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Determination of Gross Alpha and Beta Radioactivity in Underground Water at Gboko and its Environs

Atsor A.J., Akpa T.C. and Akombor A.A.
Department of Physics, Benue State University Makurdi, Benue State, NIGERIA

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Abstract

Fifteen samples of water from hand dug wells and boreholes were selected using a stratified random sampling. Ten (10mils) of concentrated nitric acid were added to each one litre of the sampled water for preservation. The samples were then evaporated and counted for Gross Alpha and Beta using MPC 2000 model gas filled proportional counter. Results show that, the range of alpha activity in water in the area was 0.309 to 14.488 Bq/L, with geometric mean of 6.576±0.328 Bq/L. The range of beta activity was 0.024 to 27.477 Bq/L with geometric mean, 11.16±0.42 Bq/L. The overall results show that, the alpha and beta activity have their values above WHO and USEPA recommended practical screening level of radioactivity in drinking water.

Keywords: Determination, Gross Alpha, Gross Beta, Radioactivity, Geometric mean.

Introduction

Water is one of the most important natural resources provided by Mother Nature and there are many demands for it. Skillful management of water bodies is therefore required if they are to be used for diverse purposes. Ninety-five percent (95%) of all fresh water on earth is ground water found in natural rock formation[1,2]. Natural and man- made sources of ionizing radiation are present in the environment in which man lives; there is a continuous release of these ionizing radiations in our environment[3,4]. This is as a result of the presence of radio nuclides in all activities undertaken by man. Naturally, occurring radionuclides are found in the food we eat, the air we breathe and the water we drink and have resulted in health hazards among the general public.

Radio nuclides from both natural and artificial sources can come in contact with water through several ways. They may be deposited from air; they may also be released to the water from the ground through erosion, seepage or human activities such as mining and drilling[5-8].

Certain rock types naturally contain radioactive elements referred to as Naturally Occurring Radioactive Material (NORM)[9]. When a source of drinking water comes in contact with NORM bearing rocks, radio nuclides may accumulate in the water to levels of concern. The predominant radio nuclides found in water include; Radium (and its decay products), Thorium (and its decay products) and Uranium (and its decay products). The small amounts of NORM present in a source of water may concentrate in sediments or sledges and because the NORM is concentrated due to human activities, it is classified as Technologically Enhanced Radioactive Material (TENORM).

In recent years, an additional concern arose in relation to international political problems. The widespread use of depleted uranium (DU) ammunition may have caused ground water and fresh water contamination. Moreover, the risk of terrorism acts involving voluntary radio contamination of water resources or the use of dirty bombs are considered not negligible by public authorities.

The quality of water is important in environmental studies for daily use, human consumption and its ability to transport pollutants. Determining the gross alpha and beta radio activities will help to estimate the radiological assessment of the surface water in the area of interest which is considered to be an important factor for the natural radiation exposure in humans.

Radioactivity in drinking water is not a new phenomenon, having been present to some extent for thousands of years. Nevertheless, exposure to radiation over a long period of time is believed to increase one's lifetime risk of developing certain types of cancer and other health hazards.

Materials and Methods

Material: The equipment used for this research work is Gross alpha and beta counter, MPC 2000 model.

Gross Alpha and Beta Counter: The gross alpha and beta counting equipment used for this research is Desktop lightweight gross alpha/beta counter, MPC 2000 model. The machine has alpha plus beta, alpha only and beta only modes respectively. It uses critical portions of PIC's electronic and mechanical designs that have been successful in other systems. It has modern control and interface options, a significantly reduced footprint, and a non-gas flow detector option. The MPC

2000 has two detector options available. A 2" active area, gas flow proportional detector is standard. This detector can be used with or without a user changeable ultra-thin entrance window. An optional non-gas flow detector is also available. The MPC-2000-B-DP version (with non-gas flow detector) completely eliminates the need for tanks of compressed counting gas. The sample drawer has been carefully designed to require the least effort and range of motion from users. The design greatly reduces the chance of repetitive motion injury. The sample drawer design also gives clear, unambiguous feedback to show that it is open or closed. The MPC-2000-B uses PIC's Gas-PRO technology to provide the same fail-safe counting as every protean gas flow counting system. Gas-PRO continually monitors the flow rate of P-10 gas through the system and halts counting if there is any change from the optimum rate.

Equipment Standard: The alpha standard used for this project work is plutonium- 239 sources. It is a sealed calibration source used to determine efficiency in the proportional counter. While the beta standard is strontium-90.The alpha and beta standards were used to calibrate the proportional counter.

Method: Sampling Area: The area under study is Gboko Local Government Area of Benue State. The population of the town is over 500,000 mostly Tiv people. The inhabitants are mostly farmers. The water used for drinking and domestic activities is mainly from wells and boreholes as there is no tap water in Gboko at the moment. It is bounded by co-ordinates 7^{o}19' 30"N, 9^{o}0'18"E

Sample Procedure: A stratified random sampling method was adopted for this work. The mapped area was divided in to 15 grids (strata). A sample was collected from each grid by simple random process.

Sample Collection: Two sets of samples were collected from each grid; acidified and non-acidified samples.

For the Acidified Sample: A two litre container each was rinsed three times with water being collected to minimize contamination from the original content of the sample container. The amount of water collected was such that air space of about 1% of container air capacity was left for thermal expansion. Thermometer was inserted into each of the samples to measure the temperature. 20ml of nitric acid was added per 2litres of sample immediately after collection to reduce the pH and to minimize precipitation and absorption on the walls of the container. Sample was tightly covered with the container cover and kept in the laboratory until analysis for alpha and beta activity was carried out. A sample was collected per grid, given a total of fifteen samples.

For Non-Acidified Sample: A one litre container thoroughly washed was used to collect water from each grid. The samples here were used to measure physical parameters in water such as pH, Total dissolve solute (TDS), and Conductivity.

Sample Preparation: Acetone (a cleansing agent) was first used to wash the apparatus needed for the sample preparation. About 600cm^3 of the sampled water was measured and transferred to a beaker. The sample was evaporated carefully on a Binatone temperature adjustable hot plate. The evaporation was done at the temperature less than 100℃ for eight hours until the volume was reduced to about 50ml and allowed to cool. The concentrated solution was transferred to a weighed planchette. The beaker was carefully washed with a minimum amount of water and the washings transferred to the planchette. Few drops of Vinyl acetate were added to the solvent to aid even distribution on the planchette. The sample was heated again to dryness and residue obtained. The planchette and residue were weighed and by subtraction, the mass m (mg) of the ignited residue was obtained. The residue was dispersed evenly over the planchette by slurring with a few drops of ethanol and allowed to dry. The planchette was weighed again to ensure that no residue has been lost. This procedure was repeated for all the samples.

The sample preparation efficiency was derived by taking the weight of the empty planchette W_B and the weight of the planchette plus sample after evaporation to 50ml, W_{B+S}. The difference between W_{B+S} and W_B gives the weight of the residue.

The ratio of the difference between the weights of the residue to 0.0770g as specified by ISO multiplied by 100 gives the sample efficiency as shown in equation 3.3;

$$\varepsilon s = \frac{W_{B+S} - W_B}{0.0770} \times 100 \quad (1)$$

The desired weight of 0.0770g of residue on the planchette was transferred to the sample holder of MPC 2000 model detector. The detector was then operated in alpha and beta modes to obtain the count rates of alpha and beta in counts per minutes respectively.

Results and Discussion

The physical parameters of sampled water investigated in this research work with their respective location names, geographical coordinates, type of water sampled and measured values of depth of the water sources are presented in table-1. The physical parameters are pH, Temperature, Total Dissolved Solids (TDS) and Conductivity. The parameters are also presented in figure-1.

Radioactivity in the Sampled Water: The gross alpha and gross beta concentrations as detected from the entire measurement sites are presented in table-2. The values of gross alpha and gross beta activities are also shown in Figure-2 and figure-3.

Table-1
Physical Parameters in Sampled Water

Name of Location	Geographical coordinates	Type of water Sampled	Depth (m)	pH	Temp (oC)	TDS (ppm)	Conductivity (S/m)
MBAKPEGH (KYUEN)	7O19.417’N,9O6.870’E	WW	7.6	5.2	30	28	0.001
GENYI-YANDEV	7O22.181’N,9O2.633’E	WW	7.9	5.9	29	13	0.258
MKOVOUR	7O18.509’N,9O8.621’E	WW	5.5	5.4	30.7	2	0.036
GATIE MBADIM	7O17.522’N,9O10.197’E	WW	7.6	6.4	31.1	12	0.231
MBAVARAKAA(1)	7O17.267’N,8O53.356E	WW	6.1	5.3	30.2	28	0.578
LUGA MARKET	7O17.810’N,8O51.25’E	BH	15.2	7.1	30.7	0	0.016
MBAKWEN	7O17.499’N,8O58.586’E	WW	7.0	6.3	31	5	0.107
UMM	7O19.316’N,9O02.373’E	BH	17.4	5.5	32	3	0.068
DAUN ENTERPRISES	7O20.074’N,8O59.765’E	BH	18.3	5.6	31.2	1	0.032
MBAASAN MBADIM	7O17.121’N,9O10.132’E	BH	16.2	5.8	31	5	0.107
MBATYU	7O22.149’N,9O2.264’E	BH	17.1	5.4	30.7	5	0.094
BCC	7O24.961’N,8O58.317’E	WW	5.8	5.9	30.5	12	0.235
MBATSEGH	7O20.270’N,8O58.086E	WW	8.5	5.4	31	2	0.039
MBAAVARAKAA(2)	7O19.053’N,9O00.109’E	BH	17.4	4.9	31	37	0.735
MBAAKPOGHUL	7O26.397’N,8O57.550’E	BH	15.2	6.2	30.9	11	0.221

well water, BH: Borehole water

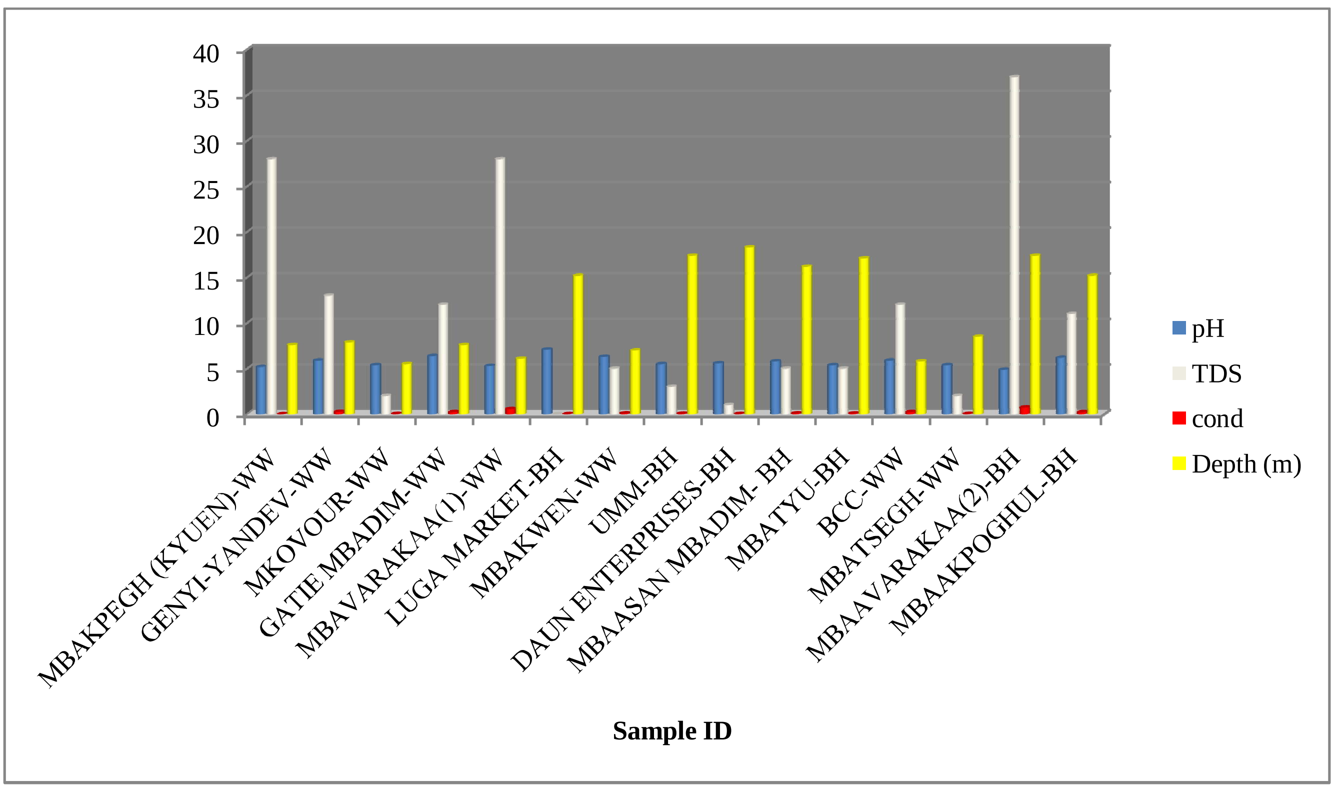

Figure-1
Physical parameters in sampled water

Table-2
Radioactivity in sampled water

Sample Location	Geographical coordinates	Type of water Sampled	Depth (m)	Alpha Activity Concentration (Bq/L)	Beta Activity Concentration (Bq/L)
MBAKPEGH (KYUEN)	7O19.417'N,9O6.870'E	WW	7.6	00	00
GENYI-YANDEV	7O22.181'N,9O2.633'E	WW	7.9	0.309±0.330	9.710±0.380
MKOVOUR	7O18.509'N,9O8.621'E	WW	5.5	0.579±0.280	0.024±0.350
GATIE MBADIM	7O17.522'N,9O10.197'E	WW	7.6	8.454±0.340	8.035±0.440
MBAVARAKAA(1)	7O17.267'N,8O53.356E	WW	6.1	6.220±0.220	9.693±0.270
LUGA MARKET	7O17.810'N,8O51.25'E	BH	15.2	3.539±0.440	4.409±0.550
MBAKWEN	7O17.499'N,8O58.586'E	WW	7.0	0.416±0.100	00
UMM	7O19.316'N,9O02.373'E	BH	17.4	5.821±0.270	18.450±0.310
DAUN ENTERPRISES	7O20.074'N,8O59.765'E	BH	18.3	9.052±0.350	9.997±0.440
MBAASAN MBADIM	7O17.121'N,9O10.132'E	BH	16.2	12.033±0.500	18.476±0.610
MBATYU	7O22.149'N,9O2.264'E	BH	17.1	0.367±0.130	1.334±0.160
BCC	7O24.961'N,8O58.317'E	WW	5.8	14.488±0.440	27.477±0.520
MBATSEGH	7O20.270'N,8O58.086E	WW	8.5	8.907±0.300	9.962±0.380
MBAAVARAKAA(2)	7O19.053'N,9O00.109'E	BH	17.4	14.213±0.640	20.347±0.790
MBAAKPOGHUL	7O26.397'N,8O57.550'E	BH	15.2	7.670±0.250	7.167±0.320

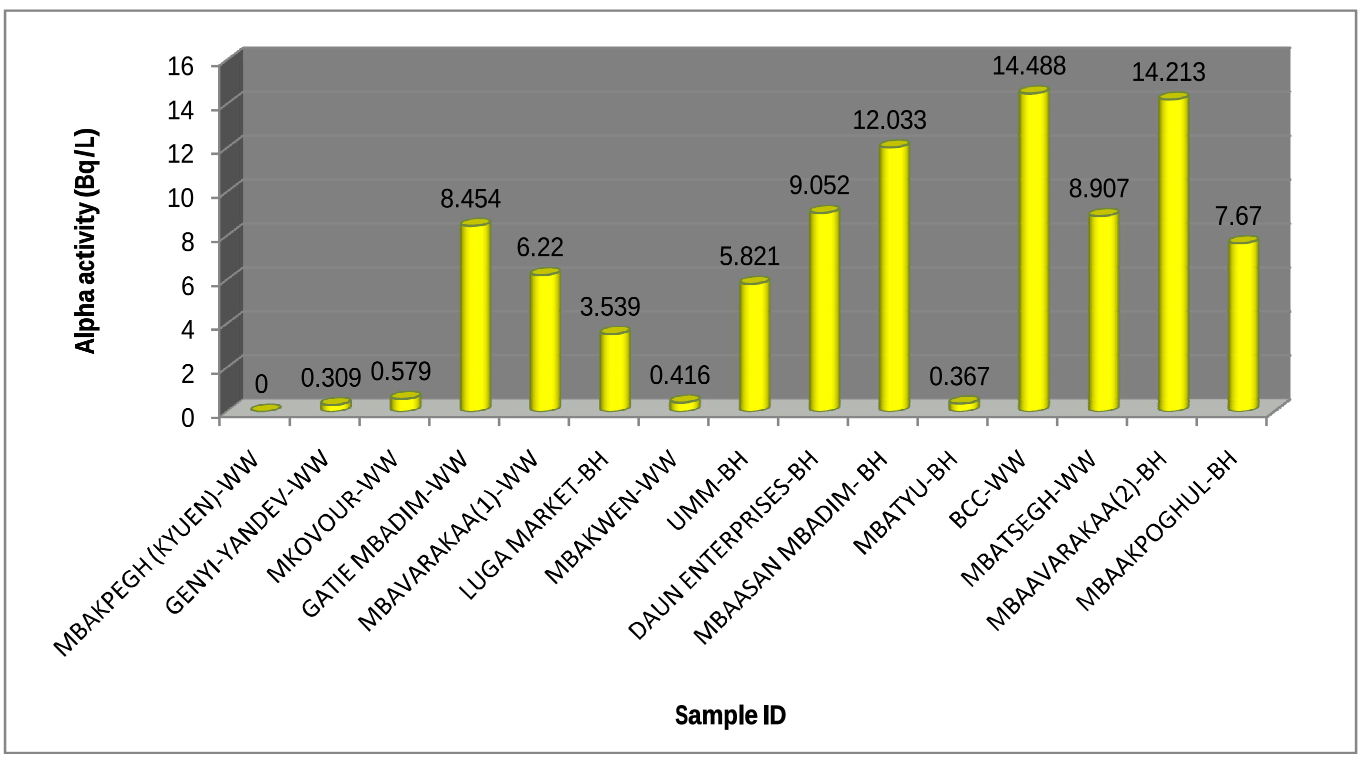

Figure-2
Alpha Activity across the Sampled Points

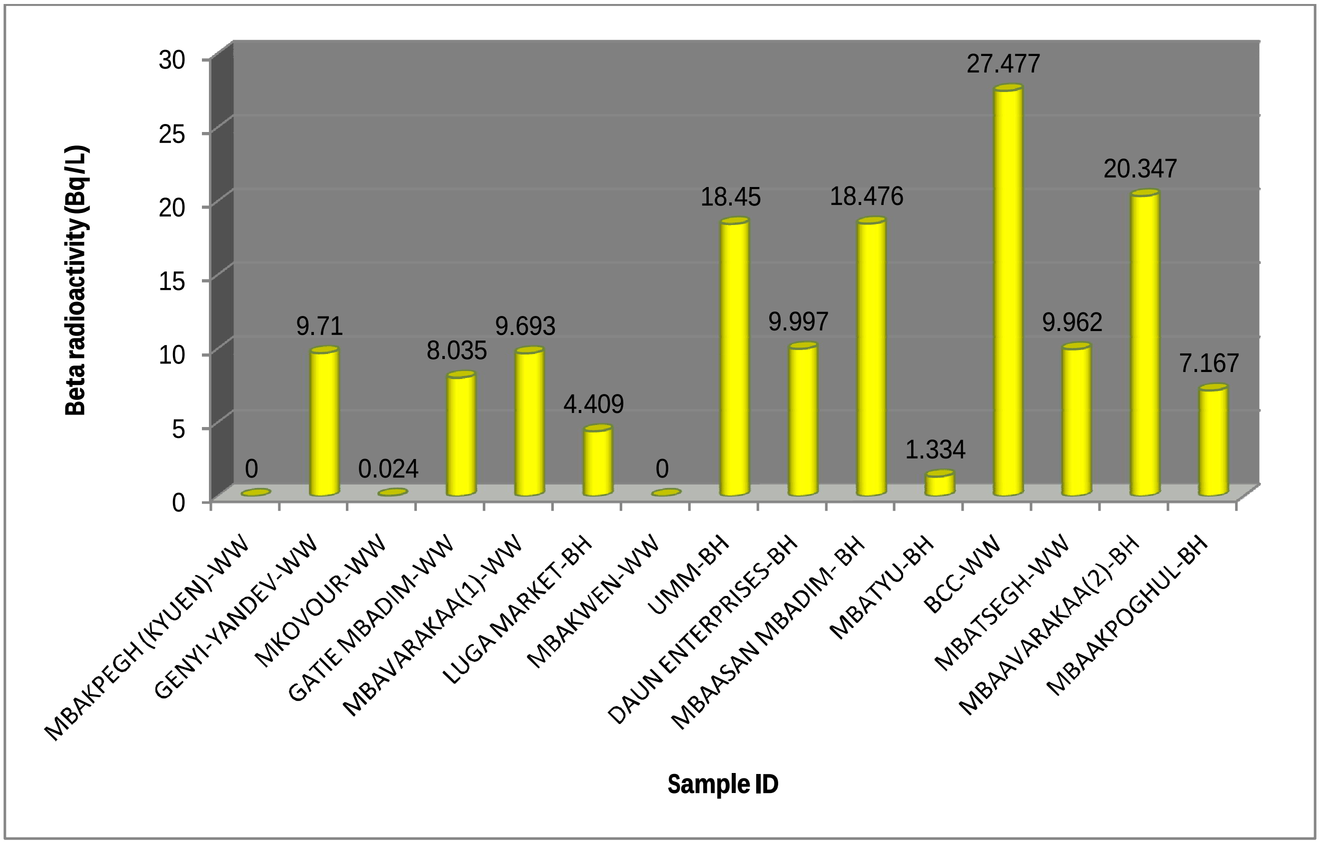

Figure-3
Beta Activity across the Sampled Points.

Determination of the Effective Dose Equivalent: The following equation was used to determine the yearly Effective Dose Equivalent[10]

$$DR_w = A_w \times IR_w \times ID_F \quad (2)$$

Where DR_w is the Effective Dose Equivalent (Sv), A_w is the activity (Bq/L), IR_w is the intake of water for a person in a year (730 litres) and ID_F the ingestion effective dose equivalent factor ($3.58 \times 10^{-7} Sv/yr$).

The mean annual Effective Dose for gross alpha is 24mSv/yr and Beta is 38mSv/yr. These values are greater than world permissible values of 0.3mSv/yr and 0.8mSv/yr for Alpha and Beta respectively

Discussion: The physical parameters of the sampled water are presented in figure-1. It was observed that, TDS values were high at almost all the measured sites, except at Mkovour, Mbatsegh, Mbatyu and Daun enterprise. Water containing TDS concentrations below 1000 mg/litre (1000ppm) is usually acceptable to consumers, although acceptability may vary according to circumstances. However, the presence of high levels of TDS in water may be objectionable to consumers owing to the resulting taste and to excessive scaling in water pipes, heaters, boilers, and household appliances [11].

The values of depth are high across most of the sampled points followed by pH. Conductivity values were low across all the sampled points. The majority conductivity values of water in the assessed area were above the WHO acceptable value of 0.03s/m for drinking water. Only Mbakpegh, Luga mkt, and Daun enterprise have their values within the World acceptable value.

The variation of alpha activity across all the sampled points is shown in figure-2. Benue Cement Company recorded the highest value of 14.488 Bq/L for Alpha followed by Mbaavarakaa (2) which has a value of 14.213 Bq/L and Mbaasan- Mbadim has a value of 12.033 Bq/L. Other places with high Alpha activity are Daun Enterprise with 9.052 Bq/L, Mbasegh with 8.907 Bq/L, Gatie-Mbadim with 8.454 Bq/L, Mbaakpoughul with 7.67Bq/L, Mbaavarakaa(1) with 6.22Bq/L, UMM has 5.821Bq/ and Luga mkt has 3.539Bq/L. These values are highly above WHO and USEPA recommended values of 0.5 Bq/L and 0.55Bq/L respectively for good water quality. The Alpha activity in Genyi-Yandev was slightly above the recommended standards and that of Mbakpegh (Kyuen) was below the detection level of 0.03 Bq/L for the instrument. The high Alpha activities in the above areas is stressed to the presence of Limestone (Sedimentary rocks) in the area and in organic fertilizers used by farmers in the area which washes from the surface of the land in to these water bodies [12].

Beta activity on the other hand recorded the highest value of 27.477Bq/L at BCC followed by Mbaavarakaa(2) with 20.347Bq/L, Mbaasan-Mbadim with 18.476 Bq/L, UMM with 18.450Bq/L, Daun with 9.997 Bq/L, Mbatsegh with 9.962Bq/L, Genyi-Yandev with 9.710Bq/L, Mbaavarakaa(1) with 9.693Bq/L, Gatie-Mbadim with 8.035Bq/L, Mbaakpoghul with 7.167Bq/L and Luga mkt with 4.409Bq/L. These values are alarming when compared to WHO and USEPA recommended values of 1.0 Bq/L and 1.85Bq/L respectively. Mbatyu has beta activity value of 1.334 Bq/L which is slightly above WHO recommended value of 1.0 Bq/L but below USEPA recommended value of 1.85 Bq/L for good quality drinking water. Mbakpegh and Mbakwen have values below detection limit of 0.05 Bq/L for the instrument used for this work. Higher values of Gross beta activity could be as a result of the geological formation of the area whose land is highly invaded with phosphorus, a by-product of phosphate that has potassium-40 which is a beta and gamma emitter whose source is fertilizer used by farmers and the presence of limestone, a sedimentary rock in the assessed area.

When alpha and beta activities across the sampled points are compared (figure-4), the result shows that Beta recorded high values across most of the sampled points than Alpha except at Mkovour, Gatie-Mbadim and Mbakwen where Alpha activities are higher than those of Beta. This result therefore suggests that, they are more gross beta emitting radionuclides in the assessed area than gross alpha emitters. The result also shows that, the values of Alpha and Beta activities were higher in the case of Hand dug wells as compared to those of Boreholes (table-3). This result agrees with a similar work at Gwammaja area of Kano State [13].

A comparison of depth, pH, TDS, Conductivity, alpha activity and beta activity was also made (figure-5). The result shows that TDS recorded the highest values in most of the sites followed by Beta activity. Depth, pH, Alpha activity and conductivity recorded the least values across the sampled points.

Theoritically, ground water with high total dissolve solids is the most radioactive and high Alpha and Beta is usually associated with granite areas [14-17]. In this work, sites with high TDS are Mbaavarakaa(1), Mbaavarakaa(2) and Mbakpegh. These sites also have high Alpha and Beta activities respectively. The gross Alpha and Beta activities in Gboko are high compared to those of similar sources in Zaria and Kano. The activities are also higher than that of similar sources in other countries i.e. Belgium, Netherlands, UK and Venezuela[18]. These values are alarming when compared to WHO and USEPA recommended safety values for good quality drinking water i.e. 0.5Bq/L for gross alpha and 1.0Bq/L for gross beta[19-24,25]. Similarly, the activities in Gboko are higher than the recommended safety values of 0.55Bq/L for Gross Alpha and 1.85Bq/L for gross Beta by USEPA. These water bodies therefore pose the risk of exposing the human beings with in the area to serious health hazards.

Table-3
Comparison of Gross Activity Levels Between Wells and Boreholes at Gboko and its environs.

Sample Description	Alpha (Bq/L)		Beta (Bq/L)	
	Max	Min	Max	Min
Boreholes	14.213	0.367	20.347	1.334
Hand dug wells	14.488	0.309	27.477	0.024

Table-4
Comparison of Measured Gross Activities in Gboko with WHO and USEPA Standards and with Results Obtained from Other Places

Location	Range of Alpha (Bq/L)	Range of Beta (Bq/L)	Sources of data.
Belgium	0.006-0.028	0.056-0.722	CEC, 1982
Netherlands	0.028-0.064	0.035-0.139	CEC, 1982
UK	0.030-0.150	0.030-0.330	CEC, 1982
Venezuela	0.070-0.540	00	Sajo-Bohus et al., 1982
Zaria	0.001-0.043	0.004-0.622	Onoja, 2004
Kano	0.002-0.011	BDL	Tajudeen, 2006
Gboko	0.309-14.488	0.024-27.477	This work
	≤ 0.5	≤1.0	WHO
	≤ 0.55	≤1.85	USEPA

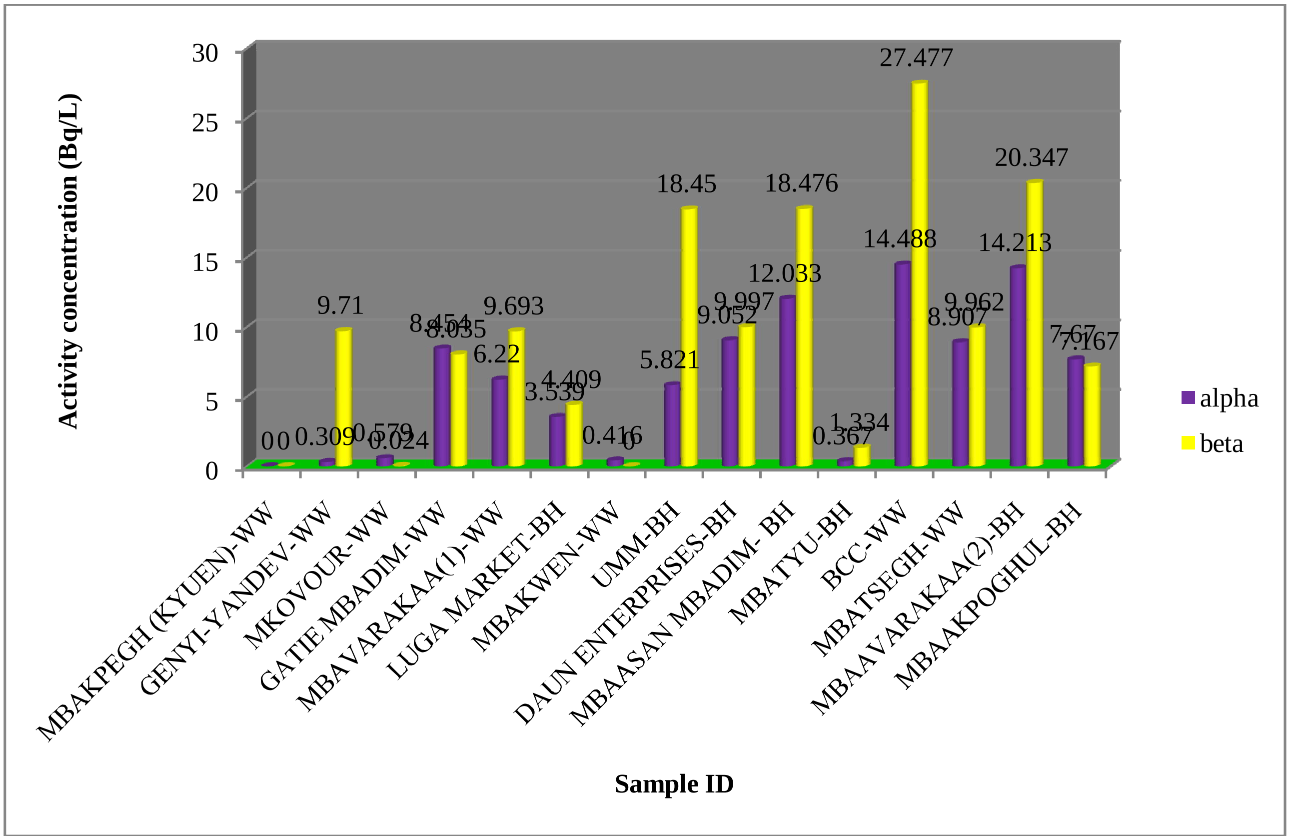

Figure-4
A comparison of Alpha and Beta Activities across the Sampled Points

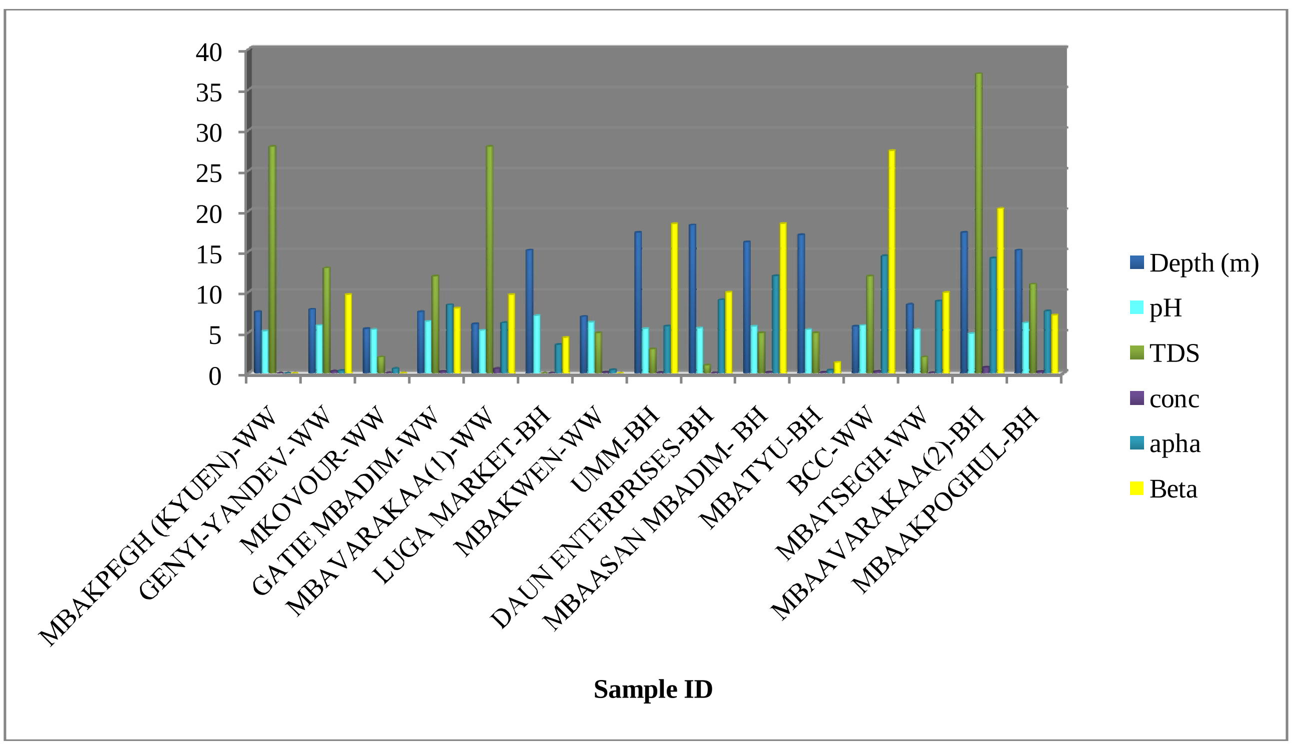

Figure- 5
A comparison of Depth, pH, TDS, Conductivity, Alpha activity and Beta Activity

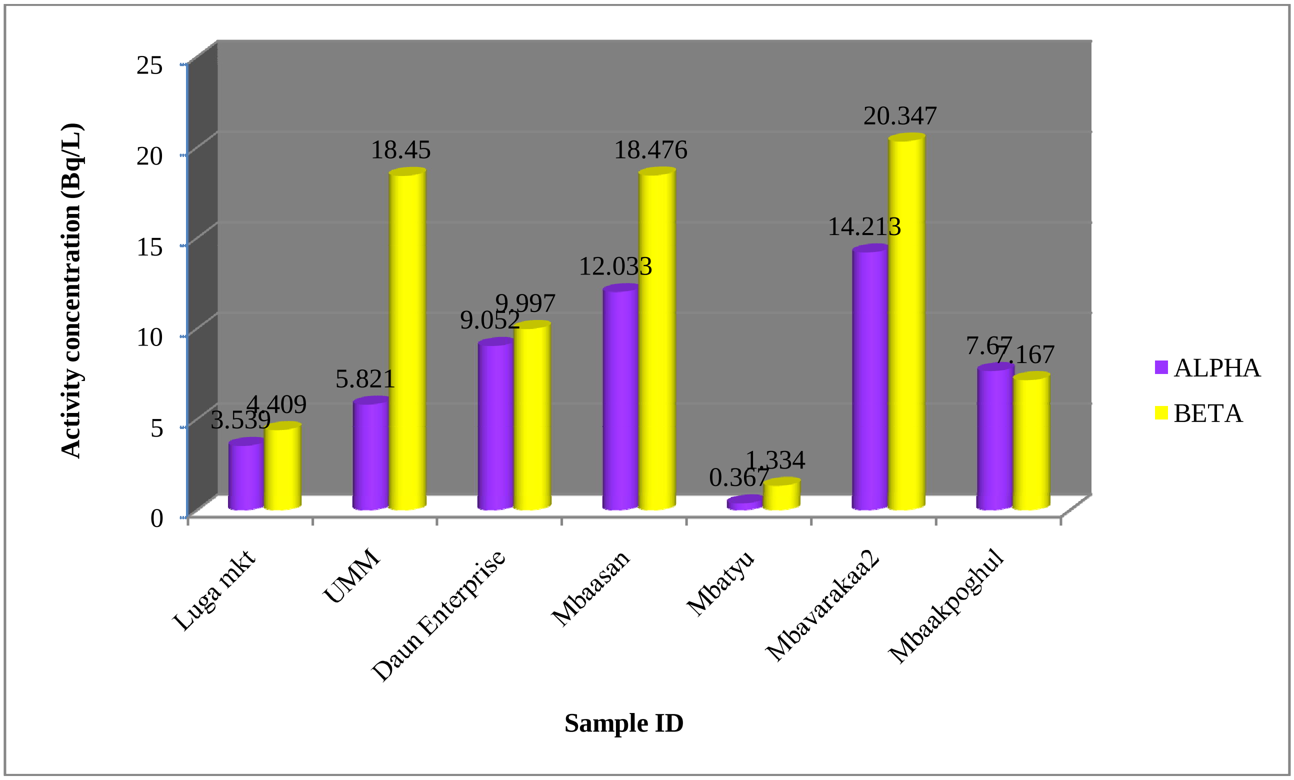

Figure-6
A comparison of Alpha and Beta Activities in Boreholes in the Assessed Area

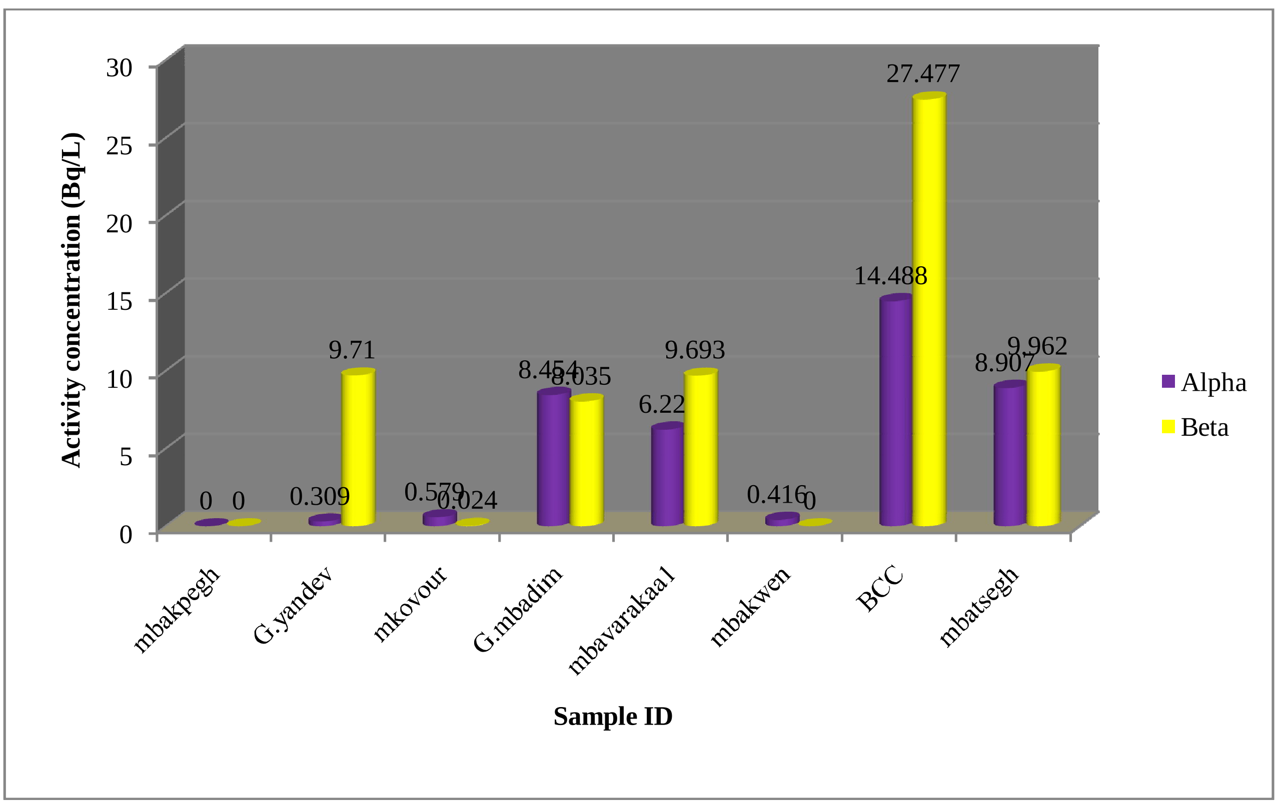

Figure-7
A Comparison of Activities of Alpha and Beta in Hand Dug Wells in the Assessed Area

Conclusion

Based on the above analysis, only few samples of water from the bore holes and hand dug wells from Gboko and its environs meet the recommendations of WHO and USEPA, majority do not meet the standards. There is therefore need for further screening for radioactivity from the bore holes and hand dug wells that are used for drinking because continues usage may pose serious health side effects to the public users.

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