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Radiological Health Risk Assessment of Groundwater from Residential area of Maiganga Mining Site in Gombe State, North-Eastern, Nigeria.

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Abstract
The water sample were analyzed using the ultra-low level Liquid Scintillation Counter (LSC), to evaluate the gross alpha and beta radioactivity dose levels of the radionuclides in water. The minimum and maximum gross alpha activity obtained was 0.8816 (Bq.1/L) and 1.0825 (Bq.1/L) respectively, while the minimum and maximum gross beta activity obtained for water samples was 0.0330 (Bq.1/L) and 0.2380 (Bq.1/L) respectively. The activity concentration for drinking water indicate that the specific activity in the water is above the WHO guideline limit of 0.5 (Bq.1/L) for gross alpha and is lower in gross beta of 1 (Bq.1/L) limit. The results obtained were also within the range of the South Africa Department of Water Affairs and Forestry target water quality limit of (1.38) (Bq.1/L) for gross alpha activity. The process of treating contaminated water is crucial for ensuring public safety and environmental protection. In recent years, there have been widespread concerns about the potential risks associated with radioactive and toxic substances in water sources. Therefore, this water after treatment is not safe for the members of the public.

Keywords: Radiological hazard, Groundwater, Mining, Health-risk

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Introduction
Modern gold mining technics have become more sophisticated and efficient in recent decades, allowing miners to extract gold from deposits that were once considered too difficult or too costly to reach. Despite the technological advances, the ancient practice of gold mining remains a cornerstone of the global economy (Madzunya *et al*., 2020). When a large concentration of natural radionuclides enters human body through inhalation or ingestion can result into health effects such as cancerous tumor development (Kamunda *et al*., 2016). The higher the rate of radioactive dust particles inhalation, the higher the risk of cardiovascular and respiratory mobility. Nevertheless when considering internal exposure, larger dust particles are less of a concern because they are unable to penetrate deep into the lungs and can be easily expelled by coughing (Bensen, 2016), therefore, it is important to monitor radionuclides in dust in areas around mines.

Johnson *et al.* (2020) carried out a comprehensive study in a uranium mining region in the United States scrutinized groundwater samples to evaluate the prevalence and dispersion of radionuclides. The study brought to light increased levels of uranium and other radionuclides in the groundwater, signifying pollution from the adjacent mining operations. The results underscored the significance of consistent monitoring and control tactics to safeguard groundwater resources.

A research was conducted by Ongaro *et al*. (2018) that delves into the radiological contamination of groundwater in the proximity of a nuclear power facility in Italy. The study scrutinizes the movement of radionuclides from the plant location to the adjacent aquifers. The outcome of the study revealed escalated levels of tritium and other radionuclides in the groundwater, signifying the necessity of proficient containment and remediation approaches to deter the aggravation of contamination.

A comprehensive evaluation of radon ^{222}Rn concentrations in tap water was conducted by (Keramati *et al.*, 2018). The study encompassed an estimation of effective doses from both inhalation and ingestion, and Monte Carlo simulation was employed to assess health risks in adults and children. The outcomes of the analysis revealed that adult ingestion doses of radon ^{222}Rn were 1.35 times higher than those of children. Furthermore, the overall radon ^{222}Rn concentration in drinking water in Iran was below the standard limits prescribed by the World Health Organization and the Environmental Protection Agency. These results underscore the significance of continued monitoring and regulation of radon ^{222}Rn levels in drinking water to mitigate the potential health ramifications.

The purpose of this study was to assess the radiological health risk of the groundwater residential area of Maiganga Mining Site in Gombe, North-Eastern Nigeria. The presence of gold mining operations has been found to have a significant impact on the environment. In particular, there lease of radionuclides in to the environment is a major concern. These radionuclides can have far-reaching consequences, such as environmental contamination and pollution, increased risk of radiation-induced health effects and negative effect on water quality. As such, it is essential that gold mining operations should be properly monitored and regulated in order to mitigate any potential environmental harm and safeguard nearby communities.

Materials and Method

Study Area

Maiganga is a community located between the latitude 10° 02' to 10° 05° and longitude 11° 06' to 11° 08' in Akko Local Government Areas of Gombe, Northeast Nigeria (Kolo *et al*., 2016). The local government is bounded by Dukku and Kwami L.G.A to the North, Yamaltudeba L.G.A to the east, Billiri and Kaltungo L.G.A to the south, as show in figure 1. The Maiganga Community covers an area of about 20,129.47 Acres (48.16 Km^2). The people are predominantly farmers, cattle rears and traders.

Geology of the Study Area

The geographical location in question is situated within the tropical continental climate, which is widely recognized for its distinct wet and dry seasons. An annual precipitation range between 850 to 1000mm^3 is recorded, with the rainy season lasting approximately 5 to 6 months. The temperature in this region remains relatively high for the majority of the year. As for geological features, the study area is developed on basement complex rocks. The vegetation consists of sparse trees, scrubs and open grasses. The demographic makeup of the study area encompasses a range of ethnicities, including but not limited to Jukun, Fulani, and Tangale, with the latter being the most prominent (Kolo *et al*., 2016). As per the 2006 population census, the estimated population of Maiganga village stands at approximately 3,520 residents.

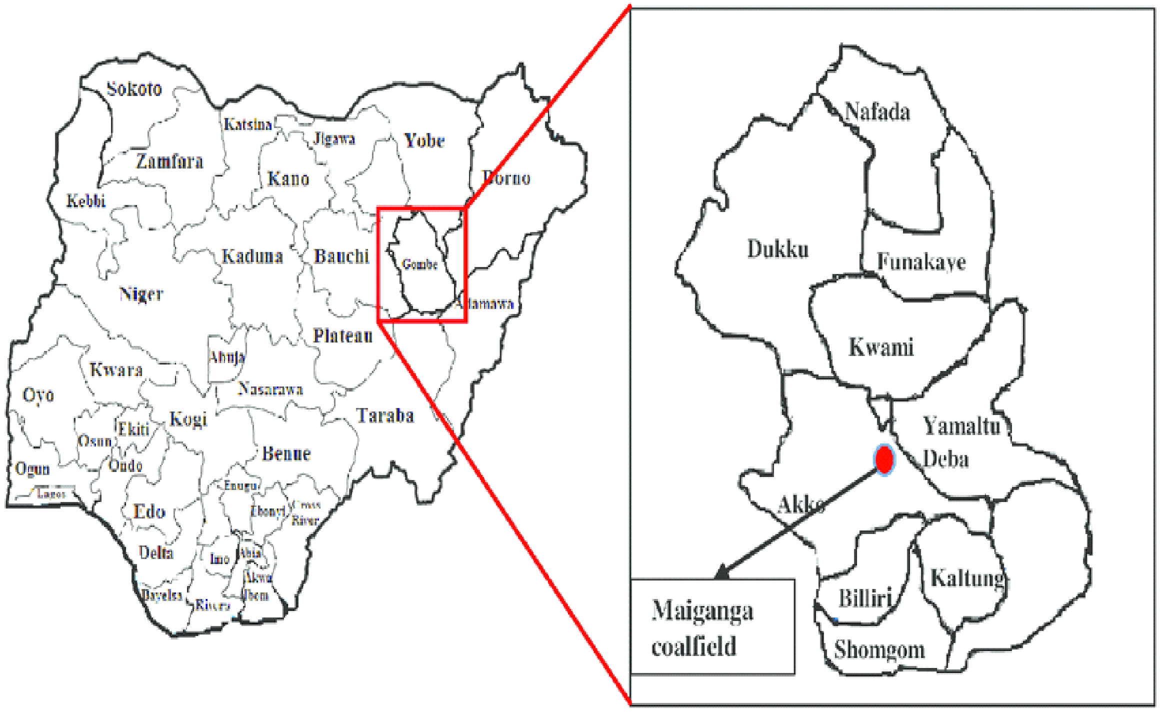

Figure 1: Map of Gombe state showing Maiganga community of Akko Local Government Area, (Kolo *et al*., 2016).

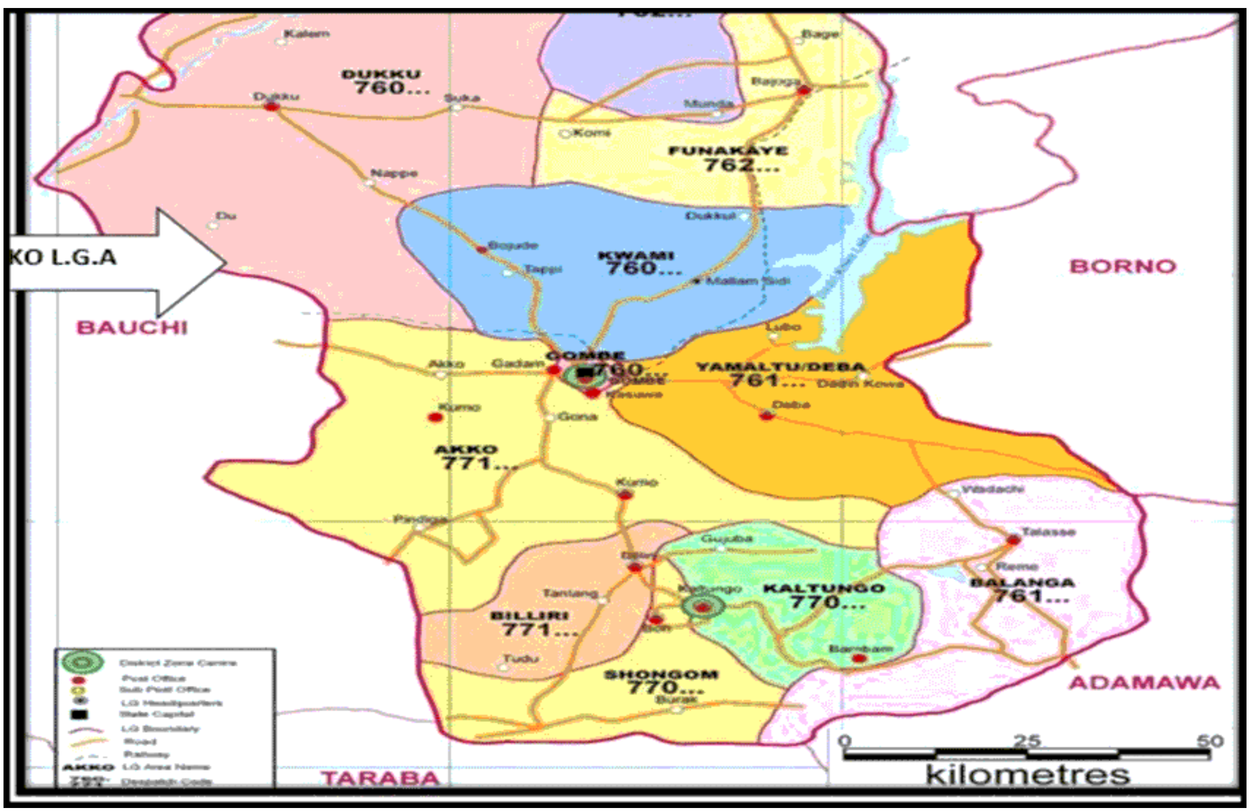

Figure 2: Geologic Map of the Gombe State showing Akko LGA (Daniel *et al*., 2020).

Materials and Reagents

The following inventory enumerates the materials and reagents utilized in this research, as delineated by the American Society for Testing and Materials (ASTM, 1999), in a publication entitled "Standard Test Method for Radon in Water."

Scintillation cocktail; Scintillation vials (20ml capacity) with polyethylene inner seal cap liners; Surgical gloves; Indelible ink and Masking tape; Distilled water; Disposable hypodermic syringe (20ml,10ml capacities) and Liquid Scintillation Counter (Packard Tri-Card LSA 1000TR).

Inclusive of the constituents and reagents elucidated in the preceding section, there exist several additional indispensable components that warrant consideration for the successful execution of scientific experimentation. Among these essentials is the Global Positioning System (GPS), a pivotal instrument for accurately charting study sites and recording spatial data. By utilizing a GPS, researchers can precisely pinpoint samples and gather crucial data pertaining to the impact of environmental factors on the studied organisms. Additionally, a sterile environment is paramount to the integrity of experimental outcomes, and as such, a pristine cloth is of utmost importance for maintaining the necessary hygienic conditions. Implementing a clean cloth to sanitize surfaces and equipment is imperative to avert contamination and ensure the precision of results.

Liquid Scintillation Counter

The Liquid Scintillation Counter is an advanced apparatus designed for the precise quantification of ionizing radiation emanating from radioactive materials, specifically alpha and beta particles. While capable of measuring gamma radiation, the device's efficacy in this regard is comparatively diminished. In liquid Scintillation counter (L.S.C), the process by which energy stemming from the emission of radiation is assimilated by a scintillator, which is a material that produces photons of light in response to incoming radiation, and subsequently re-released as photons is a fundamental mechanism utilized in various scientific applications. The process of capturing and analyzing emitted light requires a high level of precision and sensitivity. One of the key components in this process is the photomultiplier tube (PMT), which is designed to detect even the faintest traces of light. The PMT is able to do this through a series of stages, which involve the conversion of photons into electrical signals that can be amplified and analyzed. This makes it an essential tool in a wide range of applications, from medical imaging to particle physics research. In this way each emission results is a pulse of light as shown in figure 3.

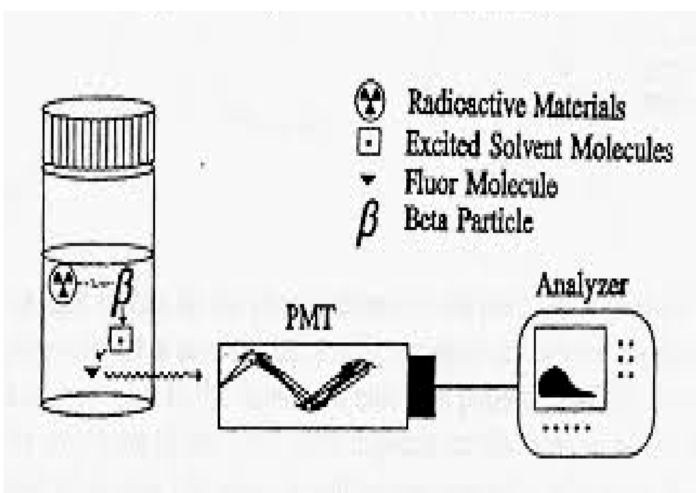

Figure 3: Schematic Diagram illustrating the principle of Liquid Scintillation Counter (Eikenberg 2013).

Plate 1: Liquid Scintillation Analyzer (Tri-carb- LSA 1000), CERT, ABU, Zaria.

Plate 2: The Full Set of Liquid Scintillation Analyzer System (Tri-carb- LSA 1000), CERT, ABU, Zaria.

Plate 3: Counted Samples in Secondary Containment Tri-carb- LSA 1000), CERT, ABU, Zaria.

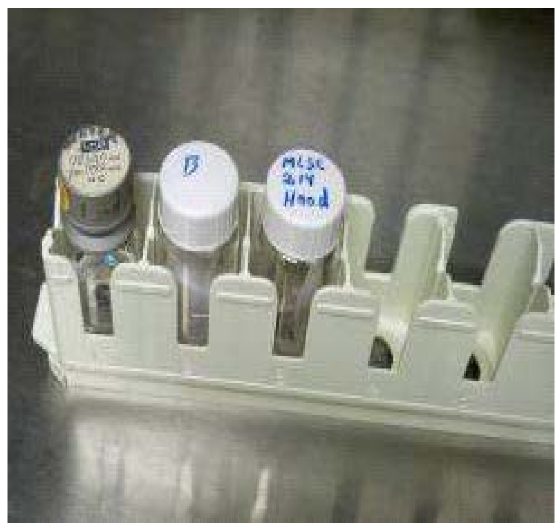

Plate 4 : Vials in Counting Rack.(Tri-carb- LSA 1000), CERT, ABU, Zaria.

Methods

Sample collection

In the Maiganga community of the Akko Local Government Area in Gombe State, 10 samples were procured for analysis from underground water sources including boreholes, tap and open wells at various locations as depicted in figures 1 and 2. The sampling collection was show in the plate below.

Plate 5: Open well water sample from the area. **Plate 6**: The borehole water of the area

Plate 7: The Tap Water from the Area

Samples were collected using a plastic vials. Water from wells was first purged before collection of samples. And water from tap was first purged before collection of samples. Here samples were first collected with bailers and then transferred into vials. Boreholes were pumped and allowed to flow each for at least three (3) minutes before samples were collected in order to ensure that fresh samples were obtained. Each collected sample was properly labeled and the time of sample collection was noted and recorded.

Sample preparation

10 ml of each sample was added into a vial containing 10 ml of toluene based cocktail (scintillation) using a hypodermic syringe. The vials were tightly capped and shaken vigorously for three (3) minutes in order to measure their gross alpha-beta activities.in water phase into the organic scintillator. In a similar manner a blank sample for the background was prepared using distilled water that has been kept in a glass bottle for at least 21 days. The prepared samples were allowed to stand undisturbed for at least three (3) hours each in order for gross alpha-beta activities products attain equilibrium before counting.

Gross alpha-beta determination

The prepared samples and the blank were each analyzed using the Liquid Scintillation Counter (Tri-Card LSA 1000) at the Center for Energy Research and Training (CERT), Ahmadu Bello University Zaria, Kaduna, Nigeria. Radiation emitted from the samples transferred energy to the organic scintillator which in turn emits light photons. This way each emission result is a pulse of light in form of digit. The alpha's and beta's can be calculated by the following equation.

$$X_{\alpha} = \frac{MCA11}{MCA12+MCA11}$$

$$X_{\beta} = \frac{MCA12}{MCA11+MCA12}$$

Where Xα is the fraction of counts observed in the beta channel (MCA11) with respect to the counts observed in α and β channel (MCA12 + MCA11) when a pure α is measured. Xβ is the fraction of counts observed in the alpha channel (MCA11) with respect to the counts observed in α and β channel (MCA12 þ MCA11) when a pure β is measured. The MCA11 contains pure sample β measurements while MCA12 contains pure sample of α measurements (Dias *et al*., 2009 and Hoang, 2016).

The gross αβ activities were calculated using the following equation (Abdellah, 2013)

$$A_{\alpha} = \frac{(MCA12_{G\alpha} - MCA12_{B\alpha})}{V \times T}$$

$$A_{\beta} = \frac{(MCA11_{G\beta} - MCA11_{B\beta})}{V \times T}$$

Where MCA12Gα and MCA11Gβ are the number of gross counts per minute recorded in the α and β window, respectively for the water sample vial. MCA12Bα and MCA11Bβ are the number of backgrounds counts per minute recorded in the α and β window, respectively for the blank vial. Aα and Aβ are the gross alpha and beta (Bq.1/L) of the sample respectively. V is the volume of sample analyzed in liters. T is the measuring time (seconds).

Results and Discussion

The overall significant results that were obtained throughout this research work as shown in table 1 have been evaluated in this chapter. The activity concentration of Radionuclides in drinking water of the ten (10) water samples collected at different locations of Maiganga Mining site in Akko Local Government Area, Gombe.

A total of ten (10) samples groundwater (wells and boreholes) and samples were collected from Maiganga Mining Site and analyzed using Liquid Scintillation Counter. The results of the analysis are shown in table 1 below.

Table 1: The activity concentration of Radionuclides in drinking water of the ten (10) water samples collected at different locations of Maiganga Mining site in Akko Local Government Area, Gombe.

S/N	Sample ID	Latitude	Longitude	Gross Alpha Activities (Bq.1/L)	Gross Beta Activities (Bq.1/L)
1.	MS1	09°58’45.49”	11°08’54.74”	0.9991	0.2380
2.	MS2	09°58’54.93”	11°08’47.46”	1.0825	0.1416
3.	MS3	09°59’48.00”	11°09’16.47”	0.9691	0.1152
4.	MS4	09°59’51.10”	11°09’14.77”	0.9847	0.1033
5.	MS5	09°59’50.32”	11°09’11.30”	0.9700	0.1816
6.	MS6	09°59’56.66”	11°09’09.86”	0.9194	0.0380
7.	MS7	10°00’05.69”	11°09’13.08”	1.0263	0.1483
8.	MS8	10°00’04.50”	11°09’42.97”	0.9611	0.0330
9.	MS9	10°00’02.12”	11°09’36.21”	0.8816	0.0347
10.	MS10	10°00’09.56”	11°09’29’01”	0.9569	0.0833

The liquid scintillation counter was used to evaluate the total gross alpha and beta activity of the radionuclides present in the water. These results from techniques show that the water activities exceed the prescribed limit and thus can pose a risk on human health. The results from the LSC obtained indicated that there is a difference between the gross alpha and gross beta activities of each water sample. Why from the gross alpha activities has a small difference of the ten samples and the gross beta activities has small difference as well of the sample. For instance, the gross alpha activities is high and gross beta activities is less from the result obtained, this might be a result of alpha particles spilling over to the beta channel and beta particles spilling over to the alpha channel (Hoang, 2016). The minimum and the maximum gross alpha activity obtained was 0.8816 (Bq.1/L) and 1.0825 (Bq.1/L) respectively, while the minimum and the maximum gross beta activity obtained was 0.0330 (Bq.1/L) and 0.2380 (Bq.1/L) respectively. There is a small difference of gross alpha activity in all the samples and the same true on gross beta activity. The gross beta activities are less than the gross alpha activities; this could be due to some alpha particles spilling over to the beta channel. Sample MS9 has the less gross alpha activity and sample MS8 has the less gross beta activity. While in sample MS1 has the highest gross beta activities and sample MS2 is very high in gross alpha activities obtain. Although the gross alpha activities are high, they do not exceed the target water quality limit of the main result 1.38 (Bq.1/L) which was stipulated by the DWAF. The both result obtain of gross alpha-beta activity limit stipulated by the WHO was not exceeded in gross activity and it was exceeded in gross alpha activity.

Gross Alpha

The result obtained from the analysis of sample collected at different locations from Maiganga mining site have the maximum concentration of gross alpha activity in the water as 1.0825 Bq/L while the minimum concentration was found to be 0.8816 Bq/L with an average value of 0.9691Bq/L as presented in table 1. All the values obtained for the gross alpha activity in water (Maiganga mining site) does not exceeded the maximum concentration level of 1.38 Bq/L set by DWAF (1996) and it exceeded the WHO guideline limit of 0.5 Bq/L. As showed in figure below.

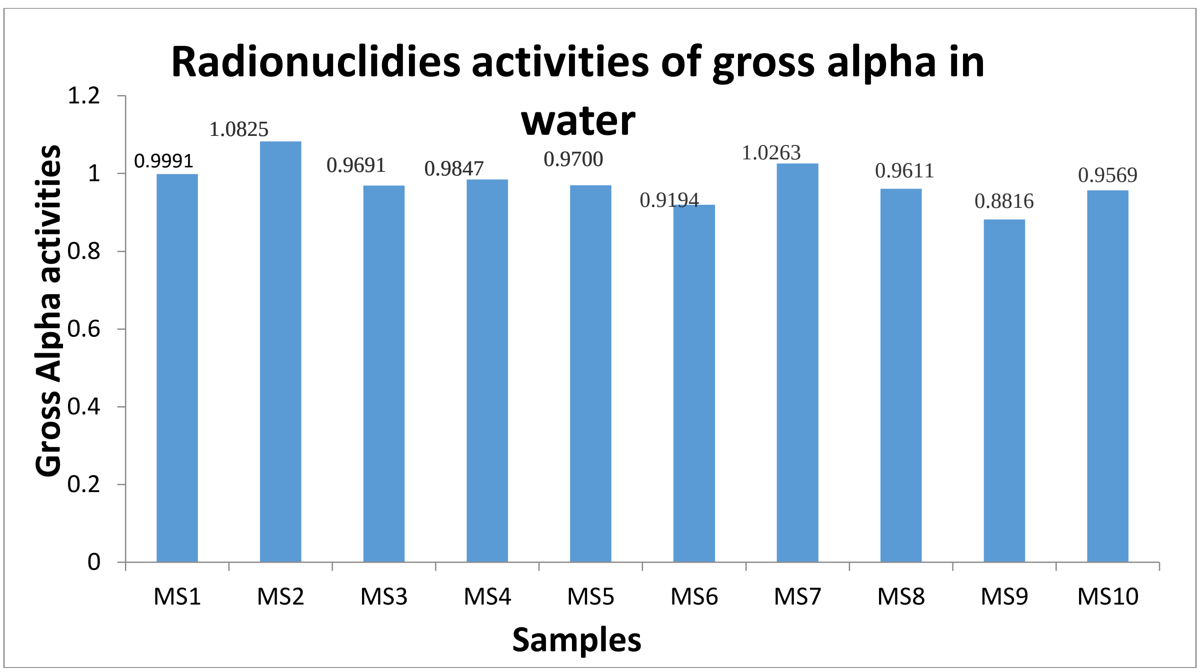

Figure 4: Bar Graph of radionuclide activity concentration for gross alpha in water

Gross Beta

The concentration of radionuclide in water sample collected from different located at the following areas in Maiganga mining site in table 1were found to be range from (0.033 to 0.238 Bq/L). The MS1 recorded the maximum radionuclide concentration of 0.238 Bq/L which does not exceeded the recommended reference level of 1.38 Bq/L set by DWAF (1996) and WHO (2011) guideline limit of 1Bq/L. for which action on the reduction of radionuclide in water is justify. While MS8 recorded the minimum radionuclide concentration of 0.0330 Bq/L as showed in figure 5. Sample MS2, MS3, MS4, MS5, MS6, MS7, MS9, MS10 from the area have radionuclide below the maximum concentration above the minimum concentration from the results obtained in gross beta activities. All the result does not exceeded the maximum radionuclide concentration level of 1.38 Bq/L set by DWAF (1996) and WHO (2011) guideline limit. Respectively as such considered fit for consumption as far as radionuclide concentration in water is concerned. Show in figure 5 below.

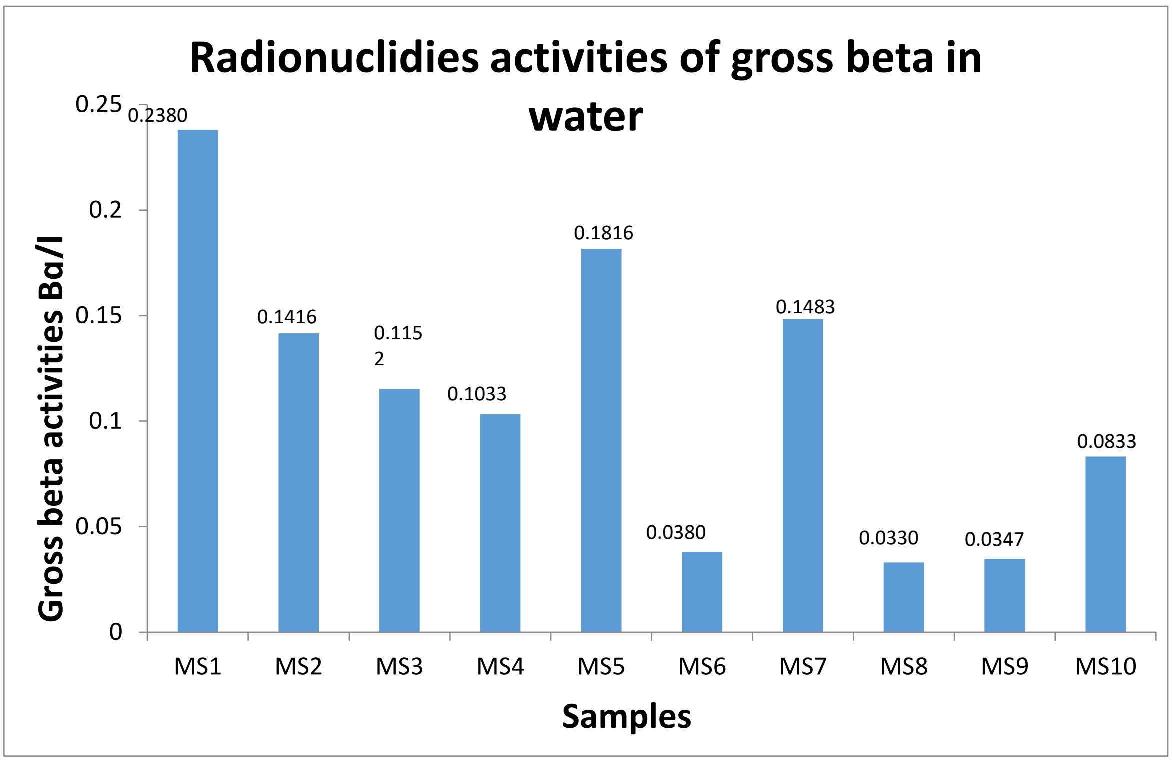

Figure 5: Bar Graph of radionuclide activity concentration for gross alpha in water

Discussion

A total of ten (10) water samples from Maiganga mining site town were analyzed for radionuclide concentration using liquid scintillation counter (LSC) at the Centre for Energy Research and Training (CERT) Ahmadu Bello University Zaria, Nigeria. The gross alpha activity radionuclide concentrations obtained from this analysis range within 0.8816 to 1.0825 Bq/L. the highest and the lowest radionuclide activity concentration were recorded from well and borehole water samples respectively. And for gross beta activity the water samples recorded the highest and the lowest radionuclide concentration within the range of 0.0330 to 0.2380 Bq/L as showed in table 1. It has been noticed that 29.75% of gross alpha activity of the recorded radionuclide concentration in this study as well as mean values obtained for the water sample were found to be below the Maximum Concentration level (MCL) of 1.38 Bq/L set by Department of Water Affairs and Forestry, DWAF (1996) and 116.5% of gross alpha activity of the recorded radionuclide concentration is above the (MCL) of 0.5Bq/L stimulated by WHO (2011) guideline limit. Also, 114.2% of the recorded values of radionuclide concentration of gross beta activity in water samples are below the recommended action level of 1.38 Bq/L set by Department of Water Affairs and Forestry, DWAF (1996) and 76.2% of gross beta activity in the water sample are below the recommended action level of 1Bq/L stimulated by WHO guideline limit (2011). However the radionuclide concentration of the both gross alpha and beta obtained from the water sample is not safe and this indicates that the water from the sample can pose radiological health problem.

Conclusion

Results obtained from the measurement of the activity of the alpha and beta concentration of radionuclide in water sample collected at different location of Maiganga Mining Site of Akko Local Government Area, Gombe State revealed that 29.75% of gross alpha of the recorded value of radionuclide concentration in the present study is below the Maximum Concentration Level (MCL) of 1.38 Bq/L set by DWAF (1996) and 116.5 of gross alpha of the recorded value is above the (MCL) of 0.5Bq/L stimulated by WHO (2011). 114.2% of gross beta of the recorded value of radionuclide concentration of water sample from the area was not exceeded the recommended action level of 1.38 Bq/L set by DWAF (1996) and 76.2% of gross beta of the recorded value is below the (MCL) of 1Bq/L stimulated by WHO (2011). This indicates that the drinking water from Maiganga Mining Site (MMS) is not safe for consumption and can pose radiological health problems to the community.

Recommendations:

- Further studies on the activity concentration of alpha and beta radionuclide in water sources including tap water should be carried out in Maiganga mining site area and other part Akko local government near the area since this is a pioneer work.
- The inhabitants of Maiganga town, particularly all the locations where concentration of alpha activity were found to above the normal government should monitor the activity in area not to higher than normal to keep exposure due to ingestion of radionuclide as low as reasonable.
- Epidemiological studies of the general population to determine lung and stomach cancer incidence should carried out.
- A detailed geological map of the study area should be made available for research and academic purposes.

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