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RADIOACTIVITY ANALYSIS OF UNDERGROUND DRINKING WATER SOURCES IN IBRAHIM BADAMASI BABANGIDA UNIVERSITY LAPAI, NIGER STATE, NIGERIA

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between all authors. Authors RLN and IJI designed the study, wrote the protocol and interpreted the data. Authors MOA, YVI and IJI anchored the field study, gathered the initial data and performed preliminary data analysis. All the authors managed the literature searches and produced the initial draft, read and approved the final manuscript.

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ABSTRACT

The activity concentration of gross alpha and gross beta in analysed four samples of borehole drinking water consumed in Ibrahim Badamasi Babangida University (IBBU) Lapai, Niger State-Nigeria have been measured using the portable single channel gas free proportional counter (MPC2000B-DP) detector. This study was focused on cancer related problems, bio-data of the environment and the radiological effect of the water on the consumers. A higher concentration of alpha and beta were recorded in Hostel block A **(DD)** with values of 0.085 ± 0.024 BqL^{-1} and 11.229 ± 0.901 BqL^{-1} respectively. A lower concentration of alpha and beta were recorded in Faculty of Management Science **(AA)** with values of 0.006 ± 0.005 BqL^{-1} and 0.017 ± 0.276 BqL^{-1} respectively. Out of four sampling sites studied, only 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 in the other three major borehole drinking water sources may pose significant radiological health hazards through ingestion to the population.

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

1. INTRODUCTION

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 [1], they contaminate the water body 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 the air particles and are washed down by rain into water bodies [2].

Drinking water sourced from deep wells and boreholes are usually expected to have higher concentration of radioactive nuclides. This is because

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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 [2]. Radioactivity in drinking water is one of the major ways in which radio nuclides from the environment gets into the human body, which might consequently lead to radiation-induced disorder [3]. 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 because of radiation exposure [4]. It is therefore important to determine the amount of radioactivity in drinking water for every area where people live, so as to guard against its health hazards [5].

Some work has been done on measurement of radioactivity in water in Nigeria. [6] determined gross α and β activities in well water from Zaria area. The result showed the geometric mean value of 75.53 Bqm^{-3} (or 0.075 BqL^{-1}) for β activity. [7] also carried out similar work for 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 survey of gross beta radioactivity in wells and boreholes from Jos city. The result shows ranges of β activity varied from 0.25 to 9.64 BqL^{-1}, with a geometric mean of 1.56 BqL^{-1} [8]. [9] surveyed gross beta radio nuclide activity in Okpare-Creek Delta State and the reported mean beta activity was 0.481 BqL^{-1}.

The maximum contaminant limit of radioactivity allowable in drinking water is 1.85 BqL^{-1} set by USEPA [10] and 1.0BqL^{-1} as set by WHO for β [11, 12]. The geographical formation of an area determines to extent the radio nuclide present in water [9]. However, [13] worked on gross β radioactivity in wells and boreholes water in Sokoto city. The values of results obtained from proportional counter showed the β activity for wells ranged from 0.35 to 49.85 BqL^{-1} with geometric mean of 4.86BqL^{-1}; and that of boreholes ranged from 0.71 to 32.69 BqL^{-1} with geometric mean of 3.38 BqL^{-1}. These results also showed that the activities were above the practical screening level recommended by [12] which is 1.0 BqL^{-1} for beta activity per year. When a radio nuclide gets into the human body through ingestion, inhalation or absorption through the skin, it continues to decay by emitting radiations such as α, β or γ such that the organ or tissue is continuously irradiated. The damage is greatest with α, and least with γ radiation. According to [14], some radio nuclides 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 [14] are found to have chemical similarity with ^{20}Ca in the bone, when these radio nuclides get into the body, they are deposited at the bone marrow causing damage to the bone cells through Osseo Sarcoma (bone cancer). Exposure of radiation is harmful to living tissue because of its ionizing power in matter. This ionization can damage living cells directly, by breaking the chemical bonds of important biological molecules viz., DNA, or indirectly, by creating chemical radicals from water molecules in the cells, which can then attack the biological molecules chemically [15]. To some extent these molecules are repaired by natural biological processes, however, the effectiveness of this repair depends on extent of damage. Obviously, if the repair is faulty or not made at all, the cell may then suffer these possible fates [16];

i. Death of the cell
ii. An impairment in the natural functioning of the cell leading to somatic effects i.e. physical effects suffered by the irradiated individual only such as cancer
iii. A permanent alteration of the cell which is transmitted to later generations i.e. a genetic effect.

In Lapai, Niger state-Nigeria, just like many other states in the country, due to portable water scarcity, people normally collect water from wells and borehole (deep and shallow). The pipe borne is mostly not operational where provided; therefore most of the population relies on untreated ground water sources (borehole and well) for domestic and industrial purposes. The groundwater collected from the borehole samples are not entirely free from radioactive pollutants which are hazardous to human health, therefore there is a need to determine the present concentration of gross alpha and gross beta 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 and therefore the emphasis has to be on prevention [17]. This is based on protection of sensitive aquifers, control of discharges and releases and 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.

Health effects from groundwater pollution depend on the specific pollutants in the water. Pollution from groundwater often causes diarrhea and stomach irritation, which can lead to more severe health effects. Accumulation of heavy metals and some organic pollutants can lead to cancer, reproductive abnormalities and other more severe health effects. This paper presents the measurement of beta activity in BqL^{-1} for water from bore hole drinking water sources from Ibrahim Badamasi Babangida University, Lapai, based on reference to USEPA maximum contaminant limit of 1.85 Bq L^{-1} and WHO maximum contaminant limit of 1.0 BqL^{-1} [10, 12].

2. MATERIALS AND METHODS

2.1 The Study Area

Lapai is a local government area of Niger state, Nigeria adjoining the Federal Capital Territory. It has an area of 3051 km^2 and a population of 110,127 as per 2006 census. The Ibrahim Badamasi Babangida University, Lapai is geographically located between latitude 9°03’17.60"N - 9°05’07.22"N and longitudes 6°33’49.53"E - 6°35’38.47"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.

Fig. 1 shows the location map of the study area [18]. The area has a gently undulating topography that is covered with vegetation, shrubs, trees and grasses. It has fine grain texture of sand; clayey-sand, laterite and pebbles of granites with few visible exposures [18].

2.2 Sample Collection and Preparation

The GPS location within the premises of Ibrahim Badamasi Babangida University Lapai, Niger State is shown in Fig. 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)**.

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 is obtained.

Each sample precipitation in planchette was directly applied to counting systems. The results were obtained by arithmetic means. The measurements of radioactivity level of all water samples were analyzed [19-21] at the Center for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria. The international standards organization procedure [22, 23] for the measurement of gross alpha and

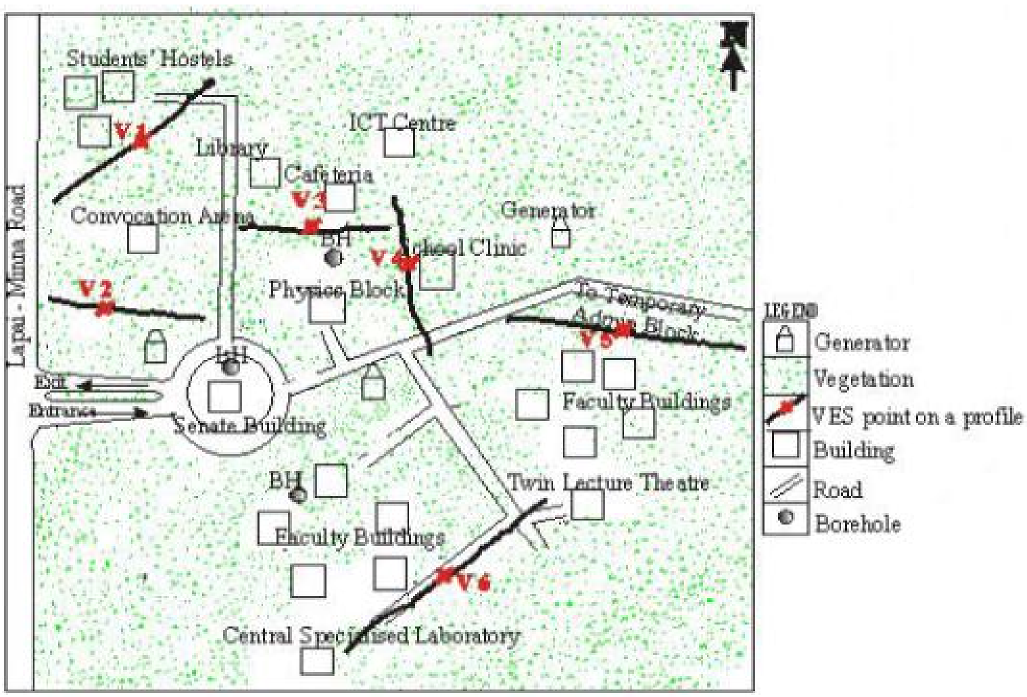

Fig. 1. Location map of IBB University main site (source: [18])

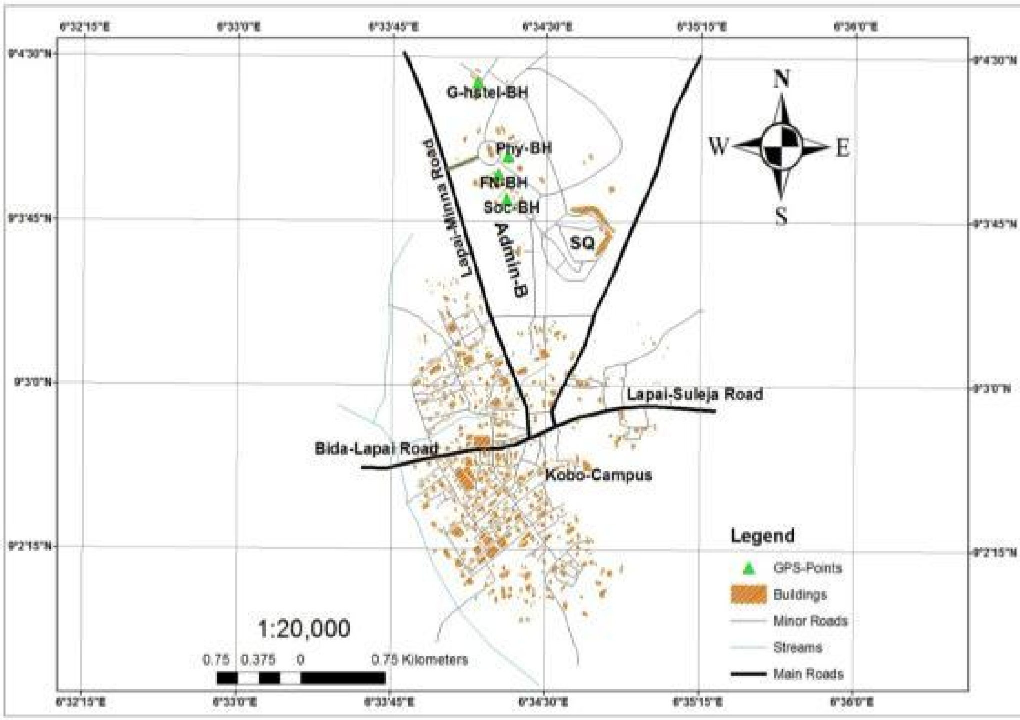

Fig. 2. Sample location in IBBU, Lapai

gross beta activity in water was employed in this analysis. This method provides a screening technique to measure the gross alpha and beta radioactivities in water samples. The water samples collected were preserved in accordance with the ISO standard (20 mL of 50% V/V of HNO_3 per liter of water). The purpose of this is to minimize the loss of radioactive material from solution due to absorption. Then the samples were analyzed from 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 [19,23,33]. The sample efficiency ε_{sam} and sample volume V_{sam} will therefore be 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 water sample evaporated and M = residue mass.

2.3 Gross Alpha Counting

For gross alpha counting, the high voltage was set at 1600 V and samples were counted for 5 cycles of 2700 seconds 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 formulae (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, 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;

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

where; R_b is observed sample count rate (S^{-1}), R_s is observed standard count rate (S^{-1}), R_o is background count rate (S^{-1}), V is volume of sample in liters, M is mass in milligrams of ignited residue from volume V, and $\frac{14.4}{1000V}$ represent 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.

2.4 Gross Beta Counting

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

$$\beta_{CR} = \frac{Raw\,\beta\,counts \times 60}{Count\,time} \qquad (6)$$

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

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

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

3. RESULTS AND DISCUSSIONS

The measured values of concentration for the four samples used for the gross alpha and gross beta counting in each water sample according to the locations are presented in Table 1.

Table 1. Result of gross alpha and gross beta radioactivities 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} for Faculty of Management Science to 0.08461±0.02436 BqL^{-1} for Hostel block A with the mean value of 0.0355±0.0103 BqL^{-1}. Similarly, the beta activities ranged from 2.264±0.2766 BqL^{-1} for Department of Physics to 11.22±0.901245 BqL^{-1} for Hostel block A with the mean value of 5.20±0.39 BqL^{-1}.

As shown in Figs. 3 and 4, the alpha and beta activities measured in the 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 radio nuclides into the soil as a particle or dissolved nutrient and primordial sources as a result of rocks/hills in an environment [24,31].

These radio nuclides may be deposited into the soil either as particles or dissolved into soil water through the application of fertilizers and compost manure as Borehole in location DD is located close to farm lands. Even the soil deposition might play important role in this regard. These radio nuclides, 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 [32] as may be the case in this work. This normally occurs as a result of nuclear disaster such as disposal of radioactive waste material into the river. Radio nuclide particles suspended in air could be deposited on the soil surface which later dissolved and the level of contamination therefore depends on the surface area, and water channels [25]. This may be the reason for observing gross alpha value of 0.084617±0.024 BqL^{-1} and gross beta of 11.229±0.901 BqL^{-1} in the borehole watch around Hostel block A (Figs. 3 and 4).

From the result presented in Table 1, it is observed that the α activities are within the maximum screening level. For the β activities in three different locations: Faculty of Science, Department of Physics, Hostel Block A, are higher than the maximum screening level. The borehole around Faculty of Management Science obtained 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 (Figs. 3 and 4).

The result of beta activities in the Hostel block (A) showed a higher value compared to other sites [26, 27, 28] within the school. This may be due to; (1) The local machine used to drill the bore hole, (2) The depth of the source, (3) Impedance and soil composition.

However, people in areas with values exceeding the recommended dose set by [12] (which is 0.5 BqL^{-1} for alpha and 1.0 BqL^{-1} for beta per year) might have some health problems if they continue to consume these water. This may be the case of consuming borehole water around 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 to know the contributing factors resulting to high gross beta activity.

Table 2, compares some similar work carried out from various locations in Nigeria. It shows that all the sources investigated had some presence of radio nuclides; the highest for alpha is Bayelsa with 4.02 BqL^{-1} and lowest in Guinea savanna with 0.0149 BqL^{-1}. For the Beta activity, the highest was in Bayelsa with 54.232 BqL^{-1} and the lowest in Guinea savanna with 0.3295 BqL^{-1}. This result showed 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.

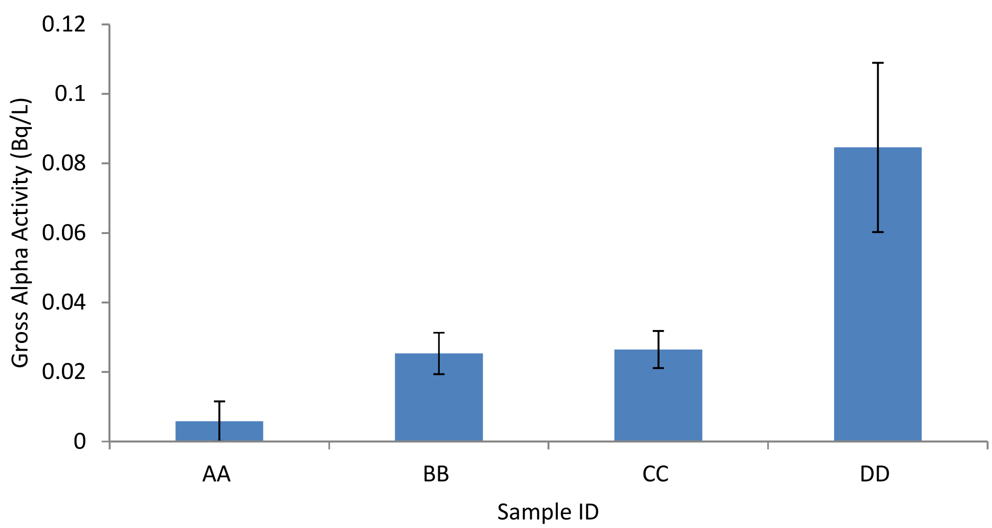

Fig. 3. Distribution of gross alpha activities

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 (ground water)	0.021-16.950	4.020	5.840-135.88	54.232	Meindinyo and Agbalagba, (2012) [29]
Guinea Savanna Zaria (groundwater)	0.035-<0.01	0.015	0.910-0.060	0.3295	Garba et al. (2013) [26]
Sokoto (groundwater)	0.010-6.000	0.260	0.520-6.320	3.420	Saidu and Ike (2013) [27]
Niger Delta (groundwater)	0.010-0.500	0.100	0.700-54.700	8.900	Agbalagba et al. (2013) [30]
Katsina (groundwater)	0.080-2.300	0.165	0.120-4.970	1.119	Muhammad et al. (2010) [28]

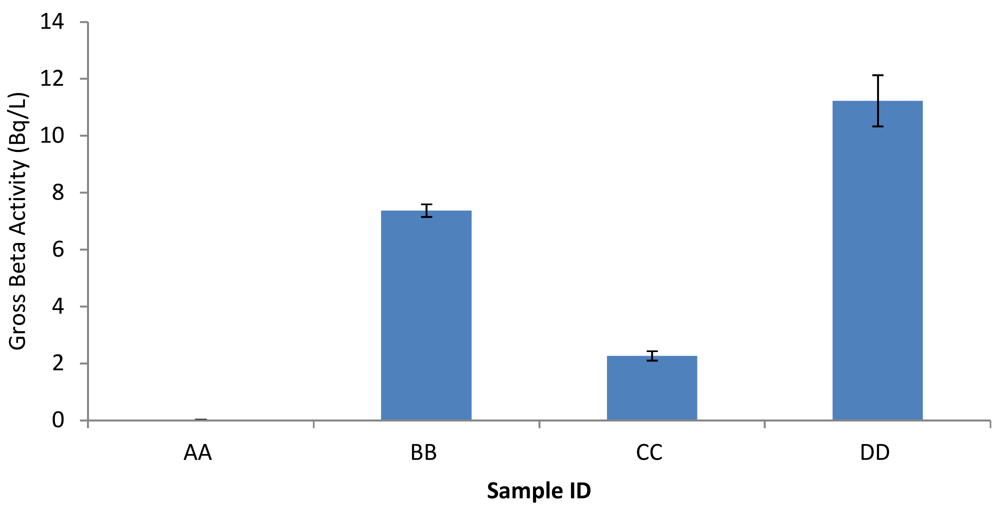

Fig. 4. Distribution of beta activity

4. CONCLUSION

The method of gross alpha and gross beta spectrometry has been adopted to determine the radioactivity concentrations of water samples commonly consumed from IBB University drinking water sources. Based on this work, the preliminary results revealed that the only safe borehole drinking water source is the one at the Faculty of Management Science. The sources in 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 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 [12] (which is 1.0 BqL^{-1} for beta activity per year). Therefore, only one sample of water from the bore holes in IBB University is well within the limit prescribed by WHO and USEPA, majority do not meet the standard. Long term measurements are very essential to give a conclusive picture for radioactivity from the bore holes and wells that are used for drinking because continuing to use it may pose serious health side effects to the public users.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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