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Radioactivity analysis in underground drinking water sources in Niger State University of Nigeria

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ABSTRACT: The activity concentration of gross alpha and gross beta particles in four samples of borehole drinking water consumed in Ibrahim Badamasi Babangida University (IBBU), Lapai, Niger State-Nigeria was measured, using a portable single channel gas free proportional counter (MPC2000B-DP) detector. This study focused on cancer related problems and the bio-data of the environment was discussed as well as the radiological effect of the water on consumers. Higher concentration of alpha and beta were observed in Hostel block A (DD) with values of 0.085± 0.024 and 11.229± 0.901 BqL^{-1}, respectively. However, lower concentration of alpha and beta particles were observed in the Faculty of Management Science (AA) with values of 0.006± 0.005 and 0.001± 0.276 BqL^{-1}, respectively. Out of the four sampling sites studied, only the Faculty of Management Science fall below the guideline levels of gross alpha (0.5 BqL^{-1}) and gross beta (1.0 BqL^{-1}) in drinking water, established by the World Health Organization. These results show that, consumption of groundwater from the other three major borehole sources, may pose significant radiological health hazards to the population.

Keywords: Activity concentration, gross alpha, gross beta, groundwater, radiological health hazards.

INTRODUCTION

Water is a major constituent of the human body and is essential for life. Fresh drinking water makes up only 6% of the total water on earth and 100% of the world's population rely on it. This includes icecaps and glaciers and if these sources are subtracted from the total, only 0.3% of the water on earth is suitable for drinking, and the majority of it is ground water. Millions of people in the developing world rely on groundwater, mostly through shallow dug wells. Most often, ground water is used by man for various purposes, ranging from agricultural to industrial, power generation and domestic consumption etc. Human activities and some natural phenomenon pollute and affect water quality. Some of these human activities can be generally categorized into four groups: municipal (sewage disposing), industrial (industrial waste disposal), agricultural (leaching of fertilizers), and individual sources (mining of minerals). Some of these waste disposals often contain radioactive materials (solid, liquid, or gaseous) which contribute significantly to the background activity of the water bodies (Gondar, 2011). Industrial pollution of groundwater results from the dumping

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of wastewater or wastes from mining activities, through leaching of mine tailing piles and leakage or spillage from other industrial processes (Faanu et al., 2011).

Agricultural contamination results primarily from the overuse of pesticides and fertilizers that later seep into groundwater sources, thereby causing groundwater pollution. On the other hand, individuals also cause ground water contamination by improper disposal of wastes namely motor oil, detergents and cleaners can leak into water sources. More significantly, groundwater can also be contaminated by naturally occurring sources. Heavy metals present in certain soils and geologic formations may pollute groundwater by leaching. This can be aggravated by over-pumping wells, particularly for agriculture purpose.

It is known that radioactive materials produce about 50% of the natural radiation which the public is exposed to (UNSCEAR, 2000). Natural radioactive mineral deposits are found in suitable geological environments (Karahan, 1997). Their occurrences in outcrop enhances the background radiation of the area (Karahan, 1997). This high level of exposure may be harmful to people residing in the region. According to the United Nations Scientific Committee on Effects of Atomic Radiation Report (UNSCEAR, 2000), the greater contribution to mankind's exposure is from natural background radiation, and the worldwide external average annual effective dose is 2.4 mSv (UNSCEAR, 2000). However, much higher levels of exposure are usual for inhabitants of natural high background radiation areas. Higher level of radiation above the earth is mainly due to naturally occurring radioactive elements in the earth's crust such as ^{238}U, ^{232}Th and ^{40}K. Residents in high altitude areas are also more affected by cosmic radiations (ICRP, 1991). Water sources are equally polluted by naturally occurring radioactive materials (NORMS) of the earth's crust (terrestrial radioactivity); which emits α, β and γ radiations. These materials which are normally from the ^{40}K, ^{238}U and ^{232}Th series are more concentrated in deep ground water than in surface water (Onoja, 2004). They contaminate water bodies directly with their radionuclide products; and indirectly, through the ^{222}Rn and ^{220}Rn gaseous products, which can solidify and attach themselves as aerosols to air particles and are washed down by rain into water bodies (Fasasi, 1999).

Drinking water sourced from deep wells and boreholes are usually expected to have higher concentration of radioactive nuclides. This is because they pass through fractures in bedrocks or within the soil which contains minerals deposits that might have radioactive constituents and thus leaking into the water ways. Radioactivity in drinking water is one of the major ways in which radionuclides from the environment gets into the human body, which might consequently lead to radiation-induced disorder (USEPA, 2010). There is evidence from both human and animal studies that radiation exposure at lower to moderate doses, may increase the long term incidence of cancer and that the rate of genetic malformations may increase by radiation exposure (Otton, 1994). It is therefore important to determine the amount of radioactivity in drinking water for every area where people reside, so as to guard against its deleterious effects (WHO, 2006).

Studies have focused on the measurement of groundwater radioactivity in Nigeria. Onoja (2004) determined gross α and β activity in well water from the Zaria area. The result shows a geometric mean value of 75.53 Bqm^{-3} (or 0.075 BqL^{-1}) for β activity. Tajudeen (2006) carried out a similar work in the Gwammaja area of Kano metropolitan city and the result shows a geometric mean value of 0.05 Bqm^{-3} for β activity. Habila worked on the survey of gross beta radioactivity in wells and boreholes from Jos city. The result shows that the range of β activity varied from 0.25 to 9.64 BqL^{-1}, with a geometric mean of 1.56 BqL^{-1} (Habila, 2008). Avwiri and Agbalagba (2007) surveyed the gross beta radionuclide activity in Okpare-Creek, Delta State and the reported mean beta activity was 0.481 BqL^{-1}.

The maximum radioactive contaminant limit in drinking water is 1.85 BqL^{-1} set by USEPA (USEPA, 1996) and 1.0 BqL^{-1}, as set by WHO for β (WHO, 1993, 2004). The geographical formation of an area determines the amount of radionuclides present in water (Avwiry and Agbalagba, 2007). However, Saidu (2010) worked on the gross β radioactivity in wells and boreholes water in Sokoto city. The values obtained from proportional counter shows that the β activity of well water ranged from 0.35 to 49.85 BqL^{-1} with a geometric mean of 4.86 BqL^{-1}; and that of boreholes ranged from 0.71 to 32.69 BqL^{-1} with a geometric mean of 3.38BqL^{-1}. These results show that the activities were above the practical screening level recommended by WHO (2003) which is 1.0 BqL^{-1} for beta activity per year. When a radionuclide gets into the human body through ingestion, inhalation or skin absorption, it continues to decay by emitting radiation such as α, β or γ radiations such that the organ or tissue is continuously irradiated. The damage is greatest with α, and least with γ radiation. According to Arnold et al. (1992), some radionuclides are chemically similar to some minerals in the human body and so when they are taken into the body, they mimic those minerals in the organs. For instance ^{226}Ra, ^{38}Sr and ^{56}Ba (Arnold et al., 1992) are found to have chemical similarity with ^{20}Ca in the bone, when these radionuclides get into the body, they are deposited at the bone marrow, causing damage to bone cells through Osseo Sarcoma (bone cancer). Exposure to radiation is harmful to living tissues because of its ionizing power in matter. This ionization can damage living cells directly, by breaking the chemical bonds of important biological molecules like DNA, or indirectly, by creating chemical radicals from water molecules in the cells, which can chemically attack biological molecules (UNSCEAR, 1993). To some extent, these molecules are repaired by natural biological processes; however, the effectiveness of this repair depends on the extent of damage. Obviously, if the repair is faulty or not made at all, the cell may then suffer either of these possible fates (Cember, 1996):

a. Death of the cell;
b. An impairment in the natural functioning of the cell leading to somatic effects, i.e. physical effects suffered by the irradiated individual, such as cancer;
c. A permanent alteration of the cell which is transmitted to later generations, i.e. a genetic mutation.

In Lapai ,Niger state-Nigeria ,like many other states in the country ,due to portable water scarcity ,people normally collect water from wells and boreholes) deep and shallow). The public water boards are generally ineffective in supplying portable drinking water; therefore most of the population rely on untreated ground water sources) borehole and well ,(for domestic and industrial purposes. The groundwater collected from borehole samples are not entirely free from radioactive pollutants which are hazardous to human health. Therefore ,there is need to determine the present concentration of gross alpha and gross beta particles in ground water from Ibrahim Badamasi Babangida University, Lapai, Niger State, and to assess the radiological health risks due to consumption of water from various water sources on the campus because students from all parts of the country and beyond are involved .

Groundwater pollution is very difficult to remediate, except in small defined areas;

therefore the emphasis has to be on prevention (Karahan et al., 2000). This is based on the protection of sensitive aquifers, control of discharges and releases as well as provision of drainage and sanitation systems to avert pollution discharges. For small areas of highly polluted groundwater, it may be possible to pump out, treat, and recharge. The effects of groundwater pollution on human health depends on the specific type of pollutants in the water. Pollution from groundwater often causes diarrhea and stomach irritation, which can lead to more severe health conditions. Accumulation of heavy metals and some organic pollutants can lead to cancer, reproductive abnormalities and other more severe health challenges. This paper presents the measurement of beta activity (BqL^{-1}) for water from bore hole sources in Ibrahim Badamasi Babangida University, Lapai, based on reference to the USEPA maximum contaminant limit of 1.85 Bq L^{-1} and WHO maximum contaminant limit of 1.0 BqL^{-1} (USEPA, 1996; WHO, 2003).

The study area

Lapai is a local government area in Niger State, Nigeria adjoining the Federal Capital Territory. It has an area of 3051 km^2 and a population of 110127 as presented in the 2006 census. The Ibrahim Badamasi Babangida University, Lapai is geographically located between latitude 9º03’17.60"N - 9º05’07.22"N and longitudes 6º33’49.53"E - 6º35’38.47"E. It is bounded on the east by a road that leads from Lapai to Borugu village and on the west by a road leading to Minna through Paiko, the area is roughly coterminous with the Lapai Emirate.

Figure 1 shows the location map of the study area (Tsepav et al., 2014). The area has a gently undulating topography covered with vegetation, shrubs, trees and grasses. It has a fine grain texture of sand; clayey-sand, laterite and pebbles of granites with few visible exposures (Tsepav et al., 2014).

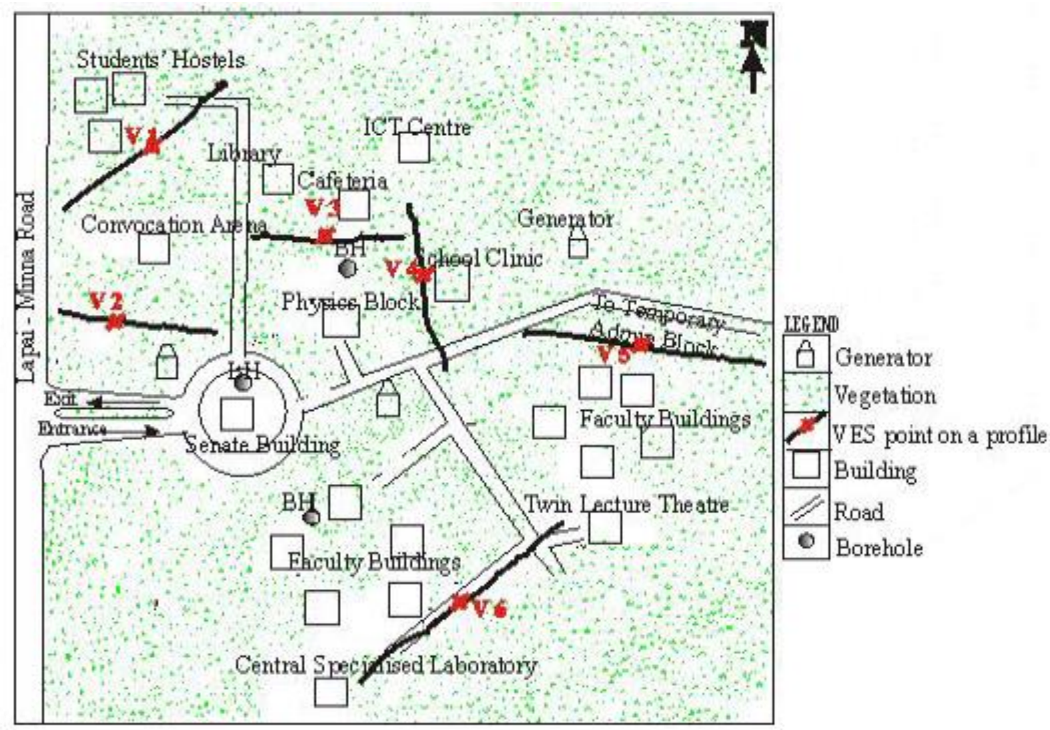

Fig. 1. Location map of IBB University main site (source: Tsepav et al., 2014)

MATERIALS AND METHODS

Sample collection and preparation

The GPS location within the premises of Ibrahim Badamasi Babangida University Lapai, Niger State is shown in Figure 2. The water samples were collected from the four major sources; Faculty of Management Science (AA), Faculty of Sciences (BB), Department of Physics (CC) and Hostel Block A (DD).

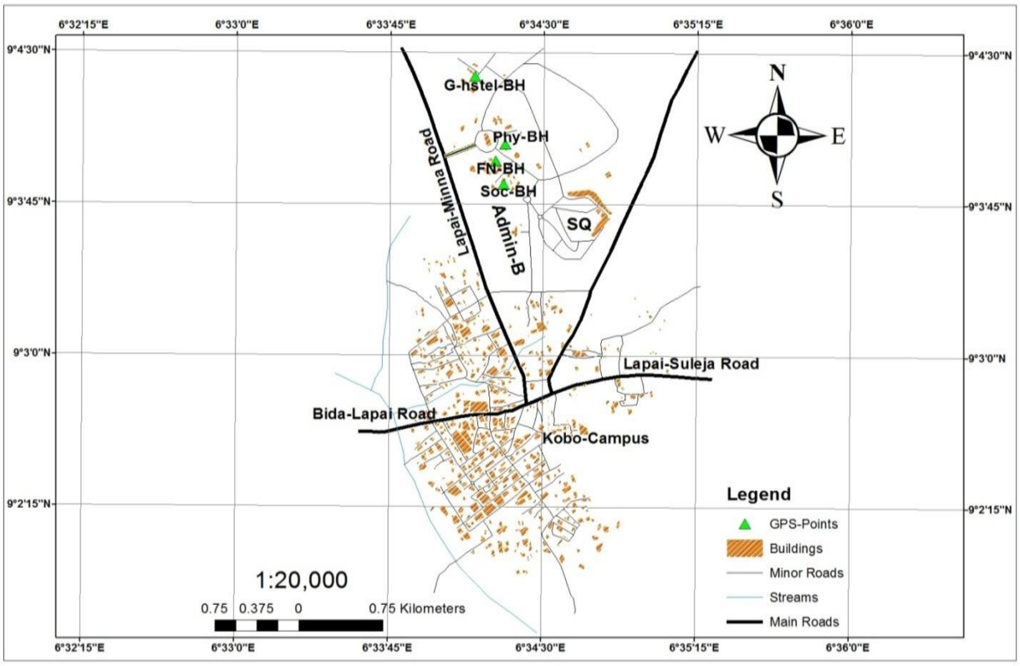

Fig. 2. Sample location in IBBU, Lapai

The samples were collected in one liter capacity, sterilized glass bottles. All the samples were prepared by evaporation, at low temperature. They were evaporated slowly at 70°C to near dryness (approximately 2-3 ml). Then each sample was transferred quantitatively to an aluminium planchette and dried until precipitation occurred.

Each sample precipitation in planchette was directly applied to counting systems. The results were obtained by arithmetic means and measurements of the radioactivity level of all water samples were analyzed (ASTM, 1995, 1999; Bonotto et al., 2009) at the Center for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria. The international standards organization procedure (ISO 9696; 9697: 1992E; Krieger, 1975) for the measurement of gross alpha and gross beta activity in water was employed in this analysis. This method provides a screening technique to measure the gross alpha and beta radioactivity in water samples. The water samples collected were preserved in accordance with the ISO standard (20 mL of 50% V/V of HNO_3 (Fig. 2) per liter of water). The purpose of this was to minimize the loss of radioactive material from solution due to absorption. Then the samples were analyzed three days after collection. A portable gas free MPC2000B-DP single channel gross alpha and gross beta radiation detector was used for the counting.

The sample efficiency, background measurements and plateau test were carried out using standard methods (ASTM, 1995; ISO, 1992). The sample efficiency ε_{sam} and sample volume V_{sam} were calculated as shown in the following Equations:

$$\varepsilon_{sam} = \frac{S_p}{M_r} \times 100\% \quad (1)$$

$$V_{sam}(L) = \frac{V}{M} \times S_p \quad (2)$$

where S_p = Sample weight on the planchette, M_r = The residual sample weight from the evaporated water sample, V = Volume of the evaporated water sample and M = residue mass.

Gross alpha counting
For gross alpha counting, a high voltage was set at 1600V and samples were counted for 5 cycles of 2700s per cycle. The results were displayed as raw counts; count rate (count/min), activity and standard deviation. The data were acquired for alpha only mode and the alpha count rate α_{CR} as well as alpha activity α_A, were calculated using Equations (3) and (4) respectively:

$$\alpha_{CR} = \frac{Raw\ \alpha\ counts \times 60}{Count\ time} \quad (3)$$

$$\alpha_A = \frac{[Raw\ \alpha - Bgd\ \alpha] \times unit\ coefficient}{Channel\ \alpha efficiency \times sample\ efficiency \times sample\ volume} \quad (4)$$

where the unit coefficient is the multiplication coefficient, making it possible to obtain the results. The alpha activity is expressed as Activity Concentration, C_α in BqL^{-1}) using the formula:

$$C_\alpha = \frac{R_b - R_0}{R_s - R_0} \times \frac{14.4}{1000V} \times 1.020 \quad (5)$$

where R_b is the observed sample count rate (S^{-1}), R_s is the observed standard count rate (S^{-1}), R_o is the background count rate (S^{-1}), V is the volume of sample in liters, M is the mass in milligrams of ignited residue from volume V, and $\frac{14.4}{1000V}$ represents the specific activity of ^{40}K in KCl. The factor 1.020 was included in the final equation to correct for the 20 ml of the Nitric acid added to the sample as a stabilizer.

Gross Beta Counting
The high voltage for gross beta counting was set at 1700V and samples were counted for 5-2700s in beta mode. The Beta Count Rate (β_{CR}), and Beta Activity (β_A), were calculated using Equation (6) and (7) respectively:

$$\alpha_{CR} = \frac{Raw\ \beta\ counts \times 60}{Count\ time} \quad (6)$$

$$\alpha_A = \frac{[Raw\ \beta - Bgd\ \beta] \times unit\ coefficient}{Channel\ \alpha efficiency \times sample\ efficiency \times sample\ volume} \quad (7)$$

The beta activity is expressed as Activity Concentration, C_β in Becquerel per liter (BqL^{-1}) using the formula:

$$C_\beta = \frac{R_b - R_0}{R_s - R_0} \times \frac{14.4}{1000V} \times 1.020 \quad (8)$$

RESULTS
The measured concentration values for the four samples used for the gross alpha and gross beta counting, are presented in Table 1 according to their locations.

Table 1. Result of Gross Alpha and Gross Beta Radioactivity in the water samples.

Sample ID	Alpha Activity BqL^{-1}	Statistical Error	Beta Activity BqL^{-1}	Statistical Error
AA	0.006	0.006	0.017	**0.003**
BB	0.025	0.006	7.368	**0.223**
CC	0.026	0.005	2.264	**0.165**
DD	0.085	0.024	11.229	**0.901**
MEAN VALUE	0.036	0.010	5.200	**0.390**

Faculty of Management Science **(AA),** Faculty of Sciences **(BB),** Department of Physics **(CC)** and Hostel Block A **(DD)**

The alpha activities ranged from 0.00582± 0.00571 BqL^{-1} in the Faculty of Management Science to 0.08461± 0.02436 BqL^{-1} of Hostel block A with mean value of 0.0355± 0.0103 BqL^{-1}. Similarly, the beta activities ranged from 2.264± 0.2766 BqL^{-1} in the Faculty of Management Science to 11.22± 0.901245 BqL^{-1} in Hostel block A with mean value of 5.20± 0.39 BqL^{-1}.

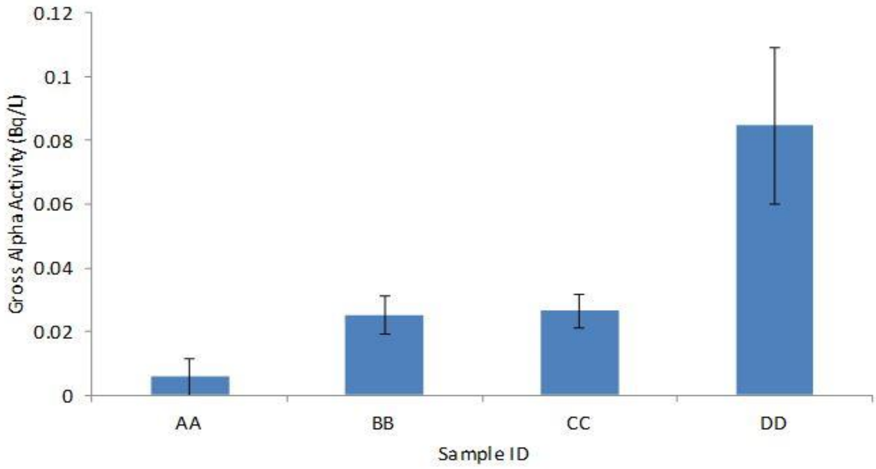

Fig. 3. Distribution of Gross Alpha Activities

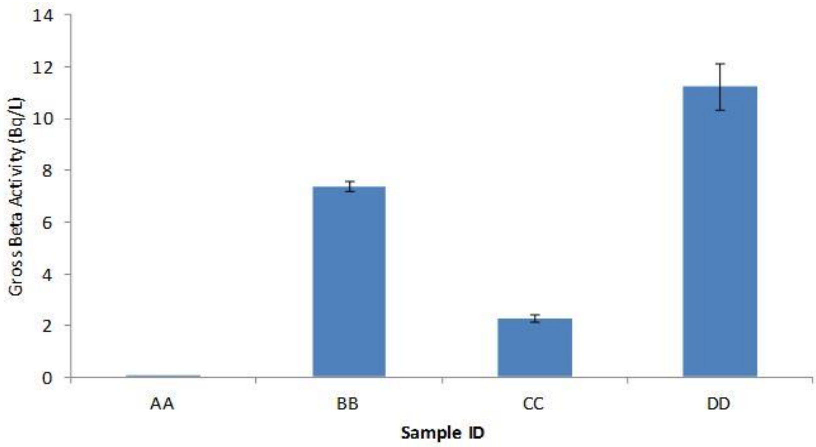

Fig. 4. Distribution of Beta Activity

As shown in Figures 3 and 4, the alpha and beta activities measured in water samples from Ibrahim Badamasi Babangida University, Lapai could be from one of the following major sources; anthropogenic factor (i.e., the atmospheric fall-out), deposition of radionuclides into the soil as a particle or dissolved nutrient and primordial sources as a result of rocks/hills in the environment (Igwe et al., 2005).

These radionuclides may be deposited into the soil either as particles or dissolved into soil water after the application of fertilizers and composite manure, because the borehole in the DD location is close to farm lands.. Even the soil deposition might play an important role in this regard. These radionuclides, when absorbed by the root as nutrient leads to translocation into various parts of boreholes and wells. The atmospheric fall-out sometimes contributes immensely to the water pollution activity concentration measured as may be the case in this work. This normally occurred as a result of nuclear disaster such as disposal of radioactive waste material into the river. Radionuclide particles suspended in air could be deposited on the soil surface which later dissolves and the level of contamination therefore depends on the surface area, and water channels (Audeen, 1989). This may be the reason for observing gross alpha value as 0.084617 ± 0.024 BqL^{-1} and gross beta as 11.229 ± 0.901 BqL^{-1} in the borehole around Hostel block A (Figs. 3 and 4). From the result presented in Table 1, it can be observed that α activities are within the maximum screening level. The β activities in three different locations, Faculty of Science, Department of Physics, and Hostel Block A, are higher than the maximum screening level. The borehole around the Faculty of Management Science recorded a relatively very low value of 0.006 ± 0.005 BqL^{-1} for gross alpha and 0.017± 0.003 BqL^{-1} for gross beta activities, respectively (Figures 3 and 4).The result of beta activities in Hostel block A showed a higher value compared to other regions (Garba et al., 2013; Saidu and Ike, 2013; Muhammad et al., 2010) within the school and as a result is thought to be caused by either the local machine used to drill the hole, the depth of drilling; the deeper the source the higher the radioactivity, impedance and soil composition.However, if people living in areas whose drinking water exceeds the recommended dose limit set by WHO (2003) (which is 0.5 BqL^{-1} for alpha and 1.0 BqL^{-1} for beta per year) continue the intake , it will result in health problems. This may be the case of drinking borehole water around the Faculty of Science with value of 7.368 ± 0.223 BqL^{-1}, Department of Physics with value of 2.264 ± 0.165 BqL^{-1}, and the highest being Hostel block A with value of 11.229± 0.902 BqL^{-1} of gross beta activity (Figs. 3 and 4). The results demand extensive investigation to be carried out, in other to ascertain the contributing factors to high gross beta activity.

Table 2 compares some similar works carried out in various locations in Nigeria. It shows that all the water sources investigated contained radionuclides. The highest for alpha is Bayelsa with 4.02 BqL^{-1} and the lowest was obtained from the Guinea savanna with 0.0149 BqL^{-1}. For Beta activity, the highest was in Bayelsa with 54.232 BqL^{-1} and the lowest was recorded in the Guinea savanna with 0.3295 BqL^{-1}. This result shows that the water sources in the sampling places of Bayelsa State, Niger Delta, Niger State, Sokoto State, and Katsina State are not radiologically safe for drinking.

Table 2. Similar work carried out within Nigeria

State (Source)	Alpha Range (BqL^{-1})	Average (BqL^{-1})	Beta Range (BqL^{-1})	Average (BqL^{-1})	Source
Niger (IBB) (groundwater)	0.006-0.085	0.036	2.264-11.223	5.200	This Work
Bayelsa (groundwater)	0.021-16.950	4.020	5.840-135.88	54.232	Meindinyo and Agbalagba (2011)
Guinea Savanna Zaria (groundwater)	0.035-<0.01	0.015	0.910-0.060	0.3295	Garba et al., (2013)
Sokoto (groundwater)	0.010-6.000	0.260	0.520-6.320	3.420	Saidu and Ike (2013)
Niger Delta (groundwater)	0.010-0.500	0.100	0.700-54.700	8.900	Agbalagba et al., (2013)
Katsina (groundwater)	0.080-2.300	0.165	0.120-4.970	1.119	Muhammad et al., (2010)

CONCLUSIONS

The method of gross alpha and gross beta spectrometry was adopted to determine the concentrations of radioactive particles in water samples commonly consumed in IBB University. Based on this study, the preliminary results revealed that the only safe borehole drinking water source is the sample obtained from the Faculty of Management Science. The water sources in the Faculty of Science (BB) with beta activity of 7.368 ± 0.223 BqL^{-1}, Hostel Block A (DD) with beta activity of 11.229 ± 0.901 BqL^{-1} and the Department of Physics (CC) with beta activity of 2.264 ± 0.165 BqL^{-1}, are not safe for drinking when compared to the recommended dose set by WHO (2003) (which is 1.0 BqL^{-1} for beta activity per year). Long term measurements are essential to give a conclusive picture of the radioactivity of water obtained from the boreholes and wells that serve the people, in other to avert any serious health effects.

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