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Research Article

Evaluation of the Risk Associated with Drinkable Water Sources Through Analysis of Gross Alpha and Beta Radioactivity Levels in Chosen Locations, Mubi – North

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Abstract

Ionizing radiation refers to a form of radiation with sufficient energy to dislodge tightly bound electrons from atoms, resulting in the formation of ions. It encompasses alpha particles, beta particles, and gamma rays. Exposure to ionizing radiation, especially through ingestion, can have detrimental effects on living organisms, including humans. The primary goal of this research is to measure and analyze the levels of alpha and beta radiation in water samples, using the obtained results to evaluate radiation concentrations. Water samples were collected from five different locations within Mubi-North Metropolis and analyzed using a desktop Alpha/Beta counting machine or detector (MPC 2000B-DP). The analysis results present the alpha and beta radiation activities in each sample location. For example, alpha activities ranged from 0.009844 Bq/L to 0.1821 Bq/L, and beta activities ranged from 0.04922 Bq/L to 10.21 Bq/L across different locations. Sample D recorded the highest alpha effective equivalent dose of 0.037mSv/y, while the lowest dose of 0.002mSv/y was recorded from sample D. Sample C had the highest beta effective equivalent dose of 5.143mSv/y, and the lowest dose of 0.329mSv/y was recorded from sample E. Sample C also recorded the highest total effective dose of 516mSv/y, while the lowest dose of 0.34mSv/y was from sample E. Only sample D exceeded the recommended screening level of 0.1mSv/y for Alpha, and only sample E recorded the lowest effective dose of 0.329mSv/y below the screening limit of 1.0mSv/y, indicating potential cancer risk for all samples except sample E. In summary, the study concludes that alpha activities in all collected samples are below the recommended screening levels for drinking water radioactivity set by organizations such as EPA, WHO, and GEG-FAO. However, beta activities in the samples, except for the one from Federal Polytechnic Reservoir, surpass the recommended screening levels, suggesting a potential health risk for individuals consuming water from those sources. Overall, the research provides valuable insights into alpha and beta radiation levels in water samples from various locations in Mubi-North Metropolis, highlighting the safety of alpha levels but indicating potential hazards in beta radiation levels.

Keywords

Ionizing Radiation, Beta Activity, Alpha Activity, Concentration

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1. Introduction

Water holds a pivotal role as a vital natural resource, facing diverse demands and requiring adept management of water bodies [37]. Its existence traces back to the origins of the universe, and various human activities, including irrigation, power generation, and domestic use, heavily depend on it [30]. Rain and groundwater constitute primary sources, manifested in rivers, wells, dams, lakes, and streams [36]. Unfortunately, both natural processes and human actions continuously introduce contaminants, leading to a deterioration in water quality [2]. The pollution often results from improper disposal practices by industries, hospitals, and farmers using fertilizers, involving waste, sewage, and agricultural chemicals being discharged into rivers and the environment [38]. Notably, these disposed substances may contain radioactive elements [26].

Commonly, primary water sources are situated in upland or deep groundwater accessed through wells or boreholes. Although the risk of chemical contamination is minimal, the potential for radioactive contamination exists due to the heightened terrestrial radioactivity with depth in the Earth's crust. [32]. Naturally occurring radioactive elements, such as those from the Uranium and Thorium series, along with their byproducts like Radium and Radon, warrant particular attention [10]. These elements contribute to the radioactivity of groundwater and rain, subsequently influencing the quality of drinking water [33]. Conversely, spring water and flowing water interact with rocks containing various radioactive elements, impacting the adjacent soil and plants. Such water can transport these elements into wells, boreholes, and tap water through pipeline leaks [1].

Critically, specific radionuclides like Tritium, Potassium 40, Radium, and Radon emit alpha, beta, and gamma radiation, posing health risks [35]. Therefore, it becomes imperative to assess the concentration of these radiation-emitting radionuclides in drinking water [34].

2. Materials and Methods

2.1. Study Area

This study concentrates on the urban area of Mubi-North in the Adamawa State local government [21-24]. The specific focus is on underground water sources, such as taps and boreholes, extensively used by the community for domestic and drinking purposes. Different letters of the alphabet will represent distinct areas of study [27].

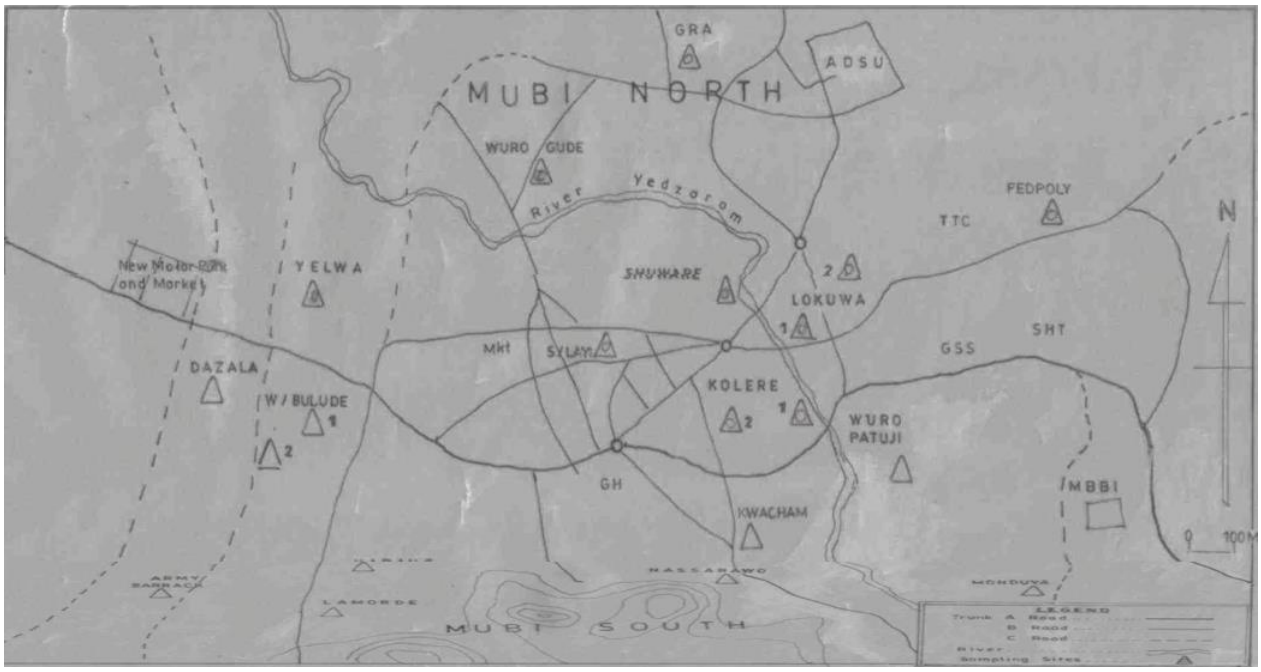

Figure 1. *Map of sample locations.*

2.2. Equipment and Materials

Pyrex beakers, Gloves, Oven, Hotplate, Plastic container (1-liter capacity), Blunt forceps, Analytical weighing balance, Spatula, Fume cupboard, Crucible (Petri-dish), Planchet, Syringe and needle, Rubber policeman [3-11].

2.3. Reagents Used

Acetone, Nitric acid (HNO), Vinyl acetate.

2.4. Sample Selection

The study utilized a convenient sampling technique (Williams, 1977), involving a total of five (5) sampling points.

3. Sampling Methodology

The sample container underwent three washes with the collected water to minimize potential contamination from its prior contents [16].

A 1% air allowance of the container's capacity was established to accommodate thermal expansion, and the container was marked to indicate the 1.0L volume of the sample corresponding to this airspace [29].

Following collection, 0.5ml of diluted nitric acid (HNO) was promptly added to the sample to lower its pH, reducing the likelihood of precipitation, colloid formation, and radioactivity absorption onto the container walls [20].

The sample was securely covered with the container lid and stored in the laboratory (in accordance with ISO, 9697, and 9698:1992a standards) for subsequent analysis [25].

4. Sample Preparation

Preparation of the sample included evaporating a one-liter sample without agitation on a hot plate set to 60 degrees Celsius [28]. This procedure lasted approximately twenty-four hours. The residual substance was rinsed using distilled water with the aid of a rubber scraper, then transferred to a petri dish (crucible) [12-15]. The material was allowed to completely dry at room temperature, approximately 25 degrees Celsius [10].

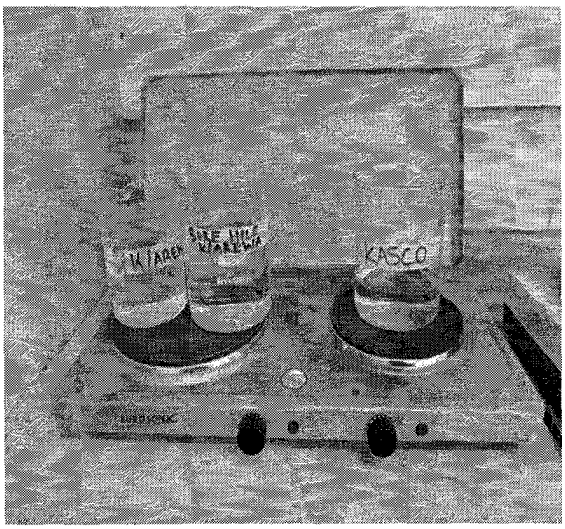

Figure 2. *Water Sample for Evaporation.*

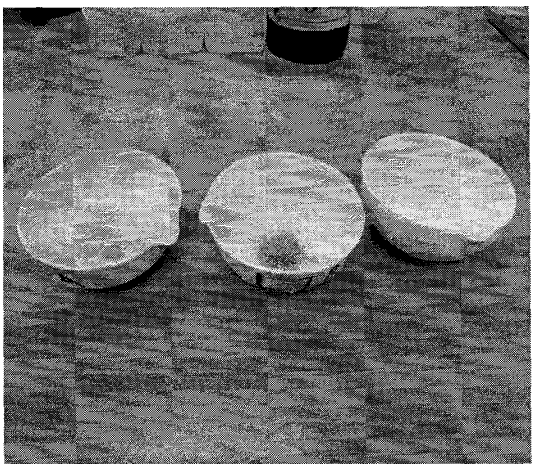

Figure 3. *Residue obtained after evaporation.*

The analytical weighing balance was employed to measure and record the total weight of both the dish and the residue. Furthermore, the weight of the residue alone was ascertained and documented [8]. To extract the residue from the Petri dish, it was meticulously scraped with a spatula and then transferred into a sterilized 9/16 planchet [17]. This planchet, holding the residue, was subsequently placed on an analytical digital weighing balance to obtain the intended weight, approximately 77mg [19].

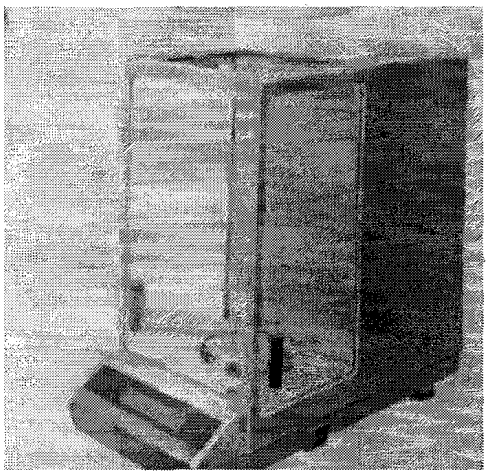

Figure 4. *Analytical Digital Weighing Balance.*

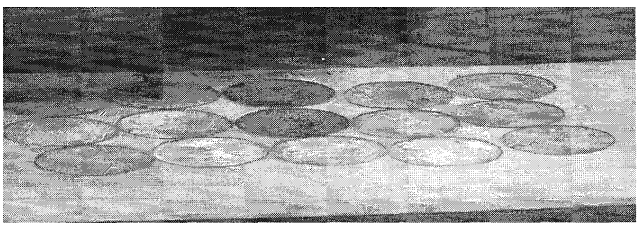

Figure 5. *Prepared Water Sample Ready for Counting.*

Vinyl acetate was administered onto the residual substance

within the sample holder to eliminate any lingering moisture and prevent absorption of moisture from the surrounding atmosphere [14]. The prepared samples are now set for the counting procedure [18].

The specimens on the planchet were placed into the MPC-2000B-DP drawer for the counting process.

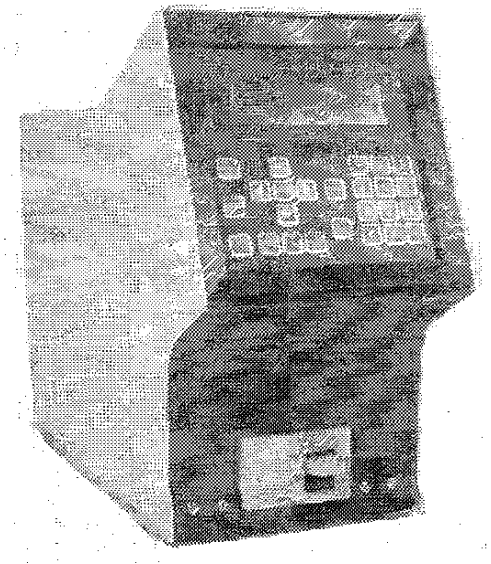

Figure 6. *MPC-2000B-DP (Dual Phosphate).*

Counting

The counting apparatus functions automatically, involving the input of predetermined time intervals, recording voltage levels, and monitoring the count cycles [5]. Furthermore, details about the counter's characteristics (including efficiency and background noise), the volume of the sample, and its sampling efficiency need to be input [7]. The results are provided as raw counts (count per millimeter), count rates, and activity levels [4]. Data acquisition took place concurrently in both alpha and beta modes, with the counting mode being optional [31]. The equations for calculating the count rate, activity, and other parameters for a specific sample are outlined below:

(a) Count Rate

$$\text{Rate } (\alpha,\beta) = \frac{Raw\ count}{Count\ time} \quad (1)$$

(b)

$$\text{Activity } (\alpha,\beta) = \frac{Netcounts}{De\ x\ 60\ x\ pellet\ weight} \quad (2)$$

(c)

$$DRw_{(\alpha/\beta)} = Aw_{(\alpha/\beta)}\ X\ DCF_{(\alpha/\beta)}\ X\ 730 \quad (3)$$

Where $DR_{w\ (\alpha/\beta)}$ is the dose effective equivalent dose (sV/y) $DCF_{(\alpha/\beta)}$ is the detector conversion factor.

(d)

$$TEED_{(\alpha/\beta)} = DRw_{(\alpha)} + DR_{w(\beta)} \quad (4)$$

Where $TEED_{(\alpha/\beta)}$ is the total effective equivalent dose.

5. Discussion of Results

The findings from Table 1 indicate that among the five collected water sources, sample D exhibits the highest alpha activity of 0.1821 Bq/L, slightly exceeding the screening limit of 0.1 Bq/L recommended by WHO (1991) [10]. On the other hand, sample B recorded the lowest activity of 0.00988 Bq/L. The average alpha activity derived from the distribution curve was 0.733 Bq/L, deviating by 0.646 Bq/L [13].

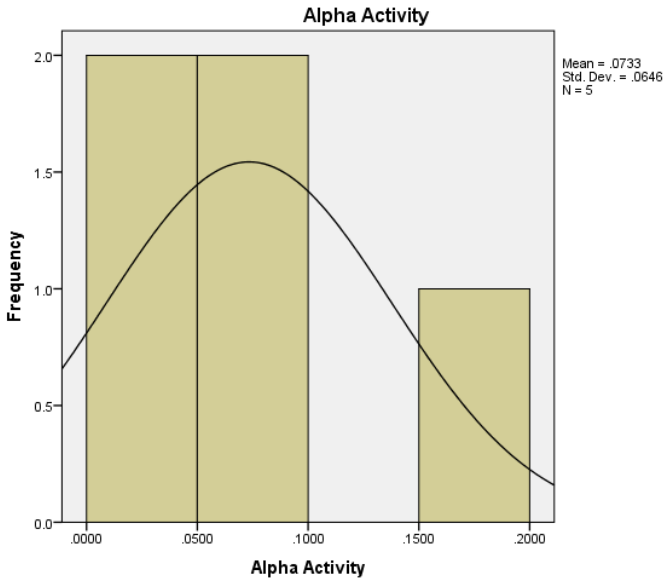

Figure 7. *Illustrates the Normal distribution curve of Alpha Activity for the water sources.*

Table 1. Gross Alpha and Beta Radioactivity in the water sources.

S/N	Sample ID	Alpha Activity(Bq/L)
1	A	0.066450
2	B	0.009844
3	C	0.059070
4	D	0.182100
5	E	0.049220

Table 2. Alpha Activity and Effective Equivalent Doses ($DRw_{(\alpha/\beta)}$).

S/N	Sample ID	Alpha Activity(Bq/L)	$DRw_{(\alpha)}$ (mSv/y)
1	A	0.06645	0.014
2	B	0.00984	0.002
3	C	0.05907	0.012
4	D	0.18210	0.037
5	E	0.00492	0.010

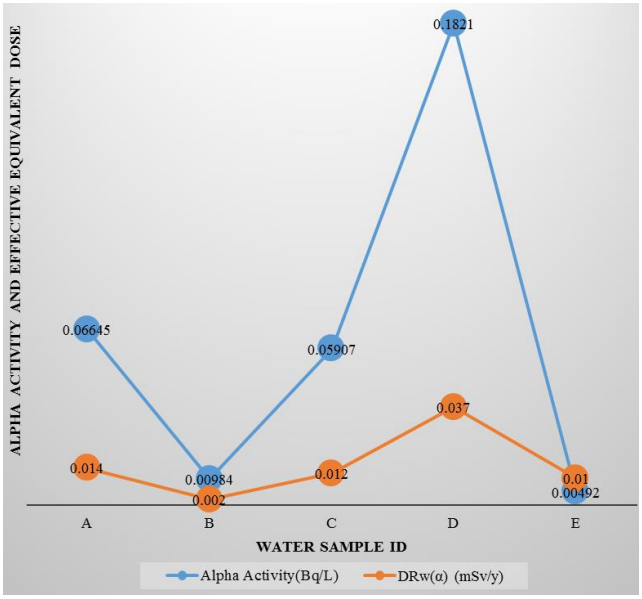

Figure 8. Alpha Activity and Effective Equivalent Dose.

The findings from the depicted figure indicate that sample location D has the highest alpha activity and effective equivalent doses. This implies that the water consumed from this location carries a potential risk of cancer causation, as the activity concentration exceeds 0.1 mSv/y, the recommended dose by WHO (1991). In contrast, locations B and E have the lowest range of absorbed doses, suggesting a lower likelihood of cancer causation in these two locations.

Table 3. Beta Activity of the water sources.

S/N	Sample ID	Beta Activity(Bq/L)
1	A	4.374
2	B	7.791
3	C	10.21
4	D	1.564
5	E	0.6536

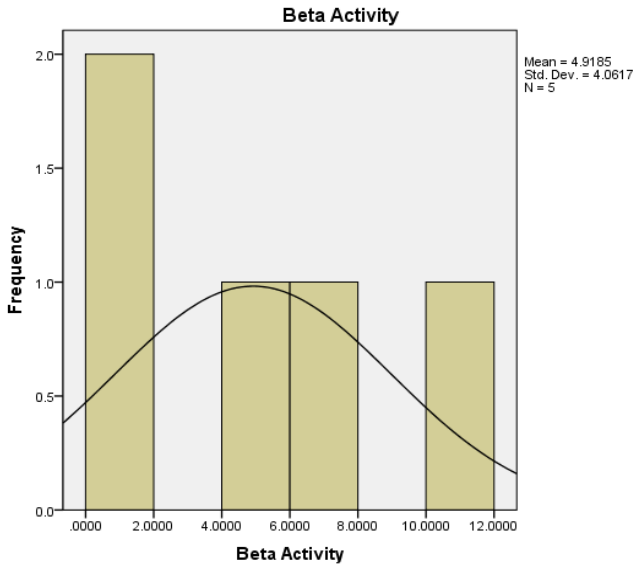

Figure 9. Alpha Activity Normal distribution curve.

Table 4. Beta Effective Equivalent dose of water sources.

S/N	Sample ID	Beta Activity(Bq/L)	$DRw_{(\beta)}$ (mSv/y)
1	A	4.374	2.203
2	B	7.791	3.924
3	C	10.21	5.143
4	D	1.564	0.788
5	E	0.6536	0.329

The obtained results indicate that sample C registered the highest beta activity of 10.21 Bq/L, while sample E recorded the lowest activity of 0.6536 Bq/L, falling below the recommended value of 1.0 mSv/y by WHO (1991). The findings suggest that all values, except for sample E, surpass the recommended limit, implying that water from these locations has a high likelihood of cancer causation.

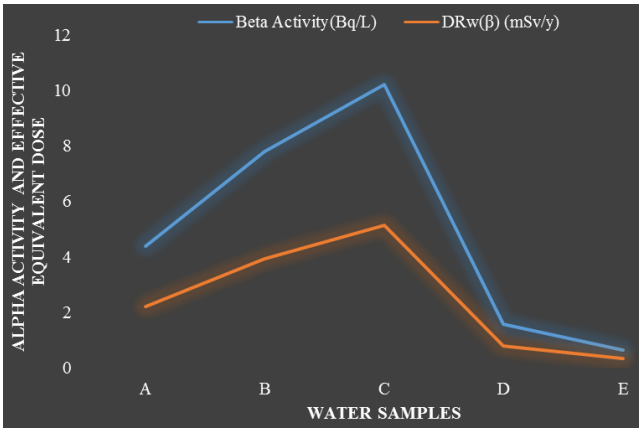

Figure 10. Beta Activity and Effective Equivalent Dose.

The above results indicate that location C recorded the highest concentration, exceeding the screening limit of 1.0 mSv/y, while location E recorded the lowest concentration. This implies that the concentrations in all locations surpass the limit, making them susceptible to cancer causation.

Table 5. Total Effective Equivalent (TEED) Dose of water samples.

S/N	Sample ID	$TEED_{(\alpha/\beta)}$ (mSv/y)
1	A	2.22
2	B	3.93
3	C	5.16
4	D	0.83
5	E	0.34

The obtained results indicate that the total effective equivalent dose ranges from 0.34 to 5.16 mSv/y, with sample C having the highest and sample E the lowest for the one-year period. This implies that water from sample C has the highest probability of cancer causation, while samples D and E have the least probability.

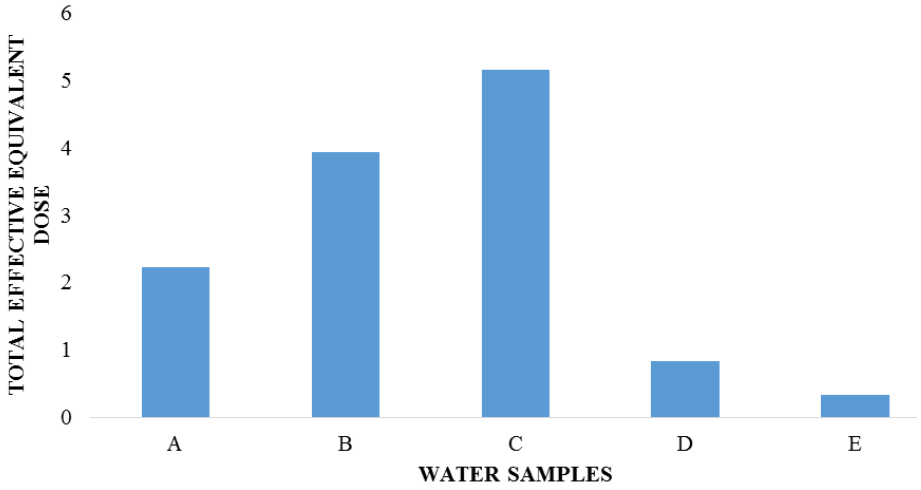

Figure 11. Water samples with their total effective equivalent dose.

6. Conclusion

This research focused on measuring the gross alpha and beta activities in drinking water. Our findings revealed a total effective equivalent dose range of 0.34 – 5.16 mSv/y for locations E and C, respectively. This range exceeds 1.0 mSv/y, except for samples D and E, where concentrations were below the recommended screening limit. This suggests a lower probability of cancer causation for these samples.

7. Recommendations

1) A comprehensive survey covering not only Mubi-North but the entire Mubi town is essential.
2) Enhancements should be made to the sample preparation technique to accurately measure total dissolved substances and minimize residue on the counting plate.
3) Individuals using water from the mentioned locations are encouraged to file complaints with the Ministry of Health for further beta radiation screening.
4) Consideration should be given to performing gamma radiation determinations on water samples.
5) To broaden the study's scope, the evaluation of surface water sources like sea ponds and river water is advisable. This is crucial as other artificial sources may contribute to increased radioactivity levels, posing potential health risks to the population.

Abbreviations

Bq: Becquerel
A: Activity
De: Detector Efficiency
L: Liter
Bq/L: Becquerel Per Liter
EPA: Environmental Protection Agency
WHO: World Health Organization
TEED: Total Effective Dose
BKW: Background
α: Alpha Activity
β: Beta Activity
Sv: Sievient

Author Contributions

Ahmadu Ibrahim is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest**.**

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