Evaluate the Radioactivity in Drinking Water from Kakuri, Kaduna

Tajudeen O. Adeeko¹ and Lilian E. Adeeko²

¹Department of Physics, University of Abuja, P.M.B. 117 Abuja, Nigeria.
²Department of Biological Sciences, University of Abuja, P.M.B. 117 Abuja, Nigeria.

Authors’ contributions

This work was carried out in collaboration between both authors. Author TOA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors LEA and TOA managed the analyses of the study. Author TOA managed the literature searches. Both authors read and approved the final manuscript.

ABSTRACT

Small traces of radioactivity are normally found in all drinking water. The concentration and composition of these radioactive constituents vary from place to place, depending principally on the radiochemical composition of the soil and rock strata through which the raw water may have passed. The aims of this work were to analyze and determine the gross concentration of alpha and beta radiation in drinking water. Ten water samples from hand-dug (HD) well (5) and borehole (BH) (5) were selected applied stratified random sampling technique from kakuri. Results of the measurements reveal that gross alpha and beta activity were presence in all the water samples investigated; the gross alpha activities range between 0.014±0.006Bq/l to 0.072±0.022Bq/l, with average of 0.037±0.014Bq/l, and gross beta activities range between 0.200±0.041Bq/l to 1.530±0.140Bq/l, with average of 0.613±0.104Bq/l. The hand-dug well and borehole were not radioactively contaminated, the obtained values were all below the World Health Organization (WHO) and International Organization on Standardization (ISO) drinking water guideline values of 1.0Bq/l for gross beta radioactivity and 0.5Bq/l for gross alpha radioactivity per year. Hence, groundwater from the area is radioactivity safe to use, it posed no threat to the health of people.
around the area when consumed, besides transformer borehole (BH08) sample which exhibit high beta activity, therefore; borehole (BH08) sample is not drinkable because it's not safe of radioactivity.

Keywords: Concentration of radioactivity; drinking water; evaluate; safe.

1. INTRODUCTION

Radioactivity refers to the process by which particles are emitted from nuclei because of nuclear instability [1,2]. Radionuclide may be settled into the soil either as particles or dissolved into soil water through the application of fertilizers and composite manure. These radionuclide, when absorbed by the root as nutrient will be translocated into various parts of boreholes and wells [3-5]. The transfer of radionuclide from soil to water channels as nuclide specific which depends on the types of soil and water samples, mobility of the radionuclide is another important factor responsible for the concentration measure varying from soil to water, this particle cause damages to the body and the other life forms when expose to [6-8]. Naturally occurring radioactive materials (NORM) are found almost everywhere and are inherent in many geologic materials; consequently, it is encounter during geological related activities [9-11]. The earth's crust contains naturally occurring radioactive materials (terrestrial radioactivity), and of most concern are the uranium series, thorium series and their progeny (radon and thoron) which increases with depth [12,13]. Water is an essential substance to all living organism, which include man, animals and all that surrounds them. The sources of groundwater in the designated area are hand dug well and borehole. This paper investigates the evaluation of gross alpha and beta radioactivity effect in groundwater intake from Kakuri, Kaduna South, Kaduna State, Nigeria. Because drinking water from deep wells and boreholes are likely to contain a higher concentration of radioactive elements than surface water [14]. Most of the sources of water supply in Nigeria are upland surface water or groundwater from boreholes and hand dug wells [15]. Also compare the results with the stipulated value by the World Health Organization and International Organization on Standardization (ISO) guideline for water quality determination which should not exceed 0.5 Bq/L for alpha and 1Bq/L for beta per year [16,17], and with the borehole records for depth penetration and other related works due to high rate of diseases in the area.

2. MATERIALS AND METHODS

Kaduna is in North central region of Nigeria between latitude 10°20′N - 10°33′N and longitude 7°45′E - 7°75′E and has an area of 46,053 km² and a population of 6,066,562 by the 2006 census. The materials used for this research were: Syringe, Planchettes, Acetone, Cotton wool, weighing balance, Infrared radiator, MPC 2000 B-DP [Dual Phosphor], Vinyl acetate, concentrated nitric acid usually called trioxonitratre (v) acid, Spatula, Ceramic dish. The method applied was stratified random sampling technique. Stratified sampling is a type of sampling method in which the larger group is divided into smaller groups or strata to complete the sampling process. The strata are formed based on some common characteristics in the group data. After dividing the group into strata, it is then randomly selected the sample proportionally. Stratified sampling is a common sampling technique used when trying to draw conclusions from different sub-groups or strata; which map the grid into five locations, two samples were obtained from each location, one from HD well and one BH source which gives total of ten samples each from kakuri area of Kaduna south, Kaduna, samples location includes: samara road, Faskere Street, Zango Street, Galadimawa Street and transformer junction. The study was design to evaluate the gross alpha and beta radioactivity in drinking water at Kakuri, Kakuna between June-July 2016. The sampling procedure was in accordance with international standard organization [ISO-5667-3]. At every point of sample collection, the container was first rinsed twice before the water was put into the plastic container and concentrated nitric acid known as trioxonitratre (v) acid was added 10ml/2 litres, to low the pH of the water to prevent microbial activities, also prevent precipitation and absorption of the sample by container wall. The water sample was transferred into 100 ml beaker and without stirring evaporation was done using hot plates. It took an average of one day to complete the evaporation of 1litre of the water sample. When the sample was almost dried up to about 50ml, it then transferred to the ceramic dish which were sterilized to avoid cross...
contamination and the dish placed under an infrared radiator at about 65°C until it completely dried and weighed to obtain the weight of the residue. Then 0.077 g of the residue was transferred into a sterilized planchette using a spatula and then weighed. The residue then uniformly spread on the planchette to obtain a uniform surface area of the sample for effective detection of the activities of the samples vinyl acetate added to bind the particles together and remove any moisture content. Sterilizations were done using acetone to avoid contamination of any form. The detector used was protean instrument corporation (PIC) MPC 2000 DP (dual phosphor) and the calibration sources used are: Sr-90 a beta source and Pu-239 an alpha source. The alpha and beta detection limit are 0.14cpm and 1.75cpm respectively.

2.1 Samples Efficiency

The sampling efficiency, measurements background and standard methods [18] were used for the test Eq. 1.

\[
\text{Sample efficiency} = \left(\frac{SW}{0.077}\right) \times 100\% \quad (1)
\]

Where:

SW = sample weight.

45 minutes sample count time was allowed for this research

2.2 Gross Alpha Counting

Selective measurement was adopted for gross alpha counting. Samples were counted for 5 cycles of 2700sec per cycle with high voltage of 1650V was applied. The alpha count rates and alpha activity were calculated using the formula Eq. (2 & 3) [19].

\[
\text{CountRate (}\alpha\text{)} = \frac{\text{Raw (}\alpha\text{) Count } \times 60}{\text{CountTime}} \quad (2)
\]

\[
\text{Activity (}\alpha\text{)} = \frac{\text{Raw(}\alpha\text{) } - \text{Background count (}\alpha\text{)}}{\text{ES} \times \text{EC} \times V} \quad (3)
\]

Where:

ES = Efficiency of Sample
EC = Efficiency of Chanel
V = Water Sample Volume

2.3 Gross Beta Counting

The samples were counted for 3 cycles of 3600sec per cycle with high voltage for gross beta counting was set at 1700volts. The count rate and the activity were calculated using the formula Eq. (4 & 5) [18].

\[
\text{CountRate (}\beta\text{)} = \frac{\text{Raw(}\beta\text{) Count } \times 60}{\text{CountTime}} \quad (4)
\]

\[
\text{Activity (}\beta\text{)} = \frac{\text{Raw(}\beta\text{) } - \text{Background count (}\beta\text{)}}{\text{ES} \times \text{EC} \times V} \quad (5)
\]

Where:

ES = Efficiency of Sample
EC = Efficiency of Chanel
V = Water Sample Volume

2.4 Alpha and Beta Activity

The activity concentration ‘S’ of alpha and beta were expressed in Becquerel per liter (Bq/l). The activity concentration was calculated using the formula Eq. 6 [19].

\[
S = \frac{(C_b - C_s) \times a_s \times m \times 1.02}{(C_s - C_0) \times 100 \times V} \quad (6)
\]

Where;

\[C_b\] = count rate observed sample (S⁻¹)
\[C_s\] = count rate observed standard (S⁻¹)
\[C_0\] = count rate background (S⁻¹)
\[a_s\] = standard solid specific activity
V = volume of sample in liters,
m = mass in milligrams of ignited residue from volume V.

To correct for the 20ml of the nitric acid added to the sample as a stabilizer 1.02 have be included in the final equation as show in Eq. 6.

3. RESULTS AND DISCUSSION

The ten water samples used for both the gross alpha and beta counting with their values according to their locations are presented in Fig. 1.
It can be seen that the alpha concentration met the standard set by the WHO and ICRP [20], in the hand-dug well samples, HD04 well has low alpha concentration of 0.021±0.010Bq/l and HD06 well has high alpha concentration of 0.055±0.022Bq/l as shown in Fig. 1, and the percentage values of alpha activities in hand-dug well as shown in Fig. 2; also in the borehole water samples, BH02 has low alpha concentration of 0.014±0.006Bq/l and BH01 has high alpha concentration of 0.072±0.022Bq/l as shown in Fig. 1, and the percentage values for borehole in the area for alpha activities as indicated in Fig. 3. While for the beta concentration, HD01 well has low beta concentration of 0.265±0.027Bq/l, HD04 well has high beta concentration of 0.976±0.103Bq/l in the HD well as shown in Fig. 1, and the percentage values for HD well in the area was represented in Fig. 4; also, BH02 has low alpha concentration of 0.200±0.04Bq/l, BH08 has high beta concentration of 1.530±0.141Bq/l in BH water samples as shown in Fig. 1, and the percentage values for BH in the area for beta activities was displayed in Fig. 5.
The concentration of alpha measured in water samples for alpha activities ranges from 0.014±0.006Bq/l to 0.052±0.008Bq/l, with a mean value of 0.037±0.014Bq/l, from the results BH01 has the highest alpha concentration of 0.072±0.022Bq/l than BH02 which has lowest alpha concentration of 0.014±0.006Bq/l in all the water samples tested for alpha activities in the study area, still does not exceeded the minimum set standard 0.5 Bq/l per year. Similarly, the concentration of beta measured in water samples for beta activities ranges from 0.200±0.041Bq/l to 1.530±0.141Bq/l, the mean value of beta activity of 0.613 ± 0.104Bq/l, from the results BH08 has the highest beta concentration of 1.530±0.141 Bq/l than BH02 which has the lowest beta concentration of 0.200±0.04 Bq/l in all the water samples tested for beta activities in the study area. Fig. (6 & 7) unveil the percentage values of alpha and beta activities for both HD well and BH in the study area, which shows that all the samples met the standard set by WHO and ICRP 1Bq/l except the sample from the BH08 which shows that beta activities is high in the area because it has high depth of penetration compare to others which agree with early
literature that says, the deeper borehole the more radioactivity element contains, therefore the water sample in BH08 is not drinkable because it is radioactively not safe but can be used for washing. The mean gross alpha activities concentration in this study is 7.4% lower than the WHO 0.5 Bq/l recommended level, while the mean gross beta activity concentration is 61.32% lower than the WHO recommended level of 1.0 Bq/l. From the results it implies that the deeper we dig the more concentration of radioactive materials encountered, as the results was related with borehole records which shows that BH08 has the highest deeper penetration depth than others. Also compared the result of average value 0.037Bq/l for alpha activity and 0.613Bq/l for beta activity obtained in this work with 6.576Bq/l for alpha activity & 11.16Bq/l for beta activity in Gboko and its Environs by Atsor et al. [2]; 0.589Bq/l for alpha activity & 0.236Bq/L for beta activity in Ado-Ekiti by Fasae [3]; 0.15Bq/l for alpha activity & 6.0Bb/L for beta activity of well in Western Niger Delta by Agbalagba et al. [6]; and 0.0062Bq/l for alpha activity & 0.0478Bq/l for beta activity in Kano by Yusuf et al. [12], which
shows that the gross alpha and beta activity obtained in this selected area of this study was low compared to other researchers' results. The depth of penetration, radiochemical composition of the soil and rock strata through which the raw water may have passed and human activities.

4. CONCLUSION

The analysis of these water samples revealed that the concentrations of alpha and beta activity measured with their average values for all samples are below the recommended activity by the international standard organization (ISO) and world health organization (WHO). If the water from the area is consumed, it poses no threat to the health of the people, except for the sample obtained from BH08, which was not safe for drinking due to high beta radioactivity but can be used for washing and the results show that the gross alpha and beta activity obtained in the selected area is low compared to other works. There is a need to identify the radionuclide responsible for the high beta activity in the water of the affected area, which is the next work we are working on. Therefore, those that concern should make sure that sampling and analysis for radionuclide should be carried out routinely enough to characterize the gross alpha and beta annual exposures.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. ALS. “Rapid Turnaround Time Gross Alpha and beta Analysis” National Health and Medical Research Council, Australian Drinking Water Guidelines (ADWQG). 2013. Available: http://www.nhmrc.gov.au/guidelines/pub/eh52_download_06th_July_2016.
2. Atsor AJ, Akpa TC, Akombor AA. Determination of gross alpha and beta radioactivity in underground water at gboko and its environs. Research J. Physical Sci. 2015;3(6):1-9.
3. Fasae KP. Gross alpha and beta activity concentrations and committed effective dose due to intake of groundwater in Ado-Ekiti Metropolis; the Capital City of Ekiti State, Southwestern, Nigeria. J. Natural Sci. Res. 2013;3(12):61-66.
4. Environmental Protection Agency (EPA). The Analysis of Regulated Contaminant Occurrence Data from Public Water
System in Support of the Second Six-year Review of National Primary Drinking Water Regulations Office of the Ground Water and Drinking Water (4607M), EPA-815-B-09-006, Washington DC. Revised September 2010, Internet: www.epa.gov/safewater, download 18th Sept. 2017.

5. Adeeko TO, Ajala EO, Ogbochukwu HO. Gross effect of beta radioactivity concentration in groundwater at Kakuri, Kaduna South Local Government Kaduna, Nigeria. Asian J. Environ. Ecology. 17; 5(2):1-8.

6. Agbalagba EO, Awiri GO, Chad-Umoren YE. Gross $\alpha$ and $\beta$ Activity concentration and estimation of adults and infants dose intake in surface and ground water of ten oil fields environment in Western Niger Delta of Nigeria. J. Applied Sci. Environ. Management. 2013;17(2):267-277.

7. Adeeko TO, Mallam A, Ogbochukwu HO, Bello HA. An assessment of alpha radioactivity concentration of groundwater in Kakuri, Kaduna South Local Government Kaduna, Nigeria. European J. Aca. Essays. 2016;3(6):221-227.

8. Sajo-Bohus L, Gomez J, Capete T, Greaves ED, Herrera O, Salazar V, Smith A. Gross radioactivity of drinking water in Venezuela. J. Environ. Radioactivity. 1996; 35(3):305-312.

9. Brassard PG. Wetland and Water Pollution Boston Colleg, Environ. Aff. Law Review. 1996;23(4):885-919.

10. Zorer OS, Ceylan H, Doğru M. Gross alpha and beta radioactivity concentration in water, soil and sediment of the Bendimahi River and Van Lake (Turkey). Environ. Monitoring Assessment. 2009;148(1–4): 39–46.

11. Mangset WE, Solomon AO, Christopher DL, Ike EE, Onoja RA, Mallam SP. Gross alpha and beta activity concentrations in surface water supplies from mining Areas of Plateau State, Nigeria and Estimation of Infants and Adults Annual Committed Effective Dose. Physical Sci. Int. J. 2015; 5(4):241-254.

12. Yusuf S, Iliyasu G, Danbatta UA, Maitama AY. Effect of gross alpha and beta in groundwater intake and estimation of groundwater table in Kano University of Science and Technology, Wudil. American Sci. Research J. Eng. Tech. Sci. (ASRJETS). 2015;14(1):46-54.

13. Sai’du A, Ike EE, Baba-Kutigi AN, Muhammed SB. Spatial distribution of beta radionuclide activity in underground water in Sokoto City North Western Nigeria. Int. J. Sci. Adv. Tech. 2012;2(9):1-10.

14. Robertson DE, Schilk AJ, Abel KE, Lopel EA, Thomas CW, Pratt SI, Cooper EL, Hartwig P, Killey RWD. Chemical speciation of radionuclides migrating in ground waters. J. Radioanalytical Nuclear Chemistry. 1995;194(2):237-252.

15. Awiri GO, Osimobi JC, Ononugbo CP. Gross alpha and gross beta activity concentrations and committed effective dose due to intake of water in solid mineral producing areas of Enugu State, Nigeria. Int. J. Phys. App. 2016;8(1):33-43.

16. World Health Organization (WHO), "Guidelines for Drinking Water Quality" 4th Edition, WHO Library Cataloguing-in-publication data, NLM Classification Washington. 2011:197-209.

17. World Health Organization (WHO). Guidance for drinking Water Quality 3rd Edition. 2008;179-192.

18. ASTM. Standard test method for alpha particle radioactivity of water, ASTM D1943-93 and D1890-90; 1995.

19. International Organization on Standardization (ISO). Water Quality Measurement of Gross Alpha Activity in Non-Saline Water, Thick Source Method, ISO (9696-1992 revised), Geneva, Switzerland; 1992.

20. International Commission on Radiological Protection (ICRP). Protection of the public in situations of prolonged radiation exposure. Pergamon Press, Oxford, UK; 2000.

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