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Assessment of Radon Concentration in Groundwater Sources in Mubo-North Metropolis, Adamawa State, Nigeria.

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Abstract

Radon is a natural alpha gas emitter, poses significant detrimental health risks when present in drinking water sources. This research assesses the Radon levels of concentration in groundwater in Mubi−North metropolis, Adamawa State, Nigeria, with a view to evaluate potential health implications for the local population. Water samples were collected from five different boreholes, in different sampling locations, the samples were analyzed with MPC2000−DP at center for energy research and training (CERT) Ahmadu Bello University, Zaria. Radon activity concentration was estimated from gross alpha activity concentration results in Bq/L. The results obtained for the five locations were ranged from 0.0082−0.1518 Bq/L. The results showed that location D recorded the highest Radon concentration, while location B recorded the least concentration. The concentration of Randon in all the sampling locations were below the recommended screening limit of 0.5Bq/L by world health organization (WHO) and other radiation protection agencies, therefore the water from the locations is good for drinking and domestic activities.

Keywords: Radon, Gross alpha, Groundwater, Concentration, Health risk, Mubi−North.

1. Introduction

The presence of radionuclide in water poses a number of health hazards, especially when these radionuclides are deposited in the human body through drinking. Dissolved radionuclides in water emit particles (alpha and beta) and photons (gamma) which gradually serve as exposure pathway to living tissues. Human and animal studies show that radiation exposure at low to moderate doses may increase the long-time incidence of cancer (Farai et al., 2023).

Radon (Rn) is a naturally occurring radioactive noble gas with three major isotopes, namely; radon (^{222}Rn), thoron (^{220}Rn) and actinium (^{219}Rn) with half-lives of 3.8 days, 55.8 seconds and 3.98 seconds each (Adetoro et al., 2021). These isotopes occur due to the spontaneous decay of ^{232}Th or ^{234}U and ^{238}U which exists in soil, rocks, and air. While ^{220}Rn is a byproduct of the alpha decay of ^{224}Rn in the ^{232}Th decay series, ^{222}Rn is part of the ^{238}U decay series (Abdullahi et al., 2020). The significance of ^{222}Rn is because of how highly abundant its weight is compared to the overall combination of other isotopes of radon; hence, the name 'radon' refers solely to this substance (Dankawu et al., 2021). ^{222}Rn exists in soil, water, and air, due to its instability, it disintegrates into four (4) radioactive decay products called progeny, namely, polonium (^{218}Po), bismuth (^{214}Bi), lead (^{214}Pb) and polonium (^{214}Po) (Belete & Anteneh, 2021).

The ground is the principal source of radon. It emanates from rock, soil, and building materials, such as concrete, cement and paint, and diffuses into buildings through the floor, holes and cracks in the walls (WHO, 2023). It may also diffuse from rocks in the crust of the Earth into water, and exists in water sources, such as groundwater and surface water, in varying proportions due to its solubility in water (USEPA, 2003).

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2. Materials and Methods

Materials

The materials used for this work are as follows:

- Gas-flow proportional counting system (MPC 2000 -DP).
- Planchets.
- Electric hot plate.
- Drying oven.
- Glassware.
- Analytical digital weighing balance.
- Spatula.

Reagents

- Vinyl acetate.
- Nitric Acid
- Acetone.

Study Area

The area for the study is Mubi-North Metropolis, where five different locations which in include; Federal Polytechnic Mubi reservoir (A), Adamawa State University (B), Faculty of Management Science borehole water (C), Lokuwa borehole water (D), Shagari Locust borehole water and Wuro gude borehole water (E).

Sampling

The method adopted for this research was convenient sampling method.

In order to cover the study areas, a survey was done to know the number of wells available in the areas and frequently used by the dwellers for drinking and domestic purpose. The weather condition of the time of sampling was favorable. The place where samples were collected were marked by using a global positioning system (GPS).
The procedure involves the following: -

(i) The sample container was rinsed three times with the water being collected, to minimize contamination from the original content of the sample container.
(ii) Each sample were collected into two litres of gallon and the amount of water collected was such that an air space of about 1% of container capacity was created for thermal expansion was left.
(iii) 1ml of concentrated nitric acid were added to the sample immediately after collection to reduce the pH level and to minimize precipitation and absorption on container walls.
(iv) The samples were tightly sealed and label with a marker and kept in the laboratory until analysis.

Sample Analysis

Evaporation was done using hot plate without stirring in open 500ml beaker. It took an average of two and half days to complete the evaporation of a two-litres sample. The residue was washed with distilled water and transferred into a 7.1cm^2 counting planchet, the sample residue was dried in a drying oven at 105^{0}C for two hours, cooled in a desiccator, weighed and counted. The sample residue was stored in a desiccator until it was counted.

Sample preparation efficiency was derived by taking the weight of empty beaker, W_B and weight of beaker plus sample after evaporation, W_{B+S}. The difference between W_{B+S} and W_B gives the weight of sample. The content of the beaker is then transferred to a planchet and the weight of the beaker was taken again, W_{B-S} . The difference between W_{B-S} and W_B gives the total weight of sample unrecovered from the beaker.

$$Sampling\ Efficiency = \frac{(W_{B+S} - W_B) - (W_{B-S} - W_B)}{W_{B+S} - W_B} \times 100\%$$ (WHO, 2023)

The Radon concentration activity is calculated using the relationship:

$$A_{Rn} = A_{g\alpha}E{\times}_{Rn}F_{Rn}$$ (USEPA, 2003)

Meaning of each term:

- A_{Rn}: This is the radon activity concentration in the water sample, usually expressed in Bq/L.
- $A_{g\alpha}$: This is the measured gross alpha activity concentration of the water sample, i.e. the total alpha activity from all alpha-emitting radionuclides present (such as U, Ra, Rn and their short-lived progeny), again in Bq/L.
- F_{Rn}: This is the radon fraction factor, a dimensionless factor representing the proportion of the total gross alpha activity that is due specifically to radon-222 and its short-lived alpha-emitting progeny under the measurement conditions. It may be derived from separate radon measurements, equilibrium assumptions, or regulatory guidance so that $A_{g\alpha}{\times}F_{Rn}$ estimates the radon-related component of the gross alpha signal.
- E_{Rn}: This is the overall detection efficiency for radon-222 (and its contributing progeny) in the gross-alpha counting setup, expressed as counts per unit activity.

Table 1.0: Gross Alpha and Radon Radioactivity concentration (Bq/L)

Constant	**Meaning**	Value	Source
F_{Rn}	Fraction of gross alpha attributable to radon-222	**0.74**	USEPA Radionuclides Rule (2003)
E_{Rn}	Counting efficiency for radon-222	**0.75**	USEPA Radionuclides Rule (2003)

Methods

500mls of the preserved water sample was gradually evaporated using beakers on a hot plate for days. When the sample is less than 100mls, it is then transferred to petri-dish residue. The dried residue was scraped and put into a stainless-steel counting planchet, 0.77g of residue was achieved and counted for alpha radioactivity using MPC 2000 DP. The count rates recorded were reproducible in terms of channels and in terms of mode of measurement. MPC 2000-DP proportional counter is not the only detector for low alpha and beta activity measurement in samples. There is other gas filled detectors such as High Pure Germanium Detector, Sodium Iodide Detector. The choice of gas filled proportional counters was based on availability and the nearly uniform low background level.

Result Analysis

Table 2.0: Gross Alpha and Radon Radioactivity concentration (Bq/L)

S/N	Sample ID	Alpha Activity (Bq/L)	Radon Activity (Bq/L)
1	A	0.0665	0.0554
2	B	0.0098	0.0082
3	C	0.0591	0.0492
4	D	0.1821	0.1518
5	E	0.0492	0.0410

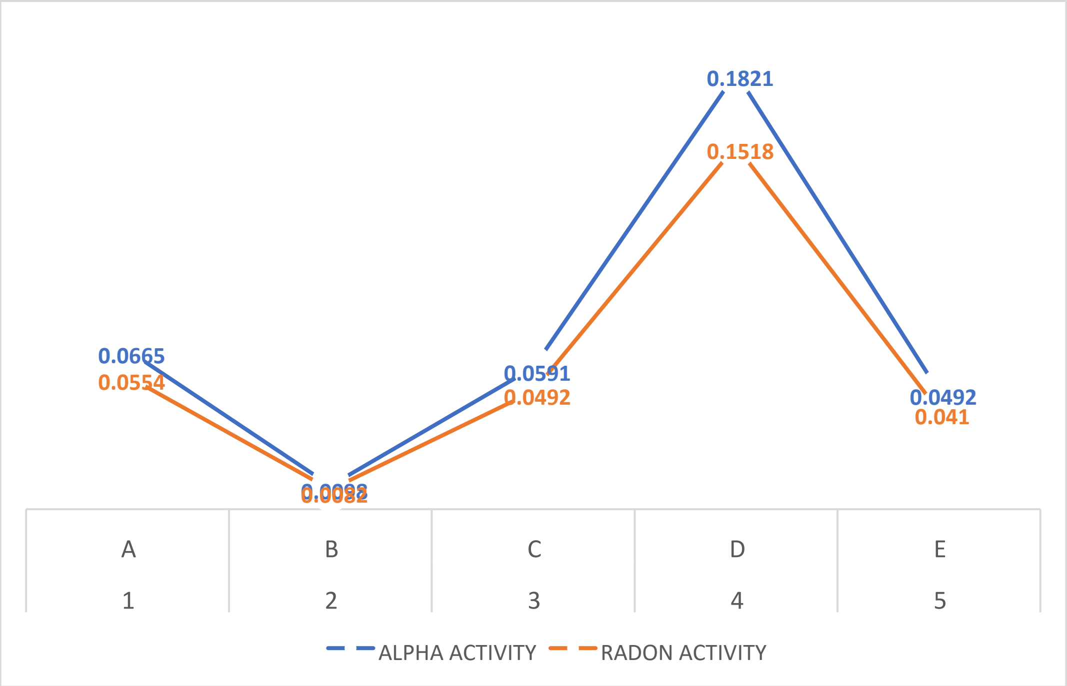

Figure 1.0: Radioactivity Concentration of Alpha and Radon (Bq/L)

The analysis of gross alpha radioactivity across the sampled locations revealed notable spatial variations in contamination levels. Location D exhibited the highest gross alpha activity, which corresponded directly to elevated radon concentrations. This relationship underscores the established link between alpha-emitting radionuclides and radon gas generation, suggesting that the elevated values at Location D are indicative of comparatively higher contamination. Such findings highlight the potential influence of geological or anthropogenic factors contributing to localized radioactivity. In contrast**,** Location B recorded the lowest gross alpha activity, which consequently resulted in the least radon concentration among all sampling points. This outcome suggests that Location B is relatively less impacted by radioactive contamination, possibly due to differences in aquifer composition, groundwater flow dynamics, or reduced exposure to sources of natural radionuclides.

Importantly, despite the observed variations between locations, the measured concentrations of both gross alpha and radon across all sites remained below the World Health Organization (WHO, 2023) screening limit of 0.5 Bq/L**.** This threshold is internationally recognized as a benchmark for safe drinking water quality. The fact that all values fall below this limit indicates that the sampled water sources are safe for human consumption and domestic use, posing no significant radiological health risks under current conditions.

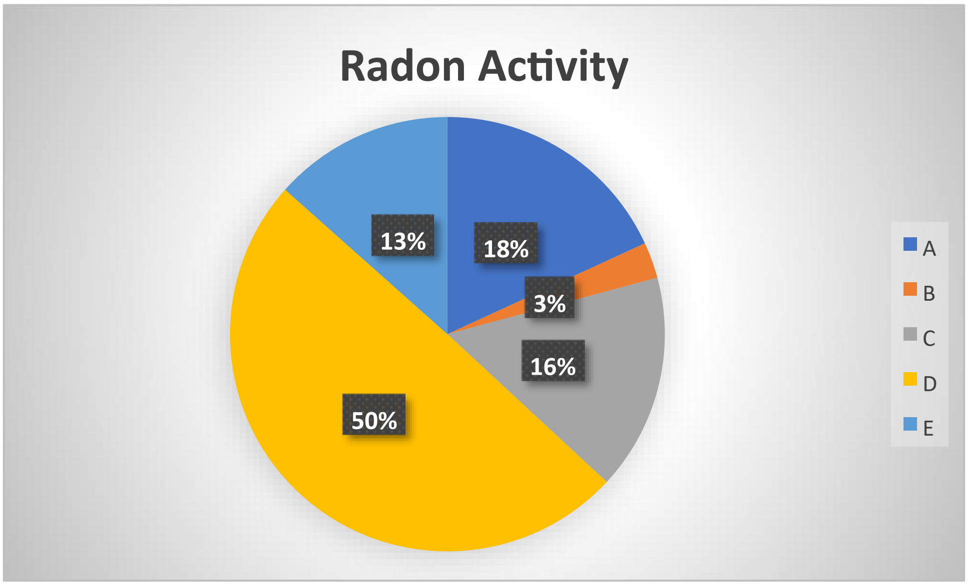

Figure 2.0: Percentage Concentration of Alpha and Radon (Bq/L)

The figure illustrating the percentage concentrations of radon across the sampling locations revealed significant spatial variation in contamination levels. Location D recorded the highest radon concentration at 50%**,** indicating that this site is comparatively more impacted by radon presence than the other locations. Such elevated values may be attributed to geological factors such as the composition of the aquifer rocks, soil permeability, or the presence of uranium-bearing minerals that naturally release radon gas into groundwater.

Conversely, Location B exhibited the lowest radon concentration at 13%**,** suggesting minimal contamination relative to the other sites. This lower percentage may reflect differences in hydrogeological conditions, reduced exposure to radon-producing substrates, or greater dilution effects within the aquifer system.

Despite these variations, it is important to note that all recorded concentrations were below 100%**,** which signifies that none of the sampling locations reached levels that could pose detrimental health effects. In practical terms, this means that the water sources remain within acceptable safety margins for human consumption and domestic use. The absence of excessive radon concentrations ensures that the risk of long-term exposure, such as increased susceptibility to respiratory illnesses or carcinogenic effects, is negligible under current conditions.

3. Conclusion

The results of the study demonstrated that the measured values of gross alpha activity and its progeny, radon activity, across all sampling locations were consistently below the recommended screening limit of 0.5 Bq/L established by both the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA, 2003). This finding is significant because it confirms that the radiological quality of the water sources under investigation does not exceed internationally recognized safety thresholds.

Consequently, the water from these locations can be considered safe for human consumption and domestic use, as the levels of radioactivity present are insufficient to pose any detrimental health effects to the population. The absence of elevated concentrations further suggests that the aquifer systems supplying these water sources are relatively free from harmful radioactive contamination.

However, while the current results are reassuring, it is important to emphasize the need for continuous monitoring and periodic assessment. Radon and other alpha-emitting radionuclides can vary over time due to geological changes, seasonal fluctuations, or anthropogenic activities. Sustained surveillance will ensure that any potential increases in contamination are detected early, thereby safeguarding public health and maintaining compliance with global water quality standards.

4. Copyright Notice

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