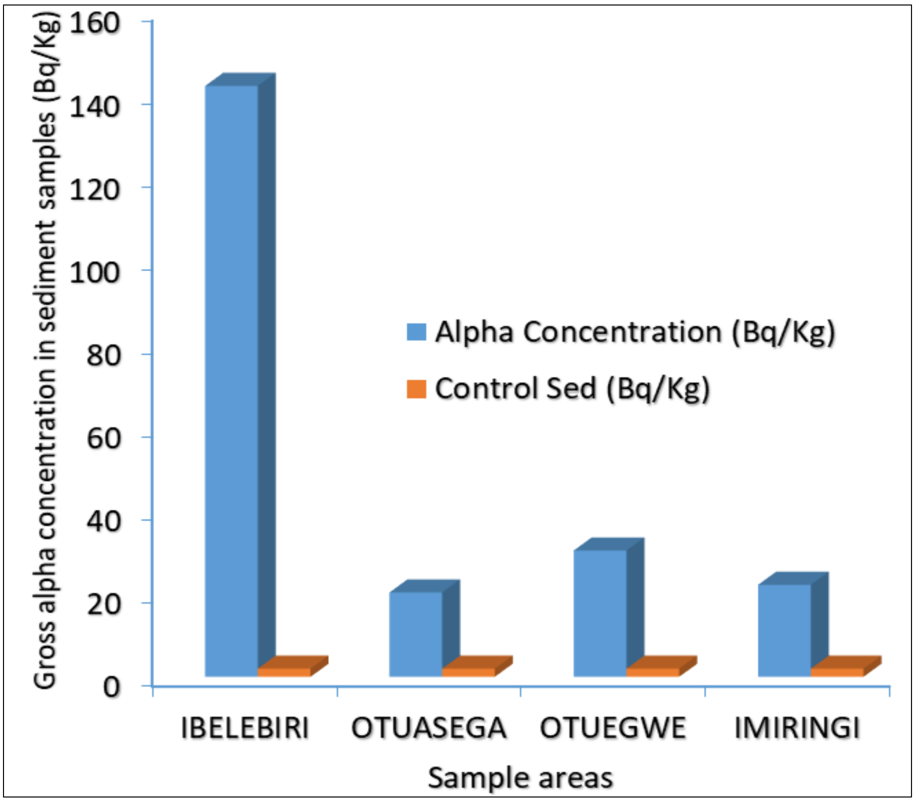

Fig 4: Shows the concentration of gross alpha activity in sediment samples and the control sample in oil spill site in Bayelsa State

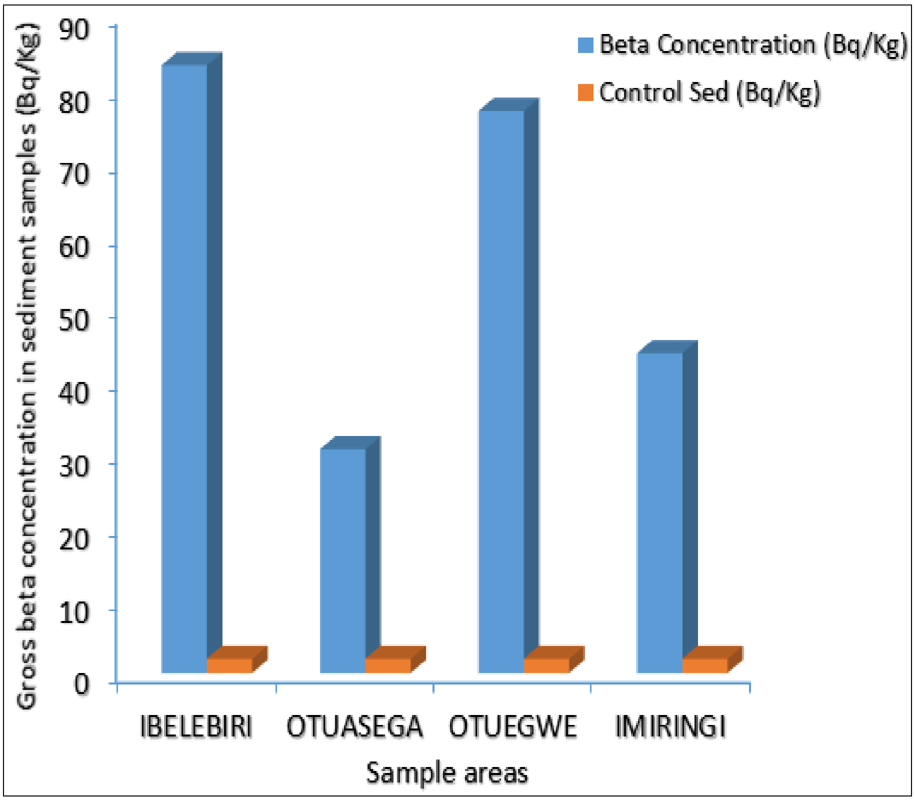

Fig 5: Shows the concentration of gross beta activity in sediment samples and the control sample in oil spill site in Bayelsa State

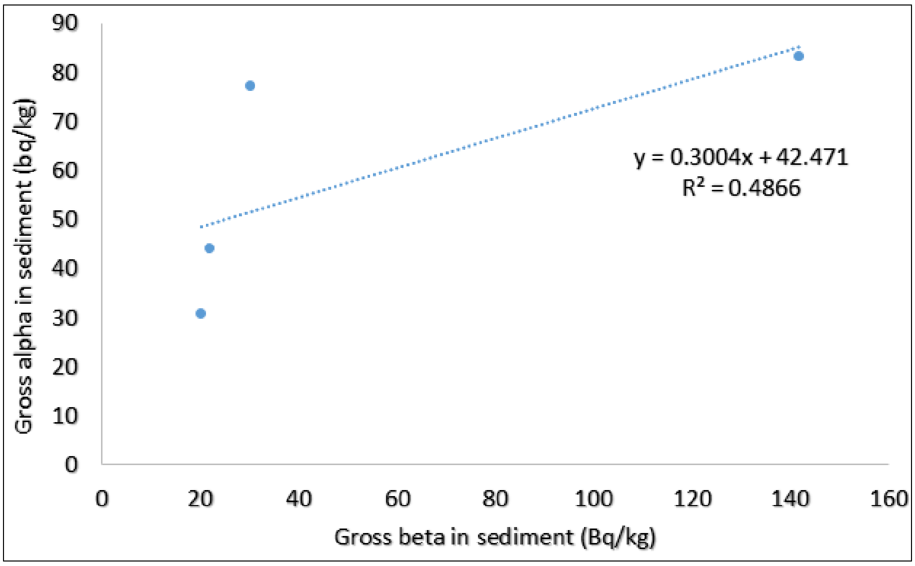

Fig 6: Linear dependency of gross alpha and gross beta activities in sediment samples

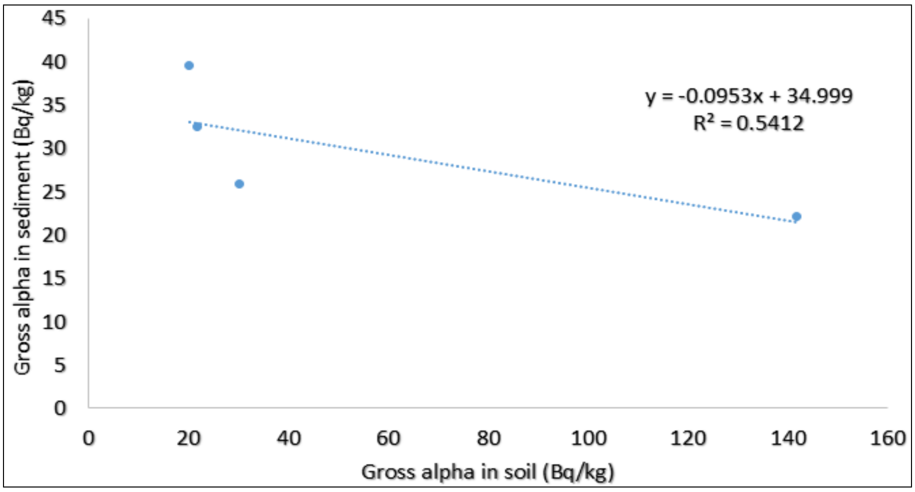

Fig 7: Linear dependency of gross alpha activities in sediment and soil samples

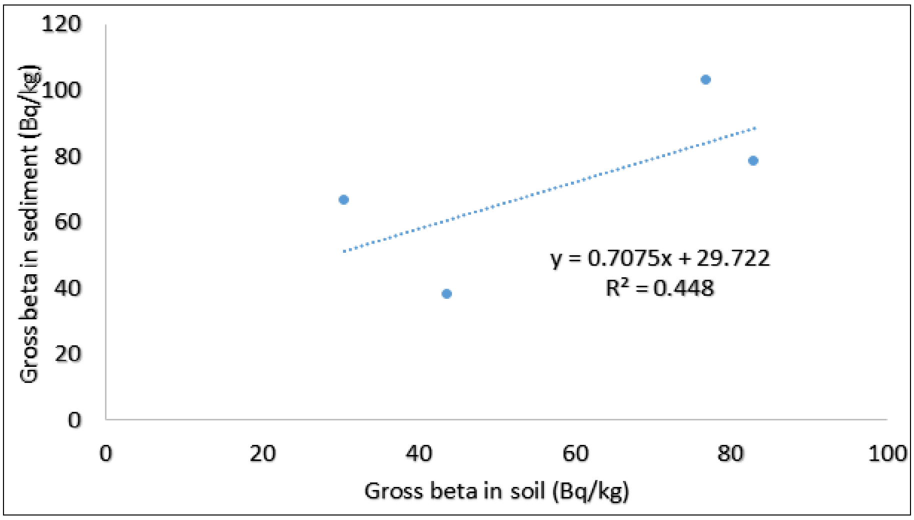

Fig 8: Correlation between gross beta activities in sediment and soil samples

Discussion

The mean gross alpha and beta activities in oil spill soil samples was between 22.00±1.78 - 39.40±1.88 Bq/kg and 37.86±2.72 - 102.57±3.43 Bq/kg respectively. The mean gross alpha activities in all studied oil spill sites were significantly lower than those at a few oil fields in the Imirigin, Bayelsa, and Rivers states (530±20 Bq/kg and 152.11±61.67 - 322±121.67 Bq/kg) [17, 18]. The mean beta activities in the current research were lower than the average values found in a few Bayelsa oil fields (2929±170Bq/kg) and a few oil fields in Rivers state (311.15±83.3 Bq/kg - 615.5±178.83 Bq/kg), respectively. The discrepancies could be as a result of different geology of these regions and the size of the oil spill zones. As demonstrated in Figures 2 and 3, the mean gross alpha and gross beta activities were higher than those of selected control samples from non-oil-spill sites. The results were within Elena's [19] limits of typical soil linked with the oil and gas sector, which are 2.4-120 Bq/kg, 60-330 Bq/kg, 8-87 Bq/kg, and 53-960 Bq/kg.

The mean activity in sediment ranged between 20.30 ± 1.54 - 142.00±1.82 Bq/kg and 30.60±3.23 - 83.10±3.93 Bq/kg in Otuasega-Ibelebiri oil spill sites for gross alpha and beta respectively. The plot of gross alpha and beta activity in the sediments for the oil spill-tested locations is shown in Figures 4 and 5. At various oil spill sites, the gross alpha and gross beta activity in sediment vary accordingly. All oil spill sites had higher gross alpha and gross beta activity than the non-oil-spill control samples. In comparison to selected oil and gas fields [20] at Ogba/Ndoni, Rivers State, the mean gross alpha and beta activity in sediments for oil spill sites were lower (203.66±6.0 Bq/kg and 7485.92±165.0 Bq/kg, respectively). The results were lower than those reported [21] for natural gross alpha and gross beta activity concentrations in the drilling cores in Holocene sediments of the Gulf of Izmir (Eastern Aegean Sea, Turkey) which ranges from 537±77 to 1800±207 Bq/kg as well as 993±60 to 1842±102 Bq/kg, respectively. The changes may be related to the presence of mineral compounds and oil exploration activity in certain areas. According to Figure 6, there is a weak linear association between the gross alpha and beta activity in the sediment collected from the oil spill sites, suggesting that varying ratios of radioactive constituents may be to blame for the contamination of the sediments. In Figure 7, there is also a weak linear correlation between gross alpha activities in soil and sediment, with a coefficient of determinant of 54%. This could also suggest that the surface contamination in the soil brought on by an oil spill may not have a significant impact on the contamination in the sediment. Based on the trend in gross alpha activities, this is apparent as we have a rapid decrease in alpha activity in sediment samples from different oil spill sites with increase in alpha activity in soil sample. In the same trend, between gross beta activity in soil and sediment, there is only a weak linear variation. These would imply (Figure 8) that sediment contamination by beta particles, which has been described as a 45% variance in the gross beta activities in sediments. The difference in concentration activities of gross beta at respective oil spill sites also suggests that the contaminant in the samples may be through different origins in the oil spill sites and may not have beta-emitting radionuclides dominance.

Conclusion

The soil and sediment samples have been evaluated for gross alpha and beta activity concentrations in different oil spill sites. The results were found to be higher than the gross alpha and beta activity for the reference/control samples, which suggests that the oil spill locations have been disturbed to some extent. Although there is little to no radioactive contamination of the soil and sediment resulting from the oil leak being discharged into the air or deposited on the ground, soil and sediment samples from the oil spill sites may not pose any harm to both local residents and the general public in and around the area.

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