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Evaluation of Cancer Risk Using the Err Model for Gross Beta Radioactivity in Drinking Water in Mubi-North Metropolis, Adamawa State, Nigeria

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Abstract

This study investigates the quality of drinking water sourced from boreholes and taps. Radionuclides such as Tritium, Potassium-40, Radium, and Radon, which emit alpha, beta, and gamma radiation, can pose health risks to humans. Therefore, it is essential to measure the concentrations of these radionuclides in drinking water. Five water samples were collected from various locations within Mubi-North Metropolis and analyzed using a desktop Beta (MPC 2000B-DP) counting machine/detector. The cancer risk, calculated using the ERR model, was found to be 3.68 x10-6 in Shagari Lowcost (A), 7.61 x10-6 in Wuro Gude (B), 1.04 x10-5 in ADSU Water Faculty of Management Science (C), 4.55 x10-7 in Lokuwa Water Adjacent to Emir Palace (D), and -5.88 x10-7 in Federal Polytechnic Reservoir (E). The results indicated that all sample locations exhibited a cancer risk below the 1.0 Sv/yr screening limit set by WHO and EPA. Consequently, while the water from these locations poses a lower cancer risk, it could still represent significant health hazards.

Keywords: Drinking Water; Radionuclide; Concentration; Wells; Boreholes

Introduction

Water stands as a crucial natural resource, facing numerous demands due to its significance. Since the inception of the universe, water has been present, necessitating adept management of water bodies. Human activities encompass diverse uses of water, including irrigation, power generation, and domestic tasks. Water derives from sources such as rain and groundwaters, existing in rivers, wells, dams, lakes, and streams. However, both natural phenomena and human actions consistently contaminate these water sources, impacting water quality (Abel, 1996). Water pollution results from the disposal of waste and sewage by industries and hospitals into the environment and rivers, as well as the use of materials like fertilizers by farmers, often containing radionuclides.

The primary sources of water supply are upland or ground water obtained from deep wells or boreholes. While these sources are less likely to be contaminated by harmful chemicals, the presence of radioactive materials is a concern. Terrestrial radioactivity increases with depth in the Earth's crust, potentially impacting ground and rainwater quality (Akpa, 2004). Naturally occurring radioactive materials, such as those from the Uranium series, Thorium series, and their progeny (Radium and Radon), contribute to the radioactivity of ground and rainwater, affecting the quality of drinking water. Flowing water, such as spring water, passing through rocks containing various radioactive materials, can influence soil and plant quality (Alabi, 2001). This flowing water may carry contaminants into wells, boreholes, and tap water through damaged pipes (Andras SS, 1993).

Crucial radionuclides in drinking water include Tritium, Potassium 40, Radium, and Radon, emitting alpha, beta, and gamma radiation, posing potential health risks. Hence, it becomes essential to assess the concentration of these radionuclides in drinking water (Cember H, 2017).

Study Area

Mubi North, situated within the geopolitical region, is positioned between latitudes 10°05’ and 10°30’ N of the equator and longitudes 13°12’ and 13°19’ E of the Greenwich meridian. Covering a land area of 192,307 square kilometers, it sustains a population of 260,009 individuals according to the National Population Census of 2006. Geographically, Mubi North shares its borders with Maiha Local Government Area to the South, Hong Local Government Area to the West, Michika Local Government Area, and The Cameroon Republic to the East.

For the purpose of this study, specific study areas are denoted by the following alphabetical codes:

A = Yelwa ward (Shagari locust, close to Jumma’a mosque)

B = Lokuwa ward (Wurogude behind river)

C = Lokuwa ward (ADSU faculty of management science)

D = Lokuwa ward (Adjacent Emir palace)

E = Lokuwa ward (Federal Polytechnic reservoir)

Figure 2 illustrates the sample locations on the map of Mubi North Local Government Area in Adamawa State, Nigeria.

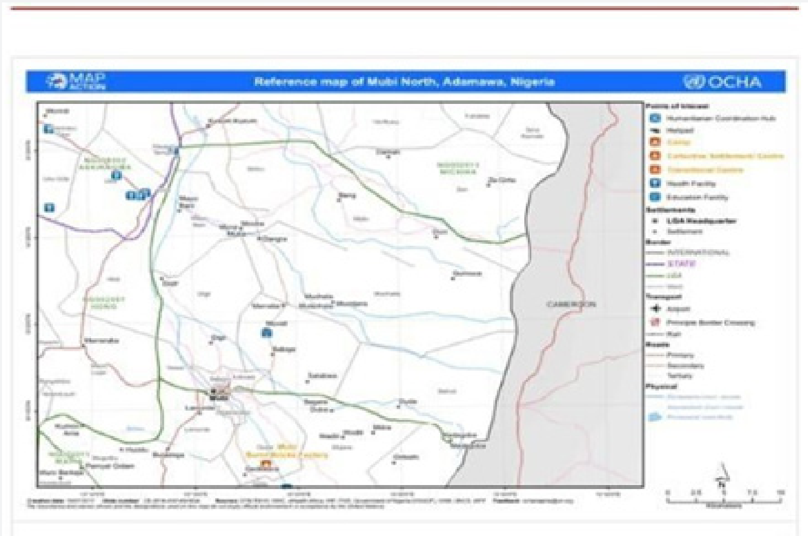

Figure 1: Map of Mubi North Local Government Area.

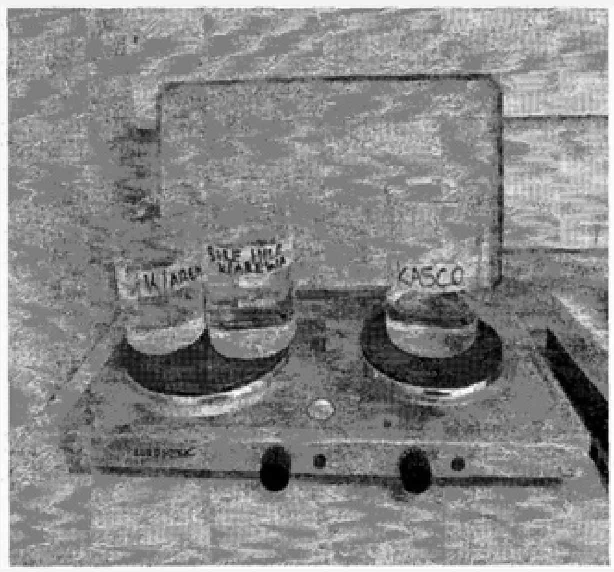

Figure 2: Water Sample for Evaporation.

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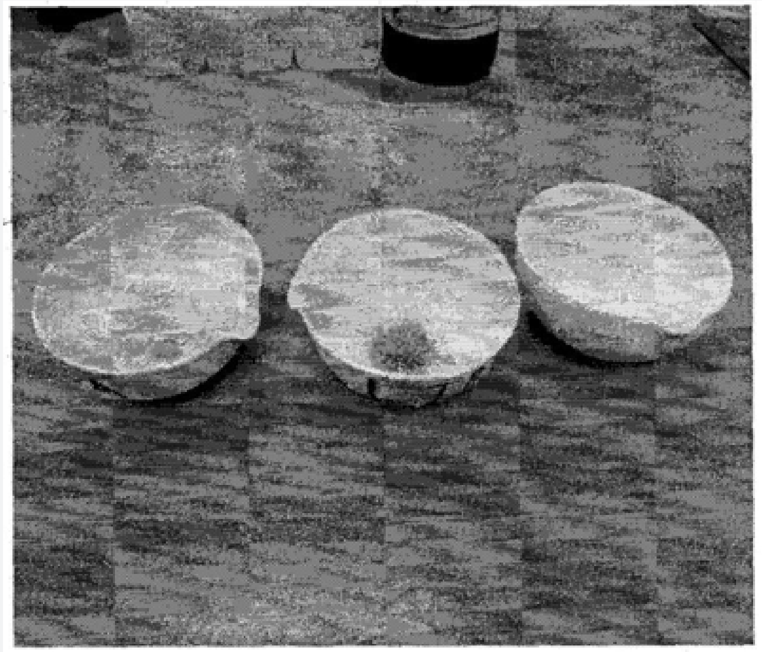

Figure 3: Residue obtained after evaporation.

Materials and Methods

Materials

The materials used include Beakers (Pyrex), gloves, oven, hot plate, plastic container (1-liter container), blunt forceps, analytical weighing balance, spatula, fume cupboard, petri-dish(crucible), planchet, syringe and needle, police man(rubber), and MPC 2000B DP (dual phosphor).

Reagents Use

- Acetone
- Nitric acid (HNO)
- Vinyl acetate

Sample Selection

The method adopted for this sampling is convenient sampling, with five sampling points (Milla, 2014).

Procedure Used in Taking the Samples

The procedure used involves the following:

- The sample container was rinsed three times with the water being collected to minimize contamination from the original content of the sample container.
- One percent (1%) air space of the container capacity was created for thermal expansion. The sampling container has a mark on it, which gives the 1.0L-volume of sample corresponding to the air gap.
- 0.5ml of dilute nitric acid (HNO) were added to the sample immediately after collection to reduce the PH and minimize precipitation, formation of colloid and absorption of radioactivity into the container walls. iv. The sample was tightly covered with container cover and kept in the laboratory (ISO, 9697 and 9698: 1992a) for analysis.

Sample Preparation

- Evaporation was done using hot plate at 60 degrees Celsius without stirring, in open 500m1 beaker. It took an average of one day to complete the evaporation of one-liter sample.
- The residue was washed with distilled water with the aid of policeman (rubber) and transferred into a petridishes (crucible) and kept to dry completely at room temperature (250).
- The weight of the dish and residue was recorded using analytical weighing balance. The weight of the residue alone was also known and recorded.
- The residue formed was scratched with the aid of spatula to remove it from Petri dish and transferred into a sterilized 9/16 planchet; residue in the planchet was placed inside Analytical digital weighing balance, to obtained a required weight of about 77mg (0.077g) Akpa, (2016).

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- Vinyl acetate was spread on the weighted residue in the planchet to remove the remained moisture and also to avoid absorption of moisture from atmosphere.
- The prepared samples are now due for counting.
- The samples in the planchet were placed into the MPC-2000B-DP drawer for counting.

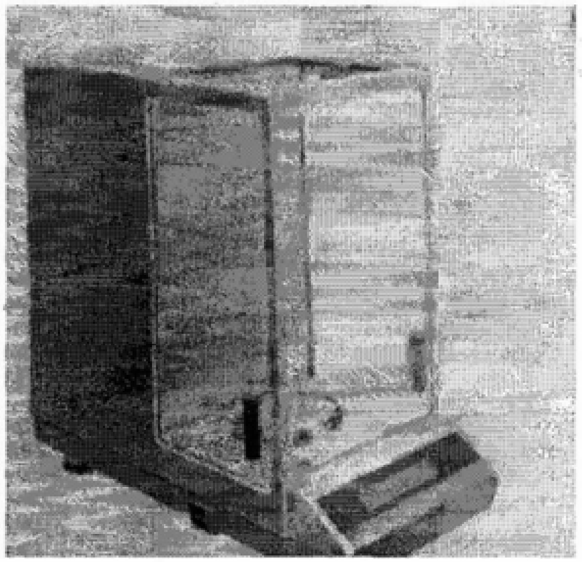

Figure 4: Analytical Digital Weighing Balance.

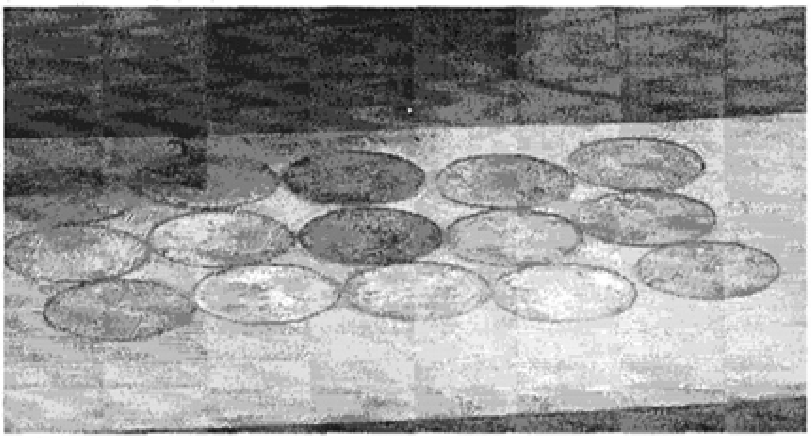

Figure 5: Prepared Water Sample Ready for Counting.

Counting

The gross beta counting was set at 1650V, and samples were counted for 45 minutes, (Leo W.R, 1987).

The alpha count rate as well as alpha activity was calculated using the relationship below;

a) Count Rate

$$Rate(\beta) = \frac{Raw(\beta)count}{count\ time} \quad 2.0$$

$$Activity(\beta) = \frac{net\ \text{count}\ (cpm)}{De \times 60 \times pellet\ \text{weight}} \quad 2.1$$

b) $$Effective\ Dose(ED) = \beta \times DCF \times V \times 365\ \text{days/yr} \quad 2.2$$

c) $$ERR = Risk\ coefficient \times ED \quad 2.3$$

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Results and Discussion

Results

Gross beta radioactivity, effective dose, and lifetime cancer risk in tap and borehole water from various locations in Mubi-North, Adamawa State were examined. Specific measurements were necessary for the detector used in this study, including background measurement and plateau tests for three different modes: alpha-beta simultaneous mode, alpha only mode, and beta only mode. For this research, we used the beta only mode. The analysis results of the gross beta radioactivity, effective dose, and lifetime cancer risk in tap and borehole water from several locations in Mubi-North, Adamawa State are summarized in the tables below.

The results presented in Table 1 indicate that sample location C has the highest levels of beta activity, effective dose, and lifetime cancer risk, according to the Excess Relative Risk (ERR) model. This high level of beta radioactivity could be attributed to the greater depth of the borehole at this location. In contrast, sample location E exhibits the lowest beta concentration, along with the lowest effective dose and lifetime cancer risk.

Table 1: Gross Beta Radioactivity, Effective dose, and ERR in taps and bore holes. This table shown the beta radioactivity, Effective dose, and ERR of the five sample locations.

S/N	Sample ID	Beta Activity (Bq/L)	Effective Dose (Sv)	Excess Relative Risk (ERR)
1	A	3.184	6.69×10^{-5}	3.68×10^{-6}
2	B	6.581	1.38×10^{-4}	7.61×10^{-6}
3	C	8.98	1.89×10^{-4}	1.04×10^{-5}
4	D	0.394	8.28×10^{-6}	4.55×10^{-7}
5	E	-0.506	-1.06×10^{-5}	-5.88×10^{-7}

Further insights are provided by Figure 7, which illustrates the distribution of beta radioactivity concentrations across different water samples. The water sample from the Faculty of Management Science at Adamawa State University in Mubi (location C) has the highest beta radioactivity concentration. This is followed by the water from Wuro Gude boreholes (location B) near the river, and then Lokuwa (location D). The water sample from the Federal Polytechnic Mubi (location E) reservoir shows the lowest concentration of beta radioactivity, followed closely by the sample from Shagari Locust (location A).

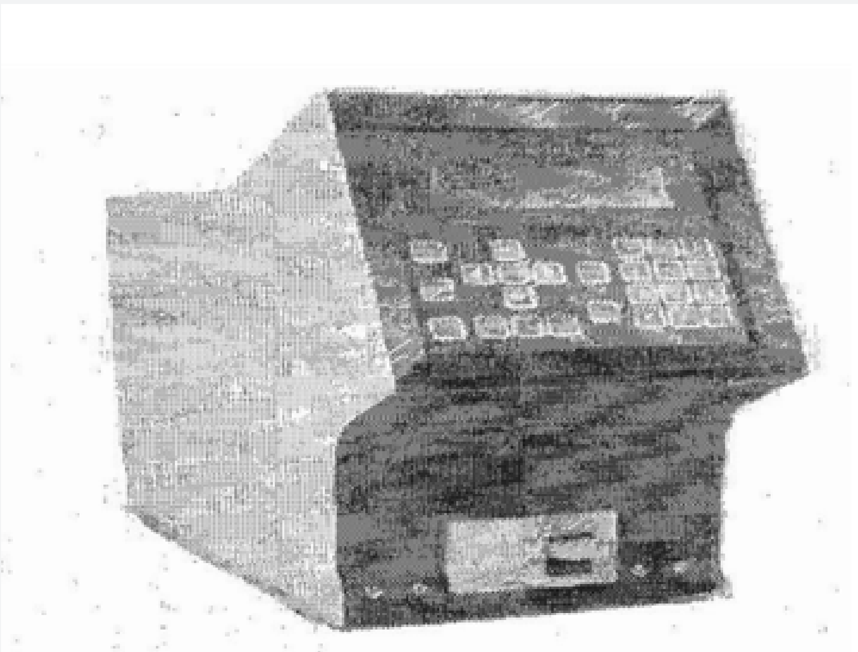

Figure 6: MPC-2000B-DP (DuaJ Phosphate).

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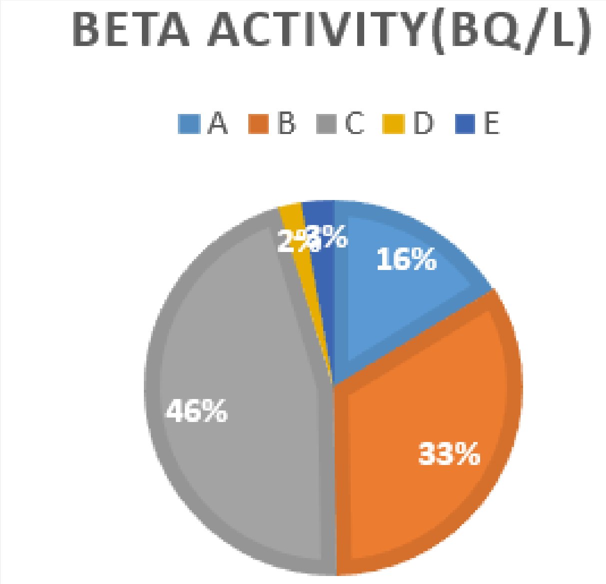

Figure 7: Pie chart showing Beta Radioactivity of the five water samples.

The observed high percentage of beta radioactivity in the deeper boreholes suggests that the depth of the borehole could be a significant factor influencing the levels of beta radioactivity. This could be due to the geological formations and materials encountered at greater depths, which might contribute to higher levels of radioactive contaminants in the water.

The results depicted in the pie chart indicate a distribution of cancer risk percentages among various sample locations. Specifically, sample location C registers the highest percentage of cancer risk. This implies that the water from this location, based on its beta radioactivity levels, poses the greatest potential health hazard in terms of cancer risk to individuals consuming or using this water over their lifetime.

On the other hand, sample location D exhibits the lowest percentage of cancer risk among all the sampled locations. This suggests that the water from location D has the lowest level of beta radioactivity, leading to a comparatively minimal risk of cancer for the consumers.

The differences in cancer risk percentages between these locations can be attributed to variations in beta radioactivity concentrations in the water samples. Higher beta radioactivity levels translate to a higher effective dose of radiation received by individuals, which in turn increases the lifetime risk of developing cancer. Conversely, lower beta radioactivity levels result in a reduced effective dose and, therefore, a lower lifetime cancer risk.

Several factors could contribute to these variations in radioactivity levels, including the geological characteristics of the locations, the depth of the boreholes, and the presence of naturally occurring radioactive materials in the soil and rock layers through which the water passes. For example, deeper boreholes, like the one at location C, may penetrate layers with higher concentrations of radioactive materials, leading to increased beta radioactivity in the water.

The results depicted in Figure 8 indicate that all sampled locations have annual effective doses that are approximately zero. This suggests that the amount of radiation the population is exposed to from these water sources is extremely low. Consequently, the probability of these low levels of radiation causing cancer is virtually nonexistent.

a) Annual Effective Dose: This is a measure used to estimate the risk associated with exposure to ionizing radiation. It takes into account the type of radiation and the sensitivity of different tissues and organs to radiation. The effective dose is expressed in sieverts (Sv), and for low levels of radiation, it is often measured in millisieverts (mSv) or microsieverts (μSv).

b) Zero Annual Effective Dose: When the annual effective dose is said to be approximately zero, it means that the radiation exposure from these water sources is minimal so low that it does not pose any significant health risks. This is far below the safety limits set by international health and safety organizations. For example, the International Commission on Radiological Protection (ICRP) recommends an annual limit of 1 mSv for the general public, excluding natural background and medical radiation. The results showing near-zero doses indicate that the levels are well within safe limits.

c) Cancer Risk and Radiation: There is a well-established link between exposure to ionizing radiation and the increased risk of developing cancer. However, this risk is dose-dependent. At

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very low doses those close to zero the additional risk of cancer is so small that it is statistically insignificant. In essence, the natural background radiation we are exposed to every day (from cosmic rays, the earth's crust, etc.) is much higher than the radiation from these water sources.

d) Implications for Public Health: The findings suggest that the water from these sampled locations does not contribute to an increased cancer risk for individuals consuming or using it. This is crucial information for public health officials and residents, as it confirms the safety of the water in terms of radiological contamination.

e) Context of the Study: The study likely involved measuring the beta radioactivity levels in water samples and calculating the corresponding annual effective dose based on these measurements. The results showing zero or near-zero effective doses indicate that the radioactive contaminants in the water are at levels that do not significantly impact human health.

f) Assurance of Safety: For residents and authorities in Mubi-North, Adamawa State, these results provide reassurance. It means that despite variations in beta radioactivity levels among different locations (as discussed in earlier results), none of the water sources poses a significant radiological health risk.

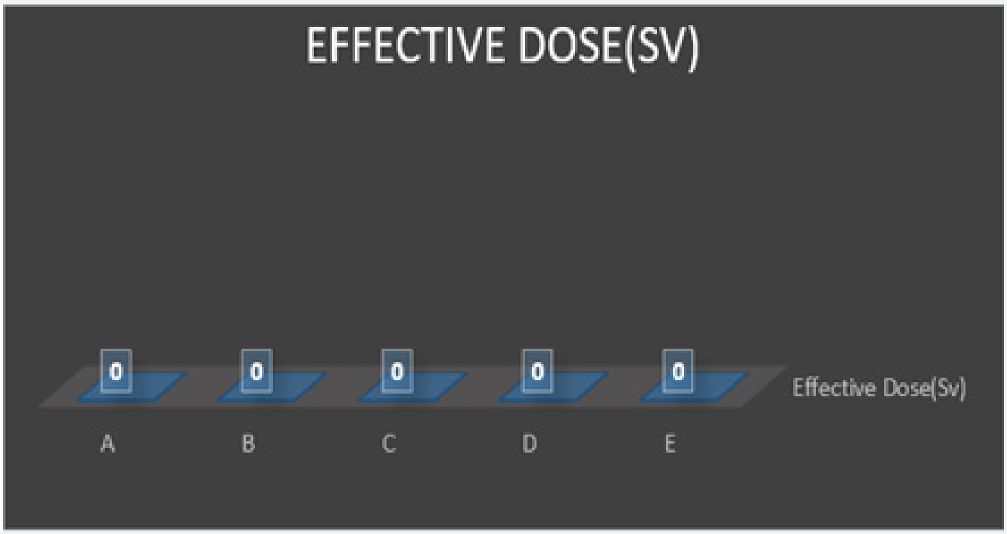

Figure 8: Bar chart showing Samples locations with their effective doses.

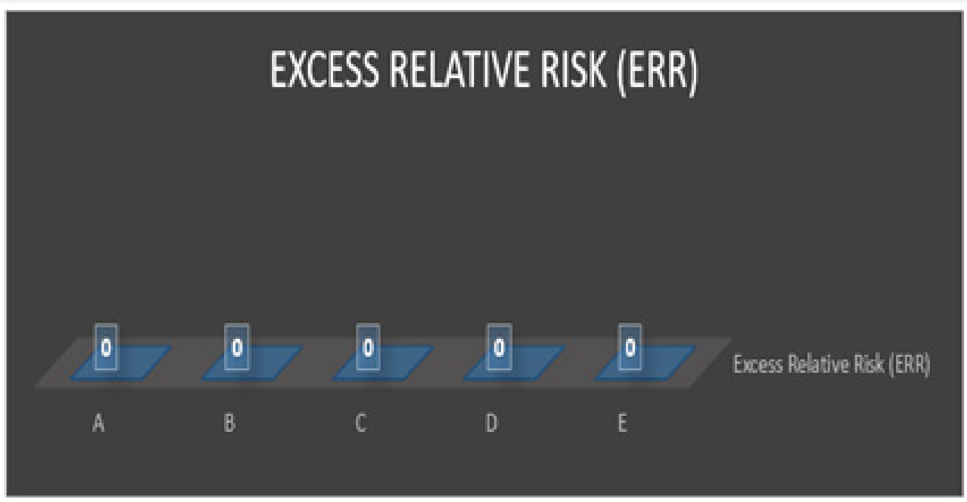

Figure 9: Bar chart showing Samples locations with their Excess relative risk (ERR).

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The results shown in Figure 9 indicate that all sampled locations have approximately zero excess relative risk (ERR). This finding suggests that there is no increased probability of cancer causation from the radiation exposure associated with these water sources. Let's break down what this means in detail:

a) Definition of ERR: Excess Relative Risk (ERR) is a measure used in epidemiology and radiation protection to estimate the additional risk of developing cancer due to exposure to a specific factor, in this case, ionizing radiation, compared to the background risk. It quantifies the increase in risk above the baseline level of risk that a population would experience without the additional exposure.

b) Interpreting Zero Err: When the ERR is approximately zero, it means that the radiation exposure from these water sources does not add any significant risk of cancer above the normal, everyday risk that individuals face. Essentially, the radiation levels are so low that they do not contribute to any measurable increase in cancer risk.

Detailed Implications

a) Radiation Levels and Health Risks: The fact that all sample locations show zero ERR indicates that the beta radioactivity levels in the water are extremely low. This low level of radiation is not enough to cause any discernible increase in cancer risk. The natural background radiation, which everyone is exposed to daily, is significantly higher than the radiation from these water sources.

b) Public Health Safety: These results are crucial for public health, as they reassure residents and health officials that the water from these sampled locations is safe in terms of radiological content. It implies that consuming or using this water will not lead to any additional cancer risk.

c) Comparative Risk Analysis: In environmental health studies, various sources of radiation are compared to assess their impact. The zero ERR result suggests that the radiation levels in these water sources are much lower than other common sources of radiation exposure, such as medical imaging, natural background radiation, or even certain foods that contain naturally occurring radioactive materials.

The results shown in Figure 10 indicate that all sampled locations have approximately zero annual effective dose and excess relative risk (ERR). This comprehensive analysis suggests that the water sources in these locations pose no additional risk of cancer causation. Here's a detailed explanation of what this means:

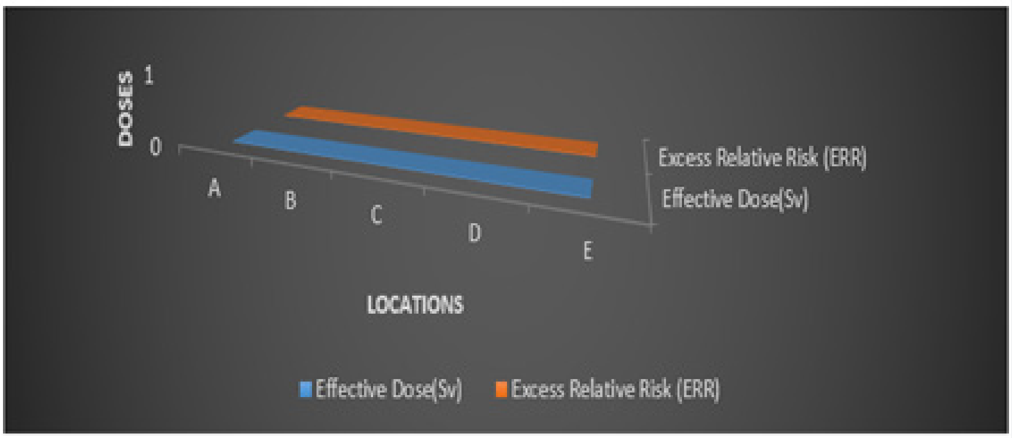

Figure 10: Bar chart showing sample locations, Effective dose and cancer risk.

Annual Effective Dose and Its Implications

a) Annual Effective Dose: This is a measure used to assess the radiation dose received by an individual from a specific source over the course of a year. It accounts for the type of radiation and its impact on different tissues and organs, providing a standardized way to evaluate potential health risks. The effective dose is measured in sieverts (Sv), with lower levels often reported in millisieverts (mSv) or microsieverts (µSv).

b) Zero Annual Effective Dose: When the annual effective dose is approximately zero, it means that the radiation exposure from the water sources is extremely low, to the point of being negligible. This level of exposure is far below the safety thresholds established by international health organizations, such as the International Commission on Radiological Protection (ICRP), which recommends an annual limit of 1 mSv for the general public (excluding natural background and medical radiation).

c) Health Implications: Given that the effective dose is close to zero, it indicates that there is no significant health risk from radiation for individuals consuming or using the water from

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these locations. The natural background radiation that people are exposed to daily from cosmic rays, the earth's crust, and even certain foods, is significantly higher than the radiation from these water sources.

Excess Relative Risk (Err) and Cancer Probability

a) Understanding ERR: Excess Relative Risk (ERR) is a metric used to estimate the increased risk of cancer due to exposure to a specific factor in this case, ionizing radiation. ERR compares the risk in an exposed population to the baseline risk in an unexposed population.

b) Zero ERR: When the ERR is approximately zero, it means that the radiation exposure from the water sources does not contribute to an increased risk of cancer. In other words, the risk of developing cancer due to this radiation exposure is no greater than the baseline risk faced by the general population from all other sources.

Comprehensive Risk Assessment

a) Combined Findings: The combination of zero annual effective dose and zero ERR from Figure 10 provides a robust assurance that the water sources are safe from a radiological perspective. It indicates that the levels of beta radioactivity in the water are so low that they do not pose any measurable health risk.

b) Public Health Assurance: These results are particularly reassuring for residents and health officials in Mubi-North, Adamawa State. They confirm that the water from these sources is not contributing to any increased cancer risk, allowing for safe consumption and use of the water.

Conclusion

The method of gross beta spectrometry has been used to determine the cancer risk from some selected taps and bore holes water samples commonly consumed in some areas of Mubi North, Adamawa state. The analysis of these water samples showed that ERR cancer risk measured for all samples are below the screening limit of 1.0 Sv/yr recommended by WHO and ICRP. Hence, water from these particular locations is safe for ERR cancer risk.

Recommendations

- It is recommended that the water from the samples collected need quick action of Government for further screening and immediate measured.
- It is recommended that before a well or bore holes is dug the geophysicist and geologist should analyze the water samples for gross alpha activity concentration.
- Establishment of monitoring programs to ensure the water treatment is carried out routinely is also recommended.
- There is need for future research to employ/use statistical tools to ascertain the significant difference between the studied areas.

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