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RADIOMETRIC ASSESSMENT OF THE SEWAGE TREATMENT SITE AT AHMADU BELLO UNIVERSITY, ZARIA

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ABSTRACT

The radiometric assessment of Ahmadu Bello University's sewage treatment site in Zaria was conducted in three profiles along two ponds in the research region. The goal is to estimate the concentration and dose rate of naturally occurring radioactive elements, as well as to assess the risk to workers in the area. Gamma-ray spectrometer alongside with GPS (global positioning system) were used. The concentration of ^{238}U, ^{232}Th and ^{40}K were contour to show the areas of high concentration of the radionuclide. The data were taken at 5 m interval in each profile along the sewage ponds. The data collected were interpreted using the golden software surfer 16. The concentration of the radionuclide ^{238}U, ^{232}Th and ^{40}K in the study area were found to be between the range of 2 ppm - 21 ppm which is equivalent to the activity levels of 22.2 Bq/kg - 233.1 Bq/kg for ^{238}U, 14.5 ppm - 29.5 ppm which is equivalent to the activity levels of 58.87 Bq/kg - 119.77 Bq/kg for ^{232}Th and 2.5% - 10.5% which is equivalent to the activity levels of 782.5 Bq/kg - 3286.5 Bq/kg for ^{40}K respectively. The dose rate of the radionuclide ^{238}U, ^{232}Th and ^{40}K in the study area were 11.35 nGy/h - 119.18 nGy/h for ^{238}U, 36.16 nGy/h - 73.57nGy/h for ^{232}Th and 32.69 nGy/h - 137.29 nGy/h for ^{40}K respectively. The total count and absorb dose spanned within the range of 330 - 395 cps and 115 - 200 nGy/h respectively. The result show that the absorbed dose rate of the radionuclide (^{238}U, ^{232}Th and ^{40}K) and total absorbed dose rate are above world average.

Keywords: Radioactivity, Uranium, Thorium, Potassium, Contaminant, Dose rate and Total count.

INTRODUCTION

The existence of long-lived radionuclides such as ^{238}U, ^{232}Th, and ^{40}K causes majority of radioactivity in the environment. The distribution of rocks in the earth crust is determined by the types of rock formation (Mujahid and Hussain, 2011). Radionuclides seep into the soil and are transferred to rivers by rain and flows when rocks disintegrate naturally (Taskin *et al*., 2009). One of the key determinants of natural background radiation is the active concentration of radionuclides in soil. The distribution of these radionuclides in soil, water, sediment, rock, and construction materials is vital for protection, measurement, geoscientific study, and guidance for their use and management (Ravisankar *et al*., 2011).

Human activities (mining, milling, and processing of uranium ores and mineral sands, fertilizer production, burning of fossil fuels, metal refining, farming, and so on) have increased natural radioactivity concentrations in the environment. Radioactivity in surface continental seas is mostly caused by the existence of radioactive materials in the earth's crust. These radioactive elements can enter surface continental seas via a variety of processes or activities. Rivers and dams can be contaminated by surface runoff of rain water transporting leached radionuclides from factories, mine waste, soil weathering, and agricultural areas (Pujol & Sanchez-Cabeza, 2000). Long-term radioactivity of water bodies is affected by contamination processes caused by gravitational settling and other depositional phenomena. The majority of radioactive elements are found in the aquatic ecosystem's sediment compartment (Oni *et al*., 2011).

The study area is located within the Samaru main campus of Ahmadu Bello University Zaria, Kaduna State, and is roughly bound by latitude

Plate 1: Location of the study area.

The area has a tropical continental climate, which is roughly described as a tropical Savannah climate with distinct wet and dry seasons. The daily maximum temperature progressively rises from 33 °C in January to 40.6 °C in April. It swiftly decreases to its lowest in August (26.6 °C) and then increases again to a second peak in October (38.2 °C) (Ahm, 1972). Furthermore, geological analysis of the studied region reveals that it is underlain by rock of the Older Granite, which is part of the Zaria granitic Batholiths (Oden *et al.*, 2015). Although there are no outcrops of granite in the research area, lateritic soil generated from weathering is well exposed in the northeastern half of the study area. This lateritic soil is approximately 3 m thick and varies from a more hardened and less compacted layer at the top to a less hardened and more compacted layer at the bottom.

River sediment is thought to have a long-lasting and dependable record of radionuclide pollution in rivers (Banzi et al., 2000). Knowledge of natural radioactivity inherent in aquatic sediments allows one to analyze any potential radioactive threats to humans posed by the use of such materials, particularly in building and construction (Ramasamy *et al.*, 2009), and the current study site might not be an exception. The objective of the work, however, is to carry out radiometric investigation of the Ahmadu Bello University, Zaria sewage treatment site along the side of two ponds. The investigated radioactivity level would thereafter inform the impact of radiological hazards associated with the site and the extent of damage based on the world average dose rate.

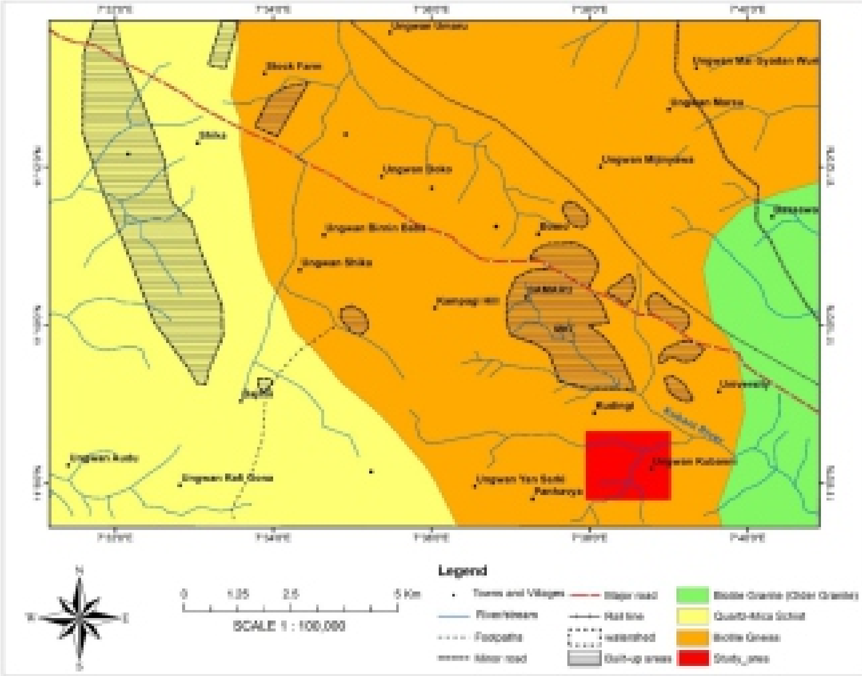

Figure 1: Geological map of the Kubanni (Adapted from McCurry, 1970).

MATERIALS AND METHODS

The materials used for the research work are:

1. Gamma – ray spectrometer (Gamma surveyor Version -77)
2. Global position system device (GPS)

The Gamma surveyor (Version -77) is a portable handheld device designed for on-the-go radiation detection and measurement. It features a high-resolution detector, real-time analysis, and a user-friendly interface. Ideal for environmental monitoring, emergency response, and nuclear facilities management, it offers quick assessments and data processing, ensuring safety protocols are met (Plate II).

Specifically, Gamma surveyor offers three basic measuring modes:

- Spectral measurements with determination of K, U and Th concentrations
- Precise radiometric searching for gamma-ray sources
- the measuring system supports points, profile and continuous measurement with the use of external GPS data

Sixty-three (63) *in-situ* gamma spectrometric measurements were taken using the Gamma surveyor. The instrument was placed on the earth surface with the detector height in the Gamma surveyor at 40 mm from the surface, this places the detector at a constant low height of 40 mm above the earth surface as recommended by IAEA in order minimize the effects of variation in local relief and radioelement distribution (IAEA, 2003). The measurements were made at each 5 m along the profiles for duration of 3 minutes and the GPS coordinates of each measurement point was obtained using a GPS. Finally, field detection data of a complicated spectrum of gamma ray decay energies from a sequence of potassium, uranium, and thorium background radiation was obtained. The Gamma surveyor displayed the readings and data collected in parts per million (ppm) for uranium and thorium, and in percentages (%) for potassium. The apparatus recorded the total count of the concentration in count per second (CPS), as well as the dose rate in nanogray/hr. (nGy/hr.).

Plate II: Portable Handheld Gamma Surveyor.

For time set at 3 minutes, the measurements with the Gamma Surveyor which contains NaI (Tl) detector have a valid order of 0.1 % for K concentration and 1 ppm for U and Th concentrations. The measuring energy range of the Gamma surveyor are; 100 keV to 3 MeV for NaI. A full spectra and assay mode was set on the multi-channel gamma spectrometer for the measurement. This mode measures the complete spectrum from which it evaluates the count per second (cps) values in the region of interests (ROIs) and calculates the concentrations of elements U (ppm), Th (ppm), K (%), Total count (cps) and Dose rate (nGy/h). The concentration of U and Th are based on detection of radioisotopes Bi-214 and Tl-208 while the concentration of K is determined directly. Stabilization of measurements was achieved using built in Cs-137 reference source. The dose rate at 1m above the ground is computed by the Gamma Surveyor according to IAEA recommendations of 1 ppm of U, 1 ppm of Th and 1% of K represents the activity levels of 5.675 nGy/h, 2.494 nGy/h and 13.078 nGy/h respectively. According to UNSCEAR (2000), 2.9 ppm of ^{238}U, 11.084 ppm of ^{232}Th, and 1.34% of ^{40}K in rocks represents 33 Bq/kg, 45 Bq/kg, and 420 Bq/kg, respectively.

This work adopted the world average statistics for ^{238}U, ^{232}Th, and ^{40}K in rocks represented as (33 Bq/kg = 2.9 ppm), (45 Bq/kg = 11.084 ppm), and (420 Bq/kg = 1.34%), respectively. The absorbed dose rate of 60 nGy/h for global average (UNSCEAR, 2000).

RESULTS AND DISCUSSION

To prevent picture colour bias and improve signal-to-noise ratio, the radiometric data are first summarized using colour images. Gamma Surveyor measurements yield concentration maps for eU, eTh, %K. The concentration of ^{238}U, ^{232}Th, and ^{40}K were contoured to illustrate areas with high radioactive concentration. The concentration of these radionuclides was determined at every 5 m along each profiling of the sewage pond. The total count and absorbed dose rate were also obtained from the Gamma Surveyor, plotted and compared with global average data.

Profile 1 (Figures 2A - C and 3A -B) exhibits concentrations ranging from 2 ppm to 21 ppm for ^{238}U, 19.5 ppm to 28.5 ppm for ^{232}Th and about 2.3 % to 7.2 % for ^{40}K with corresponding activity levels ranging from 22.215 Bq/kg to 223.1 Bq/k, 79.18 Bq/kg to 115.72 Bq/kg and 719.9 Bq/kg to 2253.6 Bq/kg, respectively. The total count and absorbed dose rate in profile 1 are in the ranges of 332 - 384 cps and 115 - 190 nGy/h, respectively.

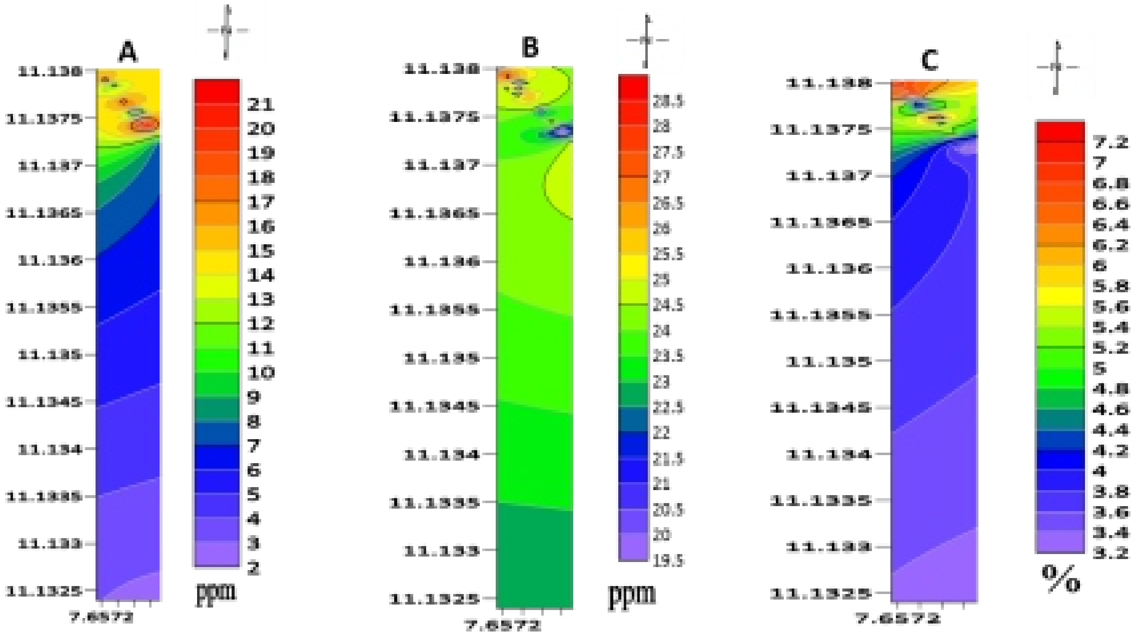

Figure 2: Concentration of Uranium (A), Thorium (B) and Potassium (C) along profile 1.

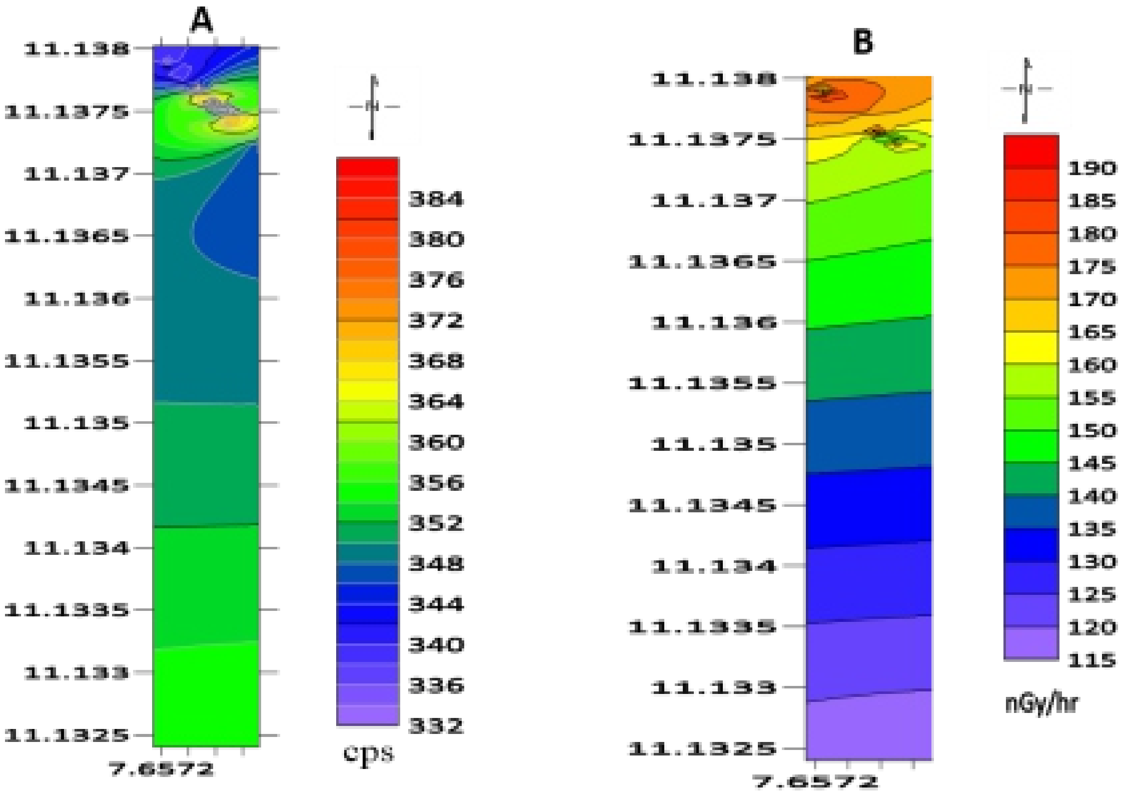

Figure 3: Total count (A) and dose rate (B) along profile 1.

In contrast, profile 2 (Figures 4A-C and 5A-B shows concentrations spanning from 3 ppm to 20 ppm for ^{238}U, 16.5 ppm to 29.5 ppm for ^{232}Th and, about 3.8% to 90% for ^{40}K, with activity levels varying from 33.3 Bq/kg to 222 Bq/kg, 66.99 Bq/kg to 119.77 Bq/kg, and 1189.4 Bq/kg to 2817 Bq/kg respectively. The total count and absorbed dose rate in profile 2 fall within the ranges of 332 - 376 cps and 115 - 195 nGy/h, respectively.

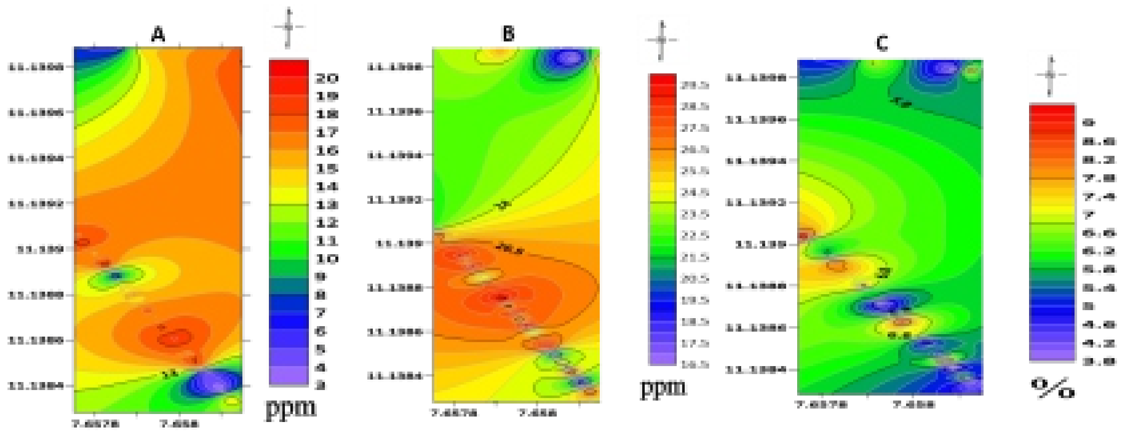

Figure 4: Concentrations of Uranium (A), Thorium (B) and Potassium (C) along profile 2.

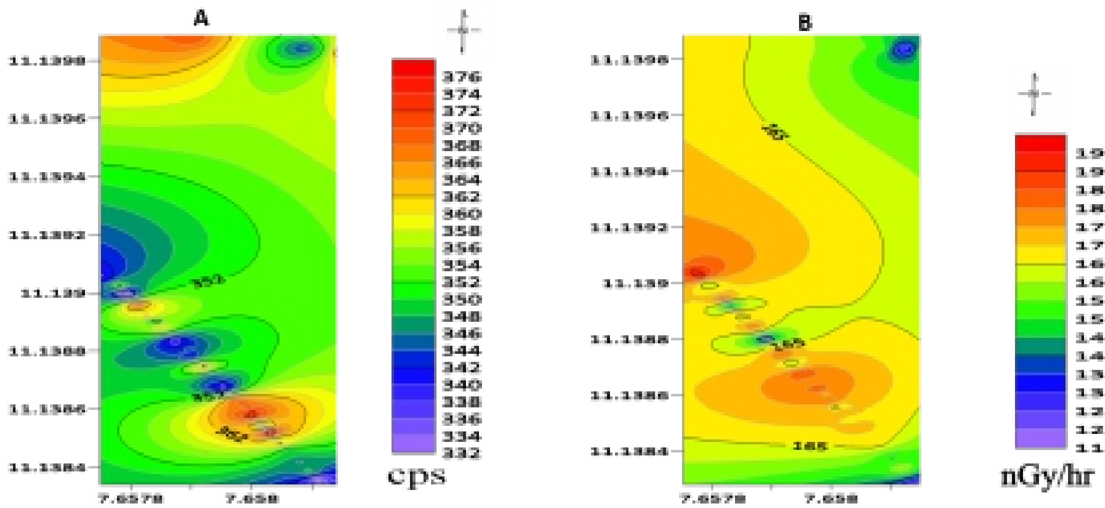

Figure 5: Total count (A) and dose rate (B) along profile 2.

Profile 3 (Figures 6A-C and 7A-B), on the other hand, demonstrates concentrations ranging from 4.5 ppm to 17.5 ppm for 238U, 14.5 ppm to 29.5 ppm for 232Th, and about 2.5% to 10.5% with associated activity levels ranging from 49.95 Bq/kg to 194.25 Bq/kg, 58.87 Bq/kg to 119.77 Bq/kg, and 785.5 Bq/kg to 3286.5 Bq/kg respectively. The total count and absorbed dose rate in profile 3 are within the ranges of 330 - 395 cps and 115 - 200 nGy/h, respectively.

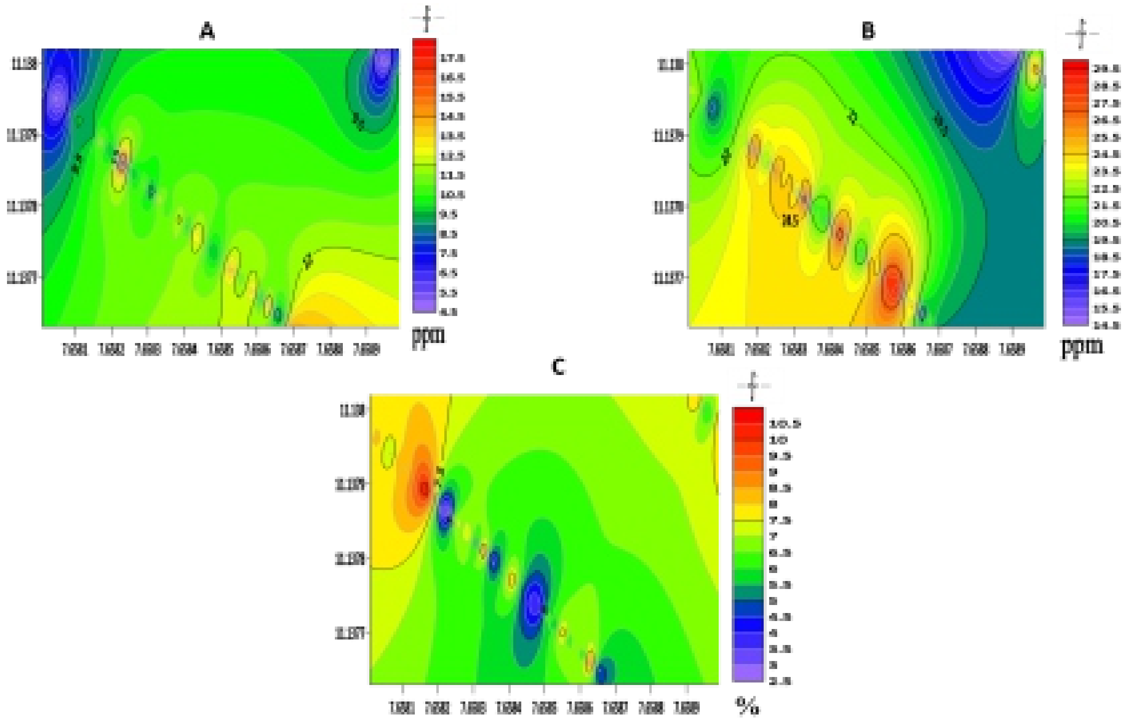

Figure 6: Concentrations of Uranium (A), Thorium (B) and Potassium (C) along profile 3.

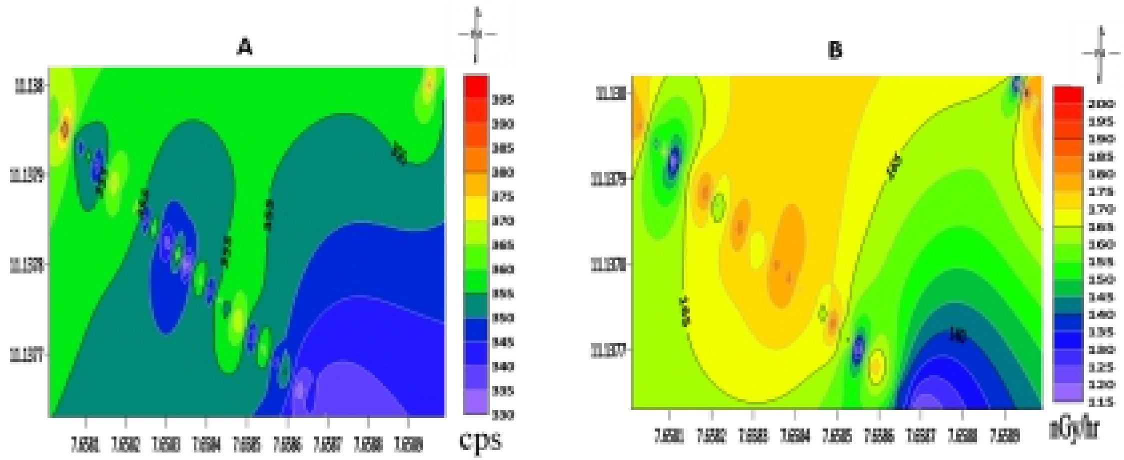

Figure 7: Total count (A) and dose rate (B) along profile 3.

Profile 1 differs from profile 2 and profile 3 in terms of the concentrations of ^{238}U, ^{232}Th, and ^{40}K, as well as the total count and absorbed dose rate. Profile 1 shows a unique range of concentrations and activity levels compared to profiles 2 and 3. Similarly, profile 2 has distinct values for the concentrations and activity levels when compared to profiles 1 and 3. Profile 3, on the other hand, exhibits its own set of concentrations and activity readings that differentiate it from profiles 1 and 2.
The information extracted from these profiles can be utilized in various ways in the field of environmental monitoring or radiological assessment. Profile 1 and profile 2, despite having differences, contribute to understanding the distribution and levels of radioactive elements within the study area.

The concentrations of uranium-238 (^{238}U), thorium-232 (^{232}Th), and potassium-40 (^{40}K) as well as the total count and absorbed dose rates in the different profiles provide valuable insight into the radiometric investigation conducted at the sewage treatment site adjacent to the ponds at Ahmadu Bello University, Zaria.

The differences observed between profiles 1 and 2 and the distinctive characteristics of profile 3 likely reflect spatial variations in the distribution of radionuclides within the study area. These variations could be indicative of differing geological compositions, local anthropogenic activities, or variations in the concentration of radioactive elements naturally present in the environment.

As for the potential uses of profiles 1 and 2 from a radiometric investigation perspective, they provide critical data for assessing environmental radioactivity levels, identifying potential radiation and possible health risk.

CONCLUSION

The concentration of ^{238}U, ^{233}Th, and ^{40}K in the study region is higher than the average world standard report; according to UNSCEAR (2000). As a result, the study area contains many contaminants that contribute to the increase in radionuclide concentrations. Furthermore, the absorbed dose rate in the study area ranges between 115 and 200 nGy/h, which is significantly higher than the global average of 60 nGy/h (UNSCEAR, 2000). Therefore, the research area is classified as a high natural background radiation risk area due to the high level of absorbed dose rate; caution was advice and periodic radiometric should carried out to contain it possible risk.

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CONFLICT OF INTEREST

This study has no conflicts of interest.

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