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The Background Dose Assessment of Highly Industrialized Area Used for Building and Construction Purposes in Ogun State, Nigeria

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Abstract

A highly industrialized and mining zone has been mapped to ensure the level of radiation exposure and environmental safety of the dwellers in the buildings within the vicinity. The highest values of ^{238}U and ^{232}Th which are 48 ± 11 and 134 ± 9 BqKg^{-1} were found to be higher than the world average values of 30 and 40 BqKg^{-1} according to UNSCEAR. The mean value of radium equivalent (Ra$_{eq}$)activity of 200.89 ± 22.54 BqKg^{-1} lies within the limit of 370 BqKg^{-1} recommended by UNSCEAR. The meanabsorbed dose rate of 87.85 nGyh^{-1} is 4 % higher than the average world value according to UNSCAER 2000.The geospatial analysis revealed that the natural radionuclides in the region have a trend, NW-SE trending with significant re-deposition at the Southern part through diffusion which may be attributed the combinations of soil geology of Dahomey (Benin) Basin and human activities. 3D scatter and ribbon plots validates the strong positive correlation between the level of radioactivity distributions which is in the order of magnitudes ^{40}K$>^{232}$Th$>^{238}$U in the study area. Significantly, the geospatial analysis of the background gamma dose rate has revealed the hot spot in the area that could pose high risk of contributing to indoor exposure if constructions are built for dwellers

Keywords: Gamma spectroscopy; excess cancer lifetime risk; activity utilization index; external index dose rate; internal index dose rate; annual effective dose.

1.0 Introduction

Ogun State in Nigeria is known to be highly industrialized coupled with other mining activities. As such, the ever increasing challenge of population increases civilization of humans and speedy has been the contributor to the increase risk of radioactive materials in the region. Monitoring of the release of radioactive materials in environment is an important environmental protection [1]. The major source of background radiation is naturally occurring radionuclides aside the man-made radiation [2]. The radioisotopes whose half-lives can be compared to the age of the Earth as well from the decay chain of the long-lived radioisotope give rise to terrestrial radiation. The natural radionuclides of ^{238}U, ^{232}Th and ^{40}K are located in every rock and soil type within the environment [3,4]. Naturally occurring radionuclides are found to be the highest contributor to the soil background dose as well as external dose exposure to human [4]. The radiation from terrestrial gamma rays constitute of primordial radioactive materials (^{40}K, ^{232}Th. ^{238}U and ^{235}U) known to be in the soil, air and water in varying concentrations depending on the geology and geographical characteristics of the area under study [5,6]. The cosmic rays in an environment depend on the magnetic latitude as well as the altitude constituted by secondary and primary cosmic radiation [7][2]. It is essential to consider and determine the source of these gamma emission from these natural sources [4]. It was found in the ^{238}U decay chain that ^{226}Ra is radiological and the foremost important, as well, reference is made to ^{226}Ra instead of ^{238}U [8]. In the world today, the average value of ^{226}Ra, ^{232}Th and ^{40}K are 30, 40 and 400 Bqkg^{-1} respectively [8].

The variation in radioactivity level in soil is due to the geological differences as well as its geochemical characteristic of different locations [3]. These radionuclides present in the soil can cause additional exposure to the public from the ionizing radiation [9]. Humans are exposed to natural terrestrial radiations which originate from the upper 20 to 30 cm of the soil when considering the outdoors [6].The changes in concentrations of the naturally occurring radionuclide of uranium-thorium series and their decay products as well as potassium-40 may vary in the public external dose from terrestrial radiation[10, 11])

The global mean effective dose caused by natural background radiation of about 2.4 mSvy^{-2} which is about one third caused by the external exposure and about two thirds caused by internal exposure [12]. As far back as 1994, United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR) conditions that even the low doses can cause health damage not only the high doses emanating from the ionizing radiation creates clinically obvious damage. The target area of effect in the system is the DNA [13].   Several radioactivity assessments in soils have been carried out previously in other countries around the world such as [14, 15] and as well in Nigeria [16, 17, 3]. Monitoring and assessing the radioactivity levels in soil is of primary importance for human, organism and environmental protection; more so, the accurate measurements of these radionuclides that emit the gamma radiation [15].This study is aimed at evaluating the radioactivity levels and exposure dose emanating from a highly industrialized area of Ado-Odo Ota using laboratory gamma spectroscopy and geospatial mapping methods.

2.0 Geographical Location and Geology of the Study Area

Ado-odo Ota is located on the latitude6.6117°   to 6.6726° N and longitude 3.0576° to 3.1612° E. It is located at about 40 -60m above sea level with a population of about 400,000. It is on the way to Idiroko Border from Ota City in Ogun State Nigeria. Geologically, the study area falls within the Eastern part of Dahomey (Benin) Basin of south-western Nigerian. It stretches towards Gulf of Guinea Continental Margin. The basin constitutes the Late Cretaceous to the age of Early Tertiary [19]. The sequence of the stratigraphy found in the basin is classified into Abeokuta group, Imo group, Oshoshun, Ilaro and Benin Formation. The Cretaceous Abeokuta Group consists of Ise, Afowo and Araromi Formations consisting of poorly sorted ferruginized grit, siltstone and mudstone with shale-clay layers [19]. The geological Map of the study is shown in Figure 1.
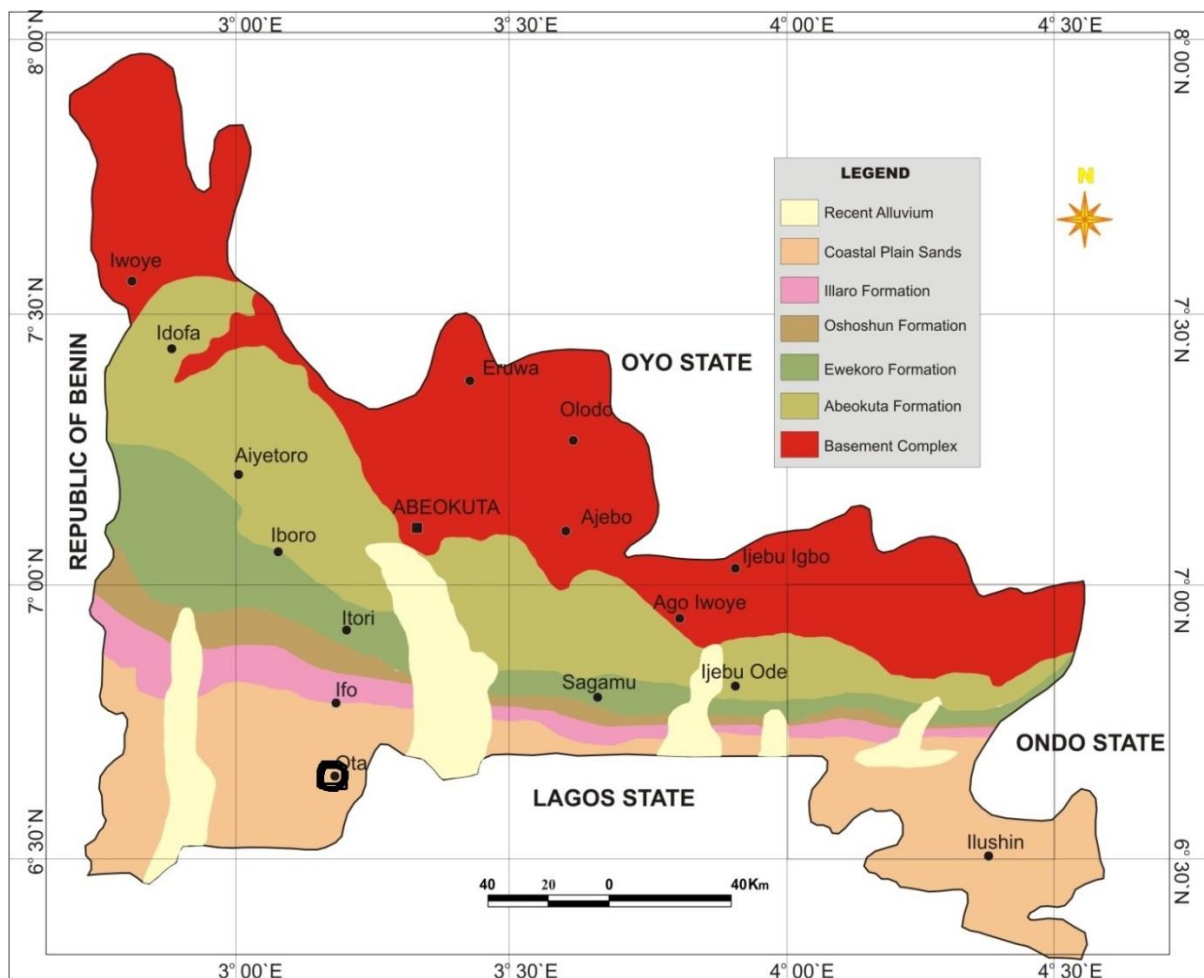
Figure 1.Geologic map of Ogun state showing the location of the study area (circled in black) Source: Nigerian Geological Survey.

3. Materials and Method

3.1 Soil Sampling for Gamma Spectroscopy Analysis

Sixteen (16) soil samples were scooped from the ground of about 10 to 15 cm using hand trowel in and around the heavily and densely industrial sites in Ota, Ogun State. The samples were first kept under the ambient temperature between 28 and 30° C for a week before drying with Oven at about 105° C for easy pulverization. Each soil sample was pulverized, passed through a sieve of 250 μm sieve size for homogeneity in powdered form according to IAEA [20,3]. 1 kg of each sieved sample was weighed out and put in the polythene nylon and

labelled accordingly for easy identification with a permanent marker. Furthermore, each soil samples in the polyethylene nylon were transferred to a well labeled high-density polyethylene bottle (HDPB) which corresponds to the label each soil sample was used to package the samples for radioactivity measurements. The bottles were washed with water and detergent and then rinsed six times with ordinary borehole water before making a final rinse with distilled water

3.2   Natural Background Radiation Measurements

The background measurements within the industrialized sites were carried out for two weeks between 7 am to 5 pm daily, coverings up to 9 km^2 using RS-25 Super Spec gamma detector from Canadian Geophysical Inc. It consists of a detector of 2.01 NaI (TI) integrated with Global Position System (GPS) as well as the data logger point on the detector coupled with Bluetooth according to [23]. The detector has a dimension and weight of 45 cm x 20cm x 14 cm and 10 kg respectively. On the ground-based measurement of radiometric mapping, 90seconds interval of transverses systematic over the selected area were mapped with 4 data values at each station with mean value. To reduce the errors in the data acquisition, measurements at the field were performed repeatedly at each point for 6 times and the dose rate average of background radiation was estimated. In addition, geospatial statistics was performed to determine the distribution of the radionuclides in the zone. This systematic configuration points the sensitive volume of the detector approximately 1 m above the ground to minimize the man-made effect on the radiation field and about 6m away from the building/walls [23]. The calibration of the detector for naturally occurring radionuclides was carried out using calibration pads with background corrections of about adjusting the high voltage according to [24] at sea level in an area with low level background less than30 nGyh^{-1}. The spectral stripping and window based methods according to IAEA, [19] were used for the ^{238}U, ^{232}Th and ^{40}K..

3.3   Geospatial Analysis of the Absorbed Gamma Dose Rate Mapping in the Study Area

The gamma absorbed dose rate measured in the air 1m above the ground were coded on the geo-reference topographical of the region. The longitude, latitude and elevation of each sampling point were measured using Garmin 62 GPS. The Isodose map of the background

natural radiation was created using ArcGIS 10.01 by applying Kriging interpolation method which reveals the most unbiased linear estimation of gamma dose rate values and its distribution. The global geodetic system of 1984 (WGS84) was adopted for the reference system of mapping the isoline according to [25, 26]

4.0 Results and Discussion

4.1 Activity Concentrations of ^{238}U, ^{232}Th and ^{40}K in the Soil Sample

Figure 2 presents the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in different locations of the industrialized site at Ado-odo Ota in Ogun State. For ^{238}U, the activity concentration varies from 32 ± 9 BqKg^{-1} to 48 ± 11 BqKg^{-1} with a mean value of 40.19 ± 10 BqKg^{-1}. The highest value was found in Civil 8 location with a value of 48 ± 11 BqKg^{-1} whereas a lower value of 32 ± 9 BqKg^{-1} was noted in a sample collected at the Mech 4 zone of the site. Comparing this highest value of 48 ± 11 BqKg^{-1} reported in Civil 8 soil sample with astandard world average value of 35 BqKg^{-1} obtained by[1]; [25], the value for this present study is higher by a factor of 0.15 BqKg^{-1}

Considering the ^{232}Th in this study site, the activity concentration ranges from 66 ± 7 to 134 ± 9 BqKg^{-1} with a mean value of 104.13 ± 8.00BqKg^{-1}. The highest value was found in EIE 15 sample location with a value of 134 ± 9BqKg^{-1}, whereas the lowest value of 66 ± 7BqKg^{-1} was noted in the sample collected at the ALDC 5. Comparing the highest value of 134 ± 9BqKg^{-1} reported in EIE 15 sample location with a value of 30 BqKg^{-1} obtained by[1];[25],it can be observed that the value of this presents studies is higher by a factor of 2.47BqKg^{-1}.

Also, in Figure 2, for ^{40}K, the activity concentrations vary from 37 ± 20 to 251 ± 24 BqKg^{-1} with a mean value 153.31 ± 19.19BqKg^{-1}. The highest value was found in Civil 8 sample location with a value of 251 ± 24BqKg^{-1},where as the lowest value was noted in Civil 1 with a value of 37 ± 20BqKg^{-1}. Comparing the highest value of 251 ± 24 BqKg^{-1} reported in Civil 8 with a value of 340 BqKg^{-1} obtained by [1]; [25], it can be found that the value of this present studies is distinctly lower than the world average
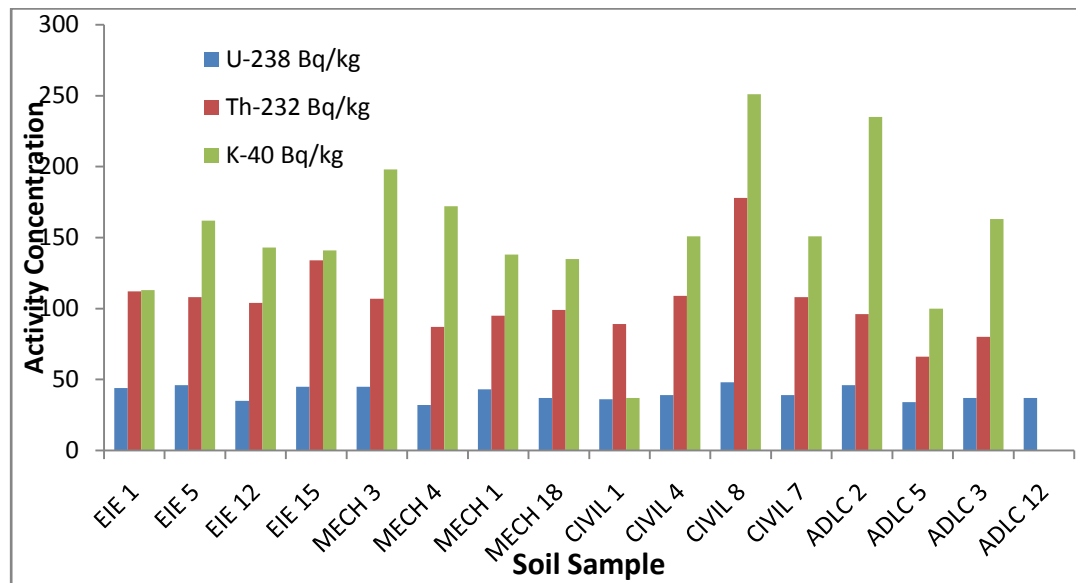
Figure 2: The Activity Concentrations of ^{238}U, ^{232}Th and ^{40}K in Selected Soil Samples

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4.2 Radium Equivalent Activity (Ra$_{eq}$) Concentrations in Soil Samples

Table 1present the radium equivalent, dose rate, and external and internal hazard index of ^{238}U, ^{232}Th and ^{40}K in different locations of the surveyed industrialized site. The radium activity describes a single index, which defines the gamma yield from the combinations of ^{238}U, ^{232}Th and ^{40}K in the soil samples in this present study. The radium equivalent activity concentration in the soil samples was calculated using Equation 1 according to [26], [1], and [27].

$$Ra_{eq}C_u(Bqkg^{-1}) = C_u(Bqkg^{-1}) + 1.43C_{Th}(Bqkg^{-1}) + 0.077\ C_k(Bqkg^{-1})$$

Where C_u is the activity concentration of ^{238}U, C_{Th} is the activity concentration of ^{232}Th and C_k is the activity concentration ^{40}K. The radium equivalent in the sample collected varies from 136.08±18.17 to 321.87±28.59 BqKg^{-1} with a mean value of 200.89±22.54 BqKg^{-1} which lies within the limit of 370 BqKg^{-1}recommended by [9] Comparing the mean value of 200.89±22.54 BqKg^{-1} reported in this work with the standard value of 370 BqKg^{-1} obtained by [9], it was observed that the mean value for this present work is lower than 168.77 BqKg^{-1}by a factor of 0.47 BqKg^{-1}.

Table 1: The Radium Equivalent Activity, Gamma Dose Rate, External and Internal Hazard Indices in Selected Soil Samples from Ota Industrialized Area

Sample ID 6.6117°N,3.0576°E	Ra_{eq} (Bqkg^{-1})	D(nGyh^{-1})
EIE 1	212.86	92.69
EIE 5	212.91	93.24
EIE 12	194.73	84.95
EIE 15	247.48	107.61
MECH 3	213.2	93.67
MECH 4	169.65	74.50
MECH 1	189.48	83.00
MECH 18	188.97	82.52
CIVIL 1	166.12	71.93
CIVIL 4	206.50	90.15
CIVIL 8	321.87	140.15
CIVIL 7	205.07	89.55
ADLC 2	201.38	89.04
ADLC 5	136.08	59.74
ADLC 3	163.95	72.21
ADLC 12	183.97	80.67
Mean	**200.89**	**87.85**

4.3 Absorbed Dose Rate

The major contributor to gamma radiation from ^{226}Ra, ^{232}Th and ^{40}K in the soil samples are the absorbed dose rate and the corresponding annual effective doses which were calculated using the mathematical expression formulated by [1]; [8]. The absorbed dose rate was calculated using Equation 2, and the values are presented in Table 1

$$DR = 0.436ARa + 0.599ATh + 0.0417Ak\,(nGyh-1)$$

The absorbed dose rate in the air observed in the samples from the study area varies from 59.7415nGyh[-1] to 140.15nGyh[-1] with a mean value of 87.85nGyh[-1]. It was found that the highest value of absorbed dose rate reported in the soil sample collected from CIVIL 8 soil with a value of 140.15nGyh[-1], whereas the lowest value was noted in ALDC soil sample with a value of 59.74nGyh[-1] as shown in Table 2. Comparing the mean value of 87.85nGyh[-1] obtained in this study with 59nGyh[-1] suggested by [1], the value for this present study is higher by a factor of 0.49.

4.4 Geospatial Analysis of the Background Dose Rate Distribution in the Study Area

The gamma dose rate, which is the background contribution effect of ^{238}U, ^{232}Th and ^{40}K are shown in Figure 9 below. It can be noted that the effect of ^{232}Th and ^{40}K shave off the higher clusters of ^{238}U distribution in the area shown in Figure 9. The clear significant distribution revealed the highest deposit of the background dose rate at the Southern part which may be that the origin of the radionuclides that contributed the dose effect has a source from the Northwest region and redeposit at the Southern part through diffusion process. The coding of the colours on the legend wasused to accurately represent the dose rate ranges based on the regulatory limit criteria according to global average external background dose rate of 60nGyh[-1] and the general public dose rate limit of 114nGyh[-1] respectively [11].
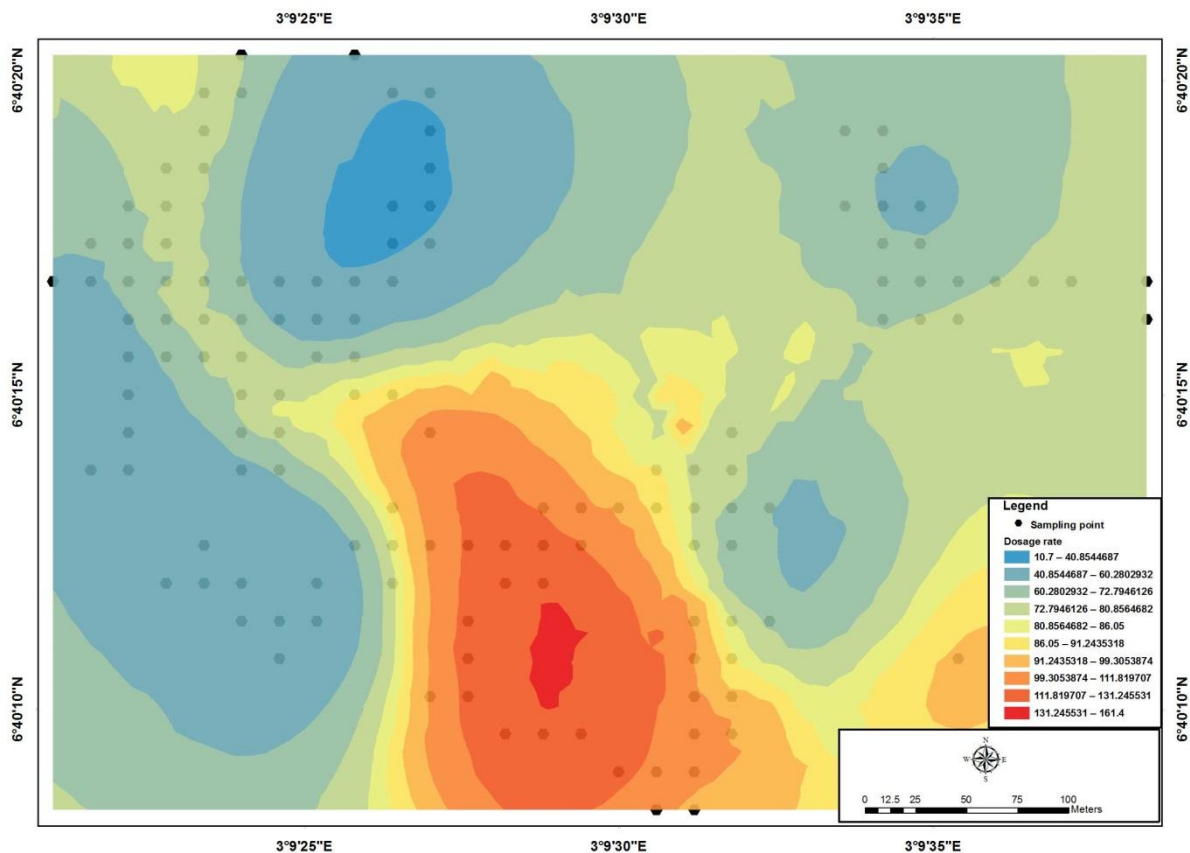
Figure 3: The Gamma Dose rate Distributions in the Study Area of Ado-Odo Ota

5. Conclusion

The soil radioactivity and geospatial analysis of background dose in different locations of the study sites were assessed to estimate the radionuclides contents in the soil, magnitude of distribution and its potential health risks exposure to the inhabitants of the region. The results show that the mean activity concentrations of ^{238}U and ^{232}Th were observed to be higher than the world mean values according to UNSCEAR by factors of 0.15BqKg^{-1} and 2.47BqKg^{-1} respectively whereas, ^{40}K was observed to be lower by a factor of 0.55BqKg^{-1}. The radiological parameters were found to be within the safe limits of precaution for environmental and human protection.The value of the activity utilization index (AUI) is in good agreement with the average world value of AUI < 2BqKg^{-1}. The mean excess lifetime cancer risk value estimated was observed to be lower than the world mean standard value by a factor of 0.36BqKg^{-1}.The ALDC 5 has the lowest external pollution load index which is 4% of the total external hazard index while CIVIL 8 contributed highest to external pollution load

index which is seen to be 10% of the total external hazard of the 16 soil samples. . The Geospatial maps for both the ^{238}U, ^{232}Th and ^{40}K indicates a trend of high concentration, NW-SE with much re-deposition at the Southern part. This reveals that the hotspot of the peak background dose exposure to the public in the region is at the Southern part of Civil 8 zone. The 3D scatter plot and 3D ribbon plot validates the strong positive correlation between the radionuclides distributions in the area. The combination of radioactivity measurements and geospatial statistical analysis will help in monitoring and regulating the background radiation effect from the soil and its potential zone of high dose ezposure to the inhabitants near industrialized areas.

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