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Comparative Evaluation of Radioactive Contamination in Soil Samples from Mining and Non-mining communities of Barkin Ladi Local Government Area, Plateau State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author ECH conceptualized the study, planned the methodology, drafted the original manuscript and oversaw the research. Author TSL analysed the data, looked at and edited the manuscript, and participated in the investigation. Author NG participated in the investigation, collected data and helped to analyze the result. Author AS offered research assistance, assisted in literature review and data collection. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To determine the level of radioactive pollution in soil samples from mining and non-mining communities in Barking Ladi local government area of plateau State and evaluate the implications for public health.

Study Design: A Comparative Study was conducted using soil samples collected randomly from mining and non-mining communities (four samples from each). The samples were subjected to analysis for gross alpha and beta radioactivity concentration at the Centre for Energy Research and Training, Ahmadu Bello University, Zaria, using a Protean Instrument Corporation (MPC 2000 Dual Phosphor) detector.

Results: The study revealed that the gross alpha activity concentration of the soil was in the range of 0.03747 $\pm$ 0.0150 to 0.04995 $\pm$ 0.0157 Bq/g, while beta activity concentration was in the range of 0.03995 $\pm$ 0.0301 to 0.1357 $\pm$ 0.0212 Bq/g. The maximum value of alpha activity concentration was 0.04995 $\pm$ 0.0157 Bq/g, and the maximum value of beta activity concentration was 0.1357 $\pm$ 0.0212 Bq/g.

Conclusion: The study shows that the radioactive concentrations in soils from both the mining and non-mining communities are below the World Health Organization's (WHO) recommended standard of 0.5Bq/l and 1.0Bq/l for gross alpha and gross beta in drinking water respectively. Even though these findings show that the soils from the study communities are safe for agricultural activities, it is essential to carry out routine monitoring activities to guard against potential radioactive pollution and protect public health.

Keywords: Radioactive contaminants; gross alpha and beta radioactivity; mining activities; soil pollution; radionuclides.

1. INTRODUCTION

The Soil is a very vital component of the ecosystem. It facilitates plant growth and preserves life [1]. However, human activities such as mining release radioactive substances, which contaminate the soil, water, and food crops, making them unsafe for human consumption [2]. The increasing global demand for natural resources has exacerbated environmental deterioration and increased the release of radioactive substances [3]. In Nigeria, the activities of artisan mining have increased, giving rise to widespread environmental degradation and poisoning in areas like Barkin Ladi Local Government Area, Plateau State [4,5,6].

Mining activities modify the composition of the soil, releasing radioactive elements like thorium, potassium, and uranium, and this pose serious human threats to the heath of humans and animals [7,8]. These radionuclides can produce ionizing radiation, which can cause cancer, genetic damage and other adverse health consequences [9]. Soil degradation from mining operations also negatively impacts food security and quality [10].

One of the major ways of human exposure to heavy metals and radionuclides is through the consumption of contaminated food and water [11,12]. Studies in Barkin Ladi have revealed excessive levels of lead, cadmium, copper, zinc and nickel in vegetables, beyond the acceptable limits [11,13]. Recent investigations in the same region has also detected considerable alpha and beta activity levels in crops irrigated with water from mining ponds [14], as well as substantial contamination factors for radioactive elements in edible plants [15]. Excessive quantities of 232Th, 238U, and 226Ra have been detected in the region's soil, which may have an impact on plant growth [16].

Several health issues have been linked to the anticipated daily intake of heavy metals through the consumption of contaminated food crops [13]. According to Orisakwe et al.'s [13] report, the bio-concentration factor of heavy metals in the investigated vegetables varies between 0.026 and 7.52 indicating accumulation in the food chain. Target hazard quotient (THQ) values exceed 1 for both adults and children, indicating potential health risk in consuming the vegetables.

The lack of adequate artisanal mining supervision in Nigeria has increased the risk of environmental contamination [6]. Poor management of waste and land rehabilitation also contribute greatly to environmental contamination and pose long-term health concerns to local communities [17].

Considering these background, it is crucial to investigate radioactive contamination in soil samples from mining and non-mining settlements in Barkin ladi. The study intends to address the knowledge gap on radiological implications of artisanal mining, and also advice policymakers and stakeholders on measures to mitigate environmental pollution and protect public health. Specifically the study will assess alpha and beta activity levels in soil samples from mining and non-mining areas, as well as examine the distribution and concentration of radionuclides in the study area. The results of the study will contribute to evidence –based policies and regulations for sustainable mining and environmental management in Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

The Study area is Barkin Ladi Local Government area, Plateau state Nigeria. The study area (Fig. 1) is bounded by the following coordinates:

Latitude: 09° 45' 26.64" N to 09° 22' 50.16" N

Longitude: 08° 55' 24.60" E to 08° 41' 46.16" E

The area was selected based on the substantial mining operations carried out in the area due to its large mineral deposits. The mining locations were selected on the basis of subsisting mining activities. The non-mining locations on the other hand were selected as control locations with comparable ecological features.

2.2 Soil Sample

The stratified sampling technique was used to collect eight soil samples (four from mining locations and four from non-mining locations). From each location, about I kg of soil was taken from a depth of 0-20cm which represents the topmost layer susceptible to contamination. The soil samples were air dried at ambient temperature, crushed and sieved to obtain uniform particle size, and kept in air tight containers for radioactivity analysis.

2.3 Radioactivity Analysis

The Protean Instrument Corporation (MPC 2000 Dual Phosphor) detector at Ahmadu Bello University, Zaria was used to analyze the gross alpha and gross beta activity in the soil samples. The detector had an alpha background of 0.5cmp and beta background of 0.73cmp with a detector efficiency of 87.95% and 42.06% for alpha and beta respectively.

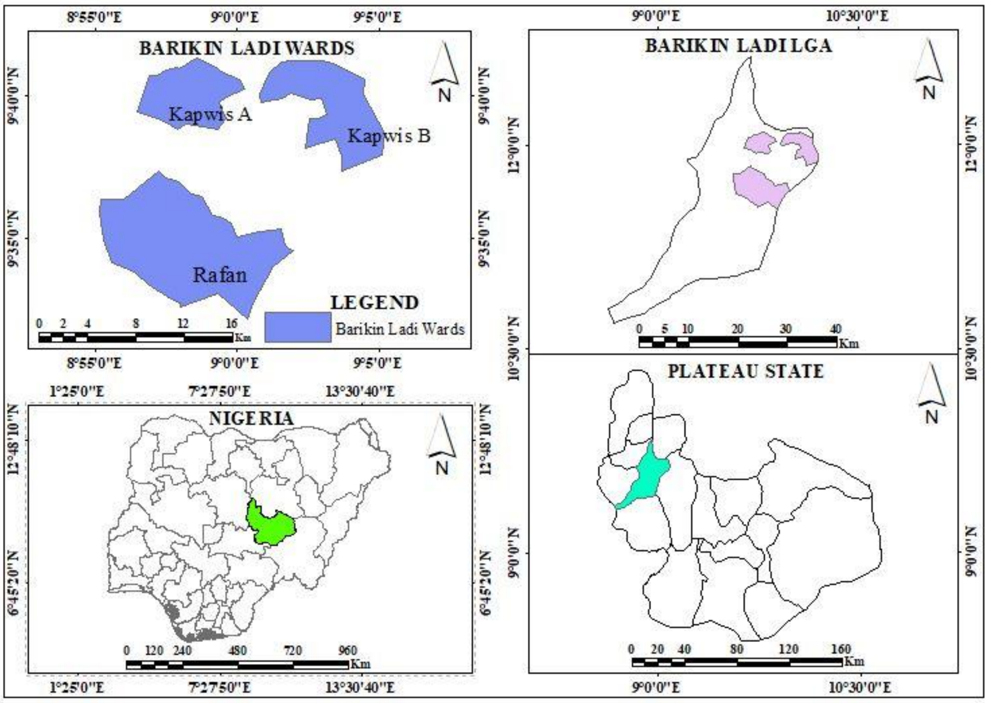

Fig. 1. Map of Barkin Ladi Local Government Area, Plateau State, Nigeria

3. RESULTS AND DISCUSSION

Tables 1 and 2 shows the results of the radioactivity measurements of gross alpha and gross beta concentrations in soil samples collected at mining and non-mining locations in Barkin Ladi Local Government area of Plateau state.

The analysis of soil samples from mining and non-mining areas in Barkin Ladi, Plateau State, reveals significant variations in gross alpha and gross beta activity concentrations. Notably, samples from mining regions (Samples A and B) showed remarkably higher levels of radioactive contamination compared to non-mining regions (Samples C and D). This disparity suggests that mining activities significantly contribute to increased radioactive contamination levels.

The highest contamination levels were recorded at the Nafan (Sample B), Rafan Ward - Tin Mining Area, with gross alpha and beta values of 0.04997 ± 0.0157 Bq/g and 0.1357 ± 0.0212 Bq/g, respectively.

The good news is that the values obtained are all below the World Health Organization's [18] recommended safety limit for drinking water of 0.5Bq/l for gross alpha and 1.0Bq/l for gross beta as indicated in Tables 3. This is an indication that there low risk to human health in the region.

Comparatively, the study's gross alpha activity concentration ranges from 0.03747 ± 0.0150 to 0.04995 ± 0.0157 Bq/g, and beta activity concentration ranges from 0.03995 ± 0.0301 to 0.1357 ± 0.0212 Bq/g. While these levels are within acceptable limits, they diverge from two studies by Waida et al. [15,19] that found elevated radioactive element pollution in soil, water, and edible plants in Barkin Ladi and Mangu. The reported discrepancies may be due to differences in sample locations, procedures or analytical techniques.

The results of the present study align with Pahalson et al.'s [20] findings of low radioactivity levels in the neighboring Jos City Centre. However, they contrast with reports of high gross alpha and beta radiation levels in surface water samples from Plateau State mining locations [21], and elevated radioactivity levels in water bodies near mine workings [22].

Lubis et al. [14] highlighted the potential risk of radioactive contamination in the food chain by detecting alpha and beta activity in vegetables irrigated with water from mining ponds in Barkin ladi. Paul et al. [16] conducted an extensive investigation on naturally occurring radioactive materials (NORMS) in Nigerian Mining sites and found higher amounts of 232Th, 40K, 238U, and 226Ra in Soil. Parsa et al. [23] examined the influence of tin mining on built environment and houses in Jos region and found high levels of radioactive substances and heavy metals.

Table 1. Sample Locations, IDs, and Descriptions

S/No	Sample Location	Sample ID	Sample Description
1	Atoso (Sample A), Rafan Ward	Sample A	Tin Mining Area
2	Nafan (Sample B), Rafan Ward - Tin Mining Area	Sample B	Tin Mining Area
3	Rapyam (Sample C), Rafan Ward	Sample C	Non- Tin Mining Area
4	Zakupang (Sample D), Kapwis Ward	Sample D	Non- Tin Mining Area

Table 2. Gross Alpha and Gross Beta Activity Concentrations in Soil Samples Collected at Mining and Non-Mining Locations

S/No	Sample ID	Gross Alpha Activity (Bq/g)	Gross Beta Activity (Bq/g)
1	Sample A (Tin Mining Area)	0.03747 ± 0.0150	0.03995 ± 0.0301
2	Sample B (Tin Mining Area)	0.04997 ± 0.0157	0.1357 ± 0.0212
3	Sample C (Non-Tin Mining Area)	0.03364 ± 0.0123	0.04589 ± 0.0205
4	Sample D (Non-Tin Mining Area)	0.02937 ± 0.0109	0.05321 ± 0.0231

Table 3. Comparison of Gross alpha and Beta Activity Concentrations with World Health Organization's (WHO, 2022) Safe limits

Parameter	Range of Measured Value (Bq/g)	Recommended safe Value (Bq/l)
Gross Alpha Activity	0.02937- 0.04997	0.5
Gross Beta Activity	0.03995-0.1357	1.0

Radioactive contamination in Bakin ladi poses serious threats to plant and animal health, with far-reaching effects for agriculture, conservation, and human well-being. Radioactive pollution can alter plant DNA, causing genetic mutations and shifts in development patterns. This can lead to reduced crop yields, lowering agricultural production. Plants can also absorb radioactive isotopes, which may enter the food chain and contribute to bioaccumulation. Furthermore, radioactive contamination can harm soil quality by modifying its chemistry and reducing nutrient availability.

These dangers have been shown in the study by Lubis et al. [14] who discovered significant alpha and beta activity in crops irrigated with mine water, whereas Waida et al. [19] found substantial contamination factors for radioactive elements in edible plants. Paul et al. [16] discovered higher amounts of 232Th, 40K, 238U, and 226Ra in soil, potentially affecting plant growth. Animals grazing in contaminated locations may eat radioactive isotopes, causing bioaccumulation in tissues and potentially endangering human consumers. Animals exposed to radiation can potentially develop genetic abnormalities and become more susceptible to disease. Radioactive contamination can harm biodiversity and ecosystem equilibrium, jeopardizing agricultural output and food security. Radiation exposure to livestock and wildlife may have an impact on human consumption. Soil degradation can result in diminished fertility and crop output.

Although, the present study findings indicate that soils in the analyzed communities are safe for agricultural use. However, the varying radioactive contamination reported in these studies underscore the complexity of the issue and the importance of location-specific assessments and regular monitoring and assessment of radiation levels in Plateau State to maintain public health safety

4. CONCLUSION

In this study, the gross alpha and gross beta radioactivity levels in soil samples from mining and non-mining areas in Barkin-Ladi local Government area of Plateau Sate were measured. Findings from the analysis revealed that the activity levels of radioactive contaminants in the study area are below the recommended WHO safety limits of 0.5 Bg/l and 1.0 Bq/l in drinking water for alpha and beta activity levels, respectively. The results, however showed a remarkable difference in the activity levels between the mining and non-mining areas with the highest gross activity level of 0.04997 $\pm$ 0.0157 Bq/g in the mining area, and the least gross activity level of 0.02937 $\pm$ 0.0109 Bq/g from the non-mining area. The maximum gross Beta activity level of 0.1357 $\pm$ 0.0212 Bq/g was recorded at the mining area, while the least beta activity level of 0.03995 $\pm$ 0.0301Bq/g was recorded at the non-mining area. Despite the overall low level of radioactive contaminates recorded, the study still emphasizes the necessity to embark on routine monitoring of radioactive concentration levels in mining areas to avoid unforeseen rise in radioactive concentration levels which can put the life of residents at risk.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of this manuscript. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1. Name if AI: Meta AI, based on Llama 3
2. Input prompts include: harmonize text, make coherent, polish.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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