PHYSICSAccess Research Paper
ISSN Online: 2756-3898, ISSN Print: 2714-500X https://doi.org/10.47514/phyaccess.2022.2.2.014

Measurement of Gross Alpha and Beta Activity Concentrations in Drinking Water from Sabon Gari Local Government Area of Kaduna State, Nigeria

Usman Adamu[1], Nuraddeen N Garba[2], Jibril Musa[2] and Daniel J Adeyemo[2]

[1] Department of Physics, Faculty of Science, Kaduna State University, Kaduna, Kaduna State, Nigeria
[2] Department of Physics, Ahmadu Bello University Zaria, Kaduna State, Nigeria

Corresponding E-mail: usmanee81@gmail.com

Received 13-11-2022
Accepted for publication 26-12-2022
Published 28-12-2022

Abstract

The gross alpha and beta activity concentrations of eighteen water samples, consisting of boreholes and Hand dug wells from Sabon Gari Local government area of Kaduna State-Nigeria have been analyzed using, the potable single channel gas free MPC-2000B-DP detector. The results show that alpha and beta activity concentrations range from 0.96×10^{-2} Bq/L to 47.00×10^{-2} Bq/L and from 0.309×10^{-2} Bq/L to 310.40×10^{-2} Bq/L, for gross alpha and gross beta respectively. It is observed that in the overall samples, the gross alpha activity concentrations were below the 0.5 Bq/L maximum allowable limits for drinking water as recommended by World Health Organization (WHO). However, for the gross beta activity concentration, eleven (11) percent of the samples, have their activity concentrations greater than the 1.0 Bq/L maximum allowable limits for drinking water as recommended by the WHO. This high beta activity concentration in these areas might be due to the waste generated from industries and hospitals or as a result of the nature of farming activities occurring in the areas. Largely, results obtained are seen to be in agreement with reports from other authors within and outside Nigeria.

Keywords: Gross Alpha; Gross Beta; Radioactivity; Borehole; Hand dug well.

I. INTRODUCTION

Water is an essential substance to all living things which include; man, animals, and all that surrounds them [1]. Every living thing is made up of water, consisting of over two-thirds of the human body. It has been in existence right from the origin of the universe itself [2]. It is an excellent solvent that readily dissolves soluble solids, liquids and gases. Water for domestic use should be colorless, odorless, reasonably cool, free from impurities and generally not harmful to the body. Natural water contains both alpha (α) and beta (β) emitters in widely varying concentrations which are responsible for a generally small fraction of the total dose received from natural and artificial radioactivity [3]. Water pollutants from residential, as well as from fertilizers on farmlands; rainwater and the naturally occurring radioactive materials (NORMs) affect the quality of water in an area [4]. For practical purposes, the activity concentrations in water are 0.5 Bq/L for gross α and 1.0 Bq/L for gross β [5]. Accumulations of gross alpha and gross beta concentrations in human body exceeding the recommended concentration may pose a potential health hazard. Therefore, for health reasons, the need to measure the gross α and gross β concentrations in water to be consumed by Humans arises. Sabon Gari Local Government Area is one of the largest local governments in Kaduna State. It houses, one of the

research reactors (NIRR-1) in Nigeria with a number of industries and hospitals. The waste and fallouts generated from the research reactor and other activities, if not properly monitored and managed can add to the radioactivity level of the research area and hence water consumed around the area, resulting in the contamination and pollution of the water. Therefore, there is a need to access the gross alpha and gross beta activity concentrations of the main source of drinking water (borehole and well) in Sabon-Gari Local Government Area of Kaduna State and compare it with world standards. The results obtained will serve as baseline data for drinking water in the study area.

II. MATERIALS AND METHOD

A. Study Area

The study area is located in Kaduna State lying between latitude 110° 50' N and 110° 150'N, and longitude 70° 35' E and 70° 15' E. It is located on a plateau at a height of 706 m and 695 m above sea level and lies within the guinea savannah belt. It has a typical savannah climate of distinct wet and dry seasons with a moderated rainfall of about 1047mm/a [6]. It comprises of mixed tribes, with Hausa/Fulani as the predominant.

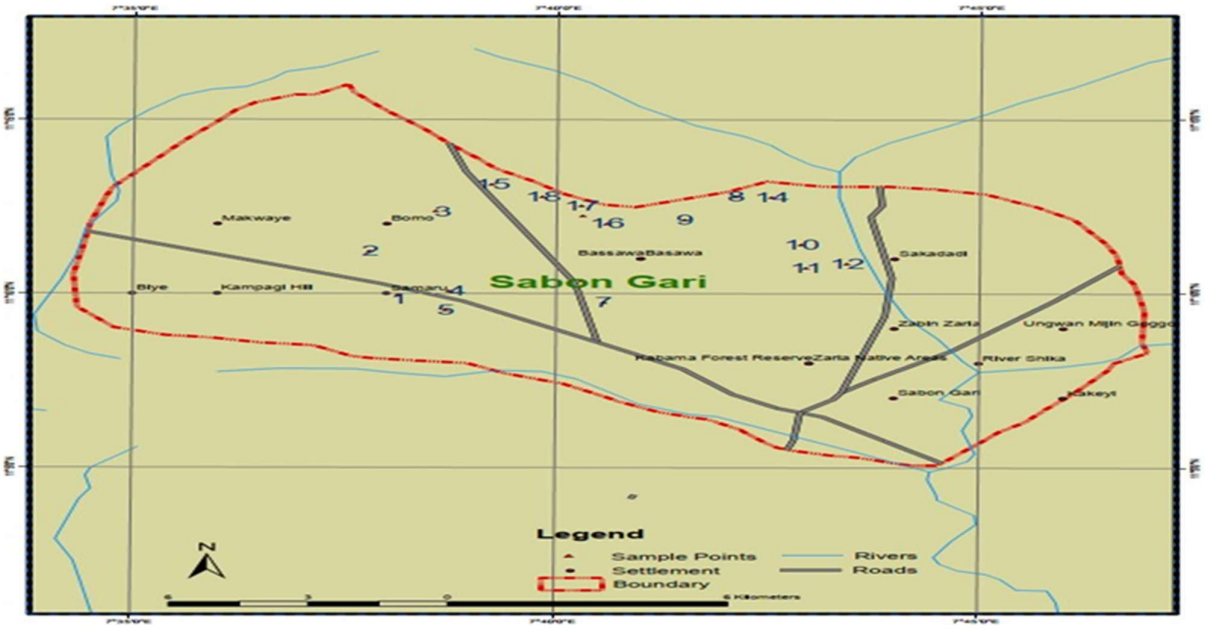

Fig. 1 Study area with sample collection points indicated with numbers

B. Sample Collection

A total number of 18 samples were collected, based on availability, with four (4) of these samples from hand dug wells and fourteen (14) form boreholes respectively. To ensure the study area was fully represented, the samples were taken randomly across the entire sample area. The samples were collected in clean 2 liters of plastic containers with tight covers. The volume of the sample collected was such that an air space of about 1% of the container was left for thermal expansion. To avoid contamination, the boreholes were allowed to run so as to evaluate the existing water in the pipe before collection. The containers were also rinsed thoroughly with the water to be sampled. 20ml of concentrated HNO_3 was added per liter of the water sample, to minimize precipitation, bacterial growths, and absorption on container walls. Also, where chloride salts are present in the samples, the HNO_3 will convert this salt to nitrate salts.

C. Sample Preparation

Two liters of each sample collected were evaporated to a decreased volume (100-50 mL) using a hot plate. The sample is then transferred into a weighed porcelain dish or petri-dish of 150 mL and placed under an infra-red lamp until it is dried completely. This is left to cool inside a desiccator at normal condition and weighed (M_2). The weight of the porcelain dish is subtracted from M_2 to obtain the weight of the residue (M_r) in milligrams. If the weight of the residue is greater than the required weight, then only the required residue size is taken into a weighed counting planchet. The reagent (Vinyl acetate) was added and the source is distributed evenly on the surface of the planchet. Each sample was counted for 45 min (2700 s) and the average result is taken. The sample efficiency and sample volume are determined using (1) and (2).

$$Sample\ efficiency\ (E_{ps}) = \frac{S_p}{M_r} \times 100\ \% \qquad (1)$$

$$Sample\ Volume\ (V_s) = \frac{V}{M} \times S_p \quad (2)$$

Where; V is the volume of water sample evaporated in liters, M is residue mass in mg, S_p is the sample weight on the planchet in mg, M_r is the total sample weight from evaporating volume in ml of water sample weight in mg.

D. Plateau Test

This test is designed to verify the suitable, optimal and operational voltages for the different modes of counting. The modes are alpha only and beta only mode. The manufacturer's standard sources were used to verify the suitable voltages to be used for the different modes of counting, and also to determine the efficiencies and detection limits of the detector.

The test was run with the manufacturer's calibration standards (Pu-239 and Sr-90) whose activities range from 133.29 - 185.49 Bq and 92.31 - 103.68 Bq respectively in all the three operating modes. This test is run for 2700 s. The operational efficiency of the channel of the counter was found to be 87.95% for the alpha counts and 42.06% for the beta counts.

E. Background count

The counting system was used to count clear empty planchets in all the counting modes to obtain the background radioactivity of the environment which is needed to be used in the subsequent measurements. A background radioactivity of 0.50 cpm for alpha, and 0.73 cpm for beta and the detection limit of 0.21 cpm for alpha and 0.22 cpm for beta were obtained. The result is a representative of the environment, and could therefore be employed in the subsequent measurements of the water samples.

F. Gross alpha and Gross Beta counting

The pre-set time for the counting mode is entered and the results are displayed as raw counts (cpm). The raw counts (cpm) are repeated twice each for all the samples and the average value is obtained. For gross alpha counting, the voltage is set at 1600 V, and samples were counted for 45 minutes in alpha only mode. For the gross beta counting, the voltage is set at 1700 V, and the samples are counted for 45 minutes in beta only mode. The count rate and the activity are calculated using (3).

$$Activity\ of\ \alpha\ or\ \beta\ (Bq/L) = \frac{Net\ Count}{D.E \times S.V \times S.E \times 60} \quad (3)$$

Where; D.E is the detector efficiency, S.E is the sample efficiency, S.V is the sample volume.

The detector's efficiency and net counts is given by:

$$Net\ counts = Raw\ counts\ (cpm) - Background\ (cpm) \quad (4)$$

Where cpm is the count per minute.

III. RESULTS AND DISCUSSION

A. Gross Alpha and Gross Beta Radioactivity

Table I, shows the gross alpha and gross beta activity concentrations of the ground water for the selected locations in Sabon-Gari Local Government Area of Kaduna State, obtained using gross alpha only measurement mode.

Table I: Gross Alpha and Beta Activity Concentrations of Groundwater Samples from Boreholes and Wells from Sabon Gari Local Government Area

S/N0	Location	Geographical coordinates	Elevation (m)	Activity Concentration of Alpha (Bq/L)×10^{-12}	Activity Concentration of Beta (Bq/L)×10^{-12}
1	DAC/ABU	11.167°N; 7.639°E	669	1.678	8.335
2	Bomo Gari	11.187°N; 7.630°E	695	2.249	3.186
3	Sogaji LCC	11.206°N; 7.643°E	694	9.701	31.760
4	Qtr. 2 Samaru	11.166°N; 7.642°E	684	0.950	0.309
5	B/Kwata	11.162°N; 7.644°E	679	39.300	137.200
6	Basawa-Barrack (Sargent Qtr.)	11.173°N; 7.672°E	672	17.330	47.550
7	Basawa-Barrack (Down Engineer)	11.169°N; 7.674°E	673	32.150	310.400
8	Dan Bami Gari	11.221°N; 7.703°E	645	5.579	92.090
9	Ang. Makera	11.202°N; 7.692°E	660	11.530	12.570
10	Ang. Hazo	11.190°N; 7.715°E	643	1.146	4.791
11	Gyatta	11.179°N; 7.716°E	630	47.000	5.110
12	Sakadadi	11.181°N; 7.724°E	638	2.934	35.190
13	Ang. Maiwasa	11.204°N; 7.672°E	667	1.943	3.872
14	Ang. Balarabe	11.213°N; 7.709°E	646	2.869	1.147
15	Tashain Iche	11.219°N; 7.654°E	679	1.490	86.380
16	Dufa-Dufa	11.203°N; 7.673°E	665	28.770	84.500
17	U/Barau	11.212°N; 7.674°E	663	3.539	14.980
18	Ang. Shekarau	11.213°N; 7.664°E	669	12.180	3.538

B. Distribution Patterns for the Gross Alpha and Beta Activity Concentrations in the Study Area

Gross alpha and beta activities concentrations and contour distribution pattern in the area is presented in Fig. 2-6.

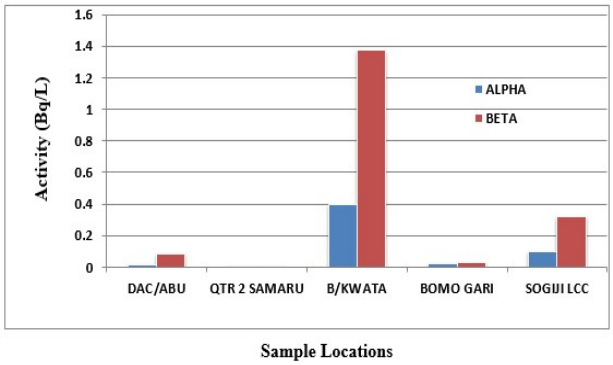

Fig. 2 Gross Alpha and Beta activity concentrations for locations with serial numbers 1, 4, 5, 2 and 3.

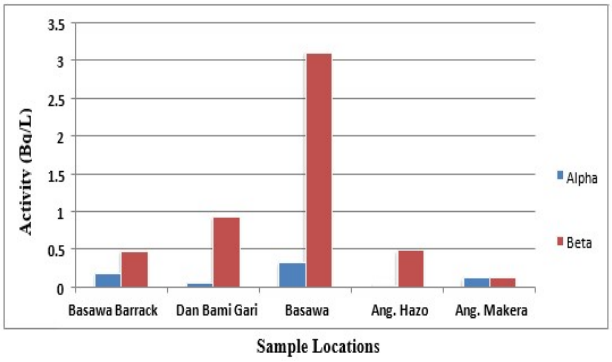

Fig. 3 Gross Alpha and Beta activity concentrations for locations with serial numbers 6, 8, 7, 10 and 9.

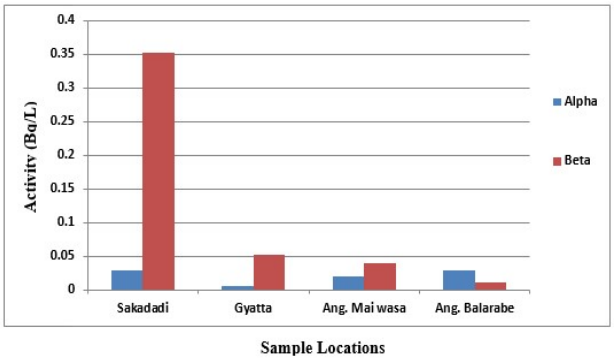

Fig. 4 Gross Alpha and Beta activity concentrations for locations with serial numbers 12, 11, 13 and 14.

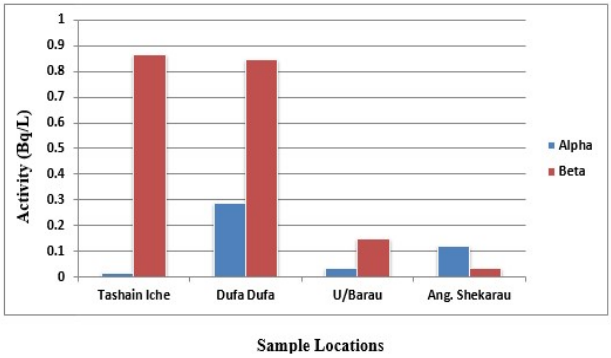

Fig. 5 Gross Alpha and Beta activity concentrations for locations with serial numbers 15, 16, 17 and 18.

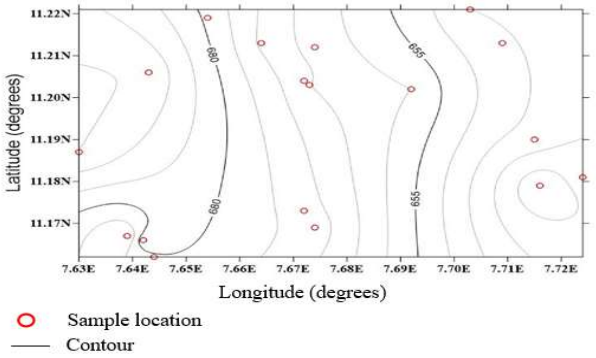

Fig. 6 Contour distribution pattern of the study area

The contour lines (Fig. 6) show the topography of the landscape and represents constant elevation using Surfer Software. Lines that are far apart indicate gentle slope, while lines that are close together indicate steep slope. From Fig. 2-5, the boreholes with the highest recorded activities of beta are those at Bakin Kwata (1.372 Bq/L) and Basawa Barrack (Down-Engineer) (3.104 Bq/L). Generally, there is low alpha activity in the water samples from the study area, indicating that there are no radiological threats from alpha radiation that could be traced to the boreholes and wells samples.

From Fig. 6, the contour distribution shows a very low alpha activity ranges from 0.0095 Bq/L in the area bounded by latitude 11.1660° N and longitude 7.6420° E to 0.47 Bq/L in the area bounded by latitude 11.1790° N and longitude 7.7160° E. The red circles show the sample location on the contour distribution pattern. The low level of gross alpha activity might be indicative of relatively low-level concentrations of the parent radionuclides in the aquifer material, since for an elevated gross alpha radiation to occur, the parent radionuclides Uranium ($^{238}_{92}U$) and radium ($^{226}_{88}Ra$)must appear in elevated concentrations in the parent rocks. On comparing the alpha activity in the groundwater samples with the recommended value set by WHO for alpha activity, it is observed that the groundwater in the study area

satisfy the recommended 0.5 Bq/L safety standard set by WHO for alpha activity concentration in potable water. Although, six (6) percent of the alpha activity measurement show elevated reading higher than those recommended by WHO for potable drinking water.

Also, from Fig. 6, the contour distribution shows a high beta activity of 1.372 Bq/L and above in the area bounded by latitude 11.1620° N and longitude 7.6440° E followed by a high beta activity of 3.104 Bq/L in the area bounded by latitude 11.1690° N and longitude 7.6740° E. Low beta activity, ranging between 0.00309 – 0.8638 Bq/L is observed in the area bounded by latitude 11.2190° N and longitude 7.6540° E. The activity tends to concentrate in the north-western part of the study area. Basawa Barrack (Down Engineer), 3.104 Bq/L has the highest reading, followed by Bakin Kwata 1.372 Bq/L. An additional six (6) percent of the samples, present readings that are quite near the maximum acceptable limit of 1.0 Bq/L, as mandated by WHO. These are samples collected from Dan Bami Gari (0.9209 Bq/L) and Tashan Iche (0.8638 Bq/L). There is a slight correlation between the high Beta and relatively high alpha values of Basawa Barrack (Down Engineer) and Bakin Kwata. This may imply that different radionuclides may be responsible for low measurements of alpha activity. A comparison of measured Gross Activities in different study areas with results obtained from this study and WHO (0.5 Bq/L for Gross Alpha and 1.0 Bq/L for Gross Beta) Standards is presented in Table II.

Table II Comparison of Measured Gross Activities from this study with different studies conducted within and outside Nigeria and WHO (0.5 Bq/L for Gross Alpha and 1.0 Bq/L for Gross Beta) Standards.

S/N0	Location	Range of Alpha (Bq/L)	Range of Beta (Bq/L)	Source of data
1	Iraq	0.095-021	0.31-0.62	[7]
2	China	0.09-0.23	0.18-0.29	[8]
3	Benue	0.013-0.283	0.025-0.516	[9]
4	Zaria LG	0.0058-0.04319	0.00358-0.622	[10]
5	Kaduna North LG	0.00069-0.41	0.286-9.506	[11]
6	Sabon Gari LG	0.0096-0.47	0.00309-3.104	This study

IV. Conclusion

The alpha and beta activities in water drawn from boreholes and hand dug wells from Sabon Gari Local Government area of Kaduna State have been measured using a gas-free proportional counter. The gross alpha and gross beta activity concentrations in the water samples are found to be in the ranges of 0.0096 to 0.4700 Bq/L and 0.0031 to 3.1040 Bq/L respectively. Most of the measured activity concentrations of the gross Alpha and gross Beta in the study area are found to be within the recommended values of 0.5 Bq/L for alpha and 1.0 Bq/L for beta except for few samples from Basawa Barrack D.E (3.104 Bq/L for Beta), Bakin Kwata (1.372 Bq/L for Beta). However, the gross Alpha and gross Beta concentrations determined in samples from Basawa Barracks (Down Engineer) and Bakin Kwata in Samaru indicates that these elements (^{238}U, ^{232}Th and ^{40}K) can pose a significant threat to people living in these areas.

Acknowledgment

The authors wish to appreciate Prof. Nasiru Rabi'u of the Department of Physics, Ahmadu Bello University Zaria for his support towards the success of this work. Usman Adamu also acknowledges the contribution of Nura Ibrahim of the Department of Physics, ABU Zaria, and also thank Dr. M.A. Onoja, and Dr. Bala Balarabe for their advice and guidance. The authors are also grateful to the former Head of section, Health Physics and Radiation Biophysics, Center for Energy Research and Training Ahmadu Bello University Zaria, Dr. Rose Ada Onoja. We also acknowledge the contribution of Mallam Auwal Bappah and Sirajudeen B. Abdullahi of CERT, ABU Zaria.

References

[1] O. E. Ojeka, "Element of Industrial Chemistry". Elberith Ventures, Kaduna, pp. 69-73, 2007

[2] M. Suleiman, "Essentials of Environmental Health". Concept Designs Prints, Zaria, 2015.

[3] I. G. E. Ibeanu, "Assessment of Radiological Effects on the Tin Mining Activities in Jos and its Environs. Ph.D. Thesis, Dept. of Phy. Ahmadu Bello Univ. Zaria, KD, 1999.

[4] J. Msteo-Sagasta, S. M. Zadeh, H. Turral and J. Burke, "Water pollution from agriculture: a global review". Executive Summary, 2017.

[5] Guidelines for drinking-water quality: 4th Ed. incorporating the first addendum. Geneva: World Health Organization; 2017. Licence: CC BY-NC-SA 3.0 IGO.

[6] M. L. Garba, Natural Radioactivity of Ground-Water in the North West Precambrian Rocks of Sheet 102, Zaria. . Ph.D. Thesis, Dept. of Phy. Ahmadu Bello Univ. Zaria, KD, 2008.

[7] S. Sh. Fleifil and Z. A. Ismail AL-Sudani, "Evaluation of gross alpha and beta activity concentrations and annual effective dose in drinking water of Misan Province-Iraq using low background gas flow proportional counter (LB-4110)". NeuroQuantology, vol.19, no. 11, pp. 22-31, 2021.

[8] Y. Shi, W. Gao, T. Siqin, Z. Li, J. Zhang, R. Guan, J. Li, P. Sun and H. Zhao, "The gross alpha and beta radioactivity levels of drinking water source in one oil industrial City in Northeast China, Rad. Med. & Protect., vol. 2, pp. 61-66, 2021.

[9] M. S. Orkaa and B. N. Akaagerger, "Assessment of radioactivity concentrations from borehole and well water in Konshisha, Benue-Nigeria". Int. J. of Sci. & R., vol. 10, no. 12, pp. 438-422, 2021.

[10] R. A. Onoja, "Evaluation of gross alpha and beta radioactivity in well water from Zaria Local Government Area of Kaduna State, Nigeria". M.Sc. thesis, Dept. of Phy. Ahmadu Bello Univ. Zaria, KD, 2004.
[11] I. Audu, "Determination of gross alpha and beta radioactivity concentrations in water from some boreholes in Kaduna North local government area, Kaduna State". M.Sc. thesis, Dept. of Phy. Ahmadu Bello Univ. Zaria, KD, 2017.

