Gross alpha and gross beta radioactivity of ground water samples from Wudil and Environs

Miftahu Gambo Idris[1*], Habu Tela Abba[1] and Zakiyyu Ibrahim Takai[2]

[1]Department of Physics, Yobe State University, Damaturu, Yobe State, Nigeria
[2]Department of Physics, Yusuf Maitama Sule University, Kano, Kano State, Nigeria

[*]*Corresponding author E-mail*: gambomiftahu@gmail.com

(Received 20 December 2018, Accepted 26 January 2019, Published 19 February 2019)

Abstract

Radioactivity in ground water is due to alpha, beta and gamma radiations from the dissolved radioactive mineral's composition. Eighteen ground water samples (from boreholes and hand-dug wells) were collected across various communities within Wudil local government area. The gross alpha and gross beta radioactivity were determined by a gas-flow proportional counter (MPC2000B-DP model). The measured activity concentration of gross alpha and beta were compared with standard and reported data from other countries, majority of the water samples were found to exceed the recommended value of 0.1 and 1.0 Bq L^{-1} respectively for gross alpha and beta in drinking water. The results indicated that the gross alpha and gross beta radioactivity were enhanced by the presence of mineral Kaolin in the area. This may constitute radiological health related risk to the populace over a long period of time. Therefore, incorporation of reverse osmosis technology in boreholes will help reduce the radiological burden of the public in the area. The results from this monitoring campaign are important for the human radiation exposure and provide the zero point, which will be useful for assessing future effects due to human activities.

1. Introduction

Portable and safe drinking water has been a global issue for the past decades. World Health Organization (WHO) guidelines for drinking water quality suggest performing an indirect evaluation of committed effective dose by measuring gross alpha and gross beta radioactivity in drinking water and checking the level of compliance to reference dose levels [1]. Analysis of specific radionuclides in water is required if the gross radioactivity exceed the reference level of 0.185 Bq L^{-1} for combined ^{226}Ra and ^{228}Ra; gross alpha-particle activity of 0.555 Bq L^{-1} (excluding radon and uranium) [2, 3].

Water for domestic use comes directly from rainfall or surface water or ground water supplies. Ground water sources contain low level of radioactivity mainly from radionuclides of natural origin. Surface waters contain fission products from fall-out, industrial waste releases, materials by rainfall, surface run-off, and washing of deposited radioactive particles into the stream [4]. Water contains a number of both alpha emitters (such as ^{238}U, ^{226}Ra, and ^{210}Po) and beta emitters (such as ^{40}K, ^{228}Ra and ^{210}Pb). Natural isotopes as ^{40}K and the nuclides from the ^{238}U and ^{232}Th series are the greatest source of internal and external exposure of human beings. The values of gross alpha radioactivity originating from these alpha emitters in ground water samples depends on the geological characteristics of the area, content of mineral deposits and the type of human activities in the area [1]. In some places, use of groundwater can be significant pathway of radionuclides to mankind.

The use of water for drinking and household activities are potentially important pathways of radiation exposure of human through food preparation and processing. Although the levels of contamination can be markedly reduced by dilution, time delays and water treatment [4]. These processes remove small amount of the radioactive materials but more hazardous or long-lived radionuclides generally remain [5]. Natural radionuclides present in water beyond the recommended level are considered to have potential risks to man from their consumption at a regular rate. This is because of their long environmental half-life, high radiotoxicity and high affinity to biota.

In environmental monitoring, much attention has been given to gamma emitter's detection and quantification even where it is possible to have alpha and beta emitters [6, 7]. But effects of alpha and beta particles inside the body are far more detrimental to human health because of their ionizing power. Therefore, this study aimed to determine the gross alpha and gross beta radioactivity levels in ground water samples various communities within Wudil town and its environs in Kano state.

2. Site description

The study site is located between $11^\circ 49^{'}$ North and $8^\circ 51^{'}$ East of the Green Which Meridian at an altitude of 45 m in the north western region of Nigeria. It has an estimated land size area of 458 km^2 and a population of 185,189 as at the 2006 census [8]. The climate is the tropical wet and dry climate with mean annual rainfall of 850 mm usually from May to September and a mean annual temperature of 26^0C. The area is characterized in terms of natural vegetation types by having moderately tall grasses and scattered trees. Geologically the study area is predominantly underlined by sedimentary rocks characterized with mineral, Kaolin and to some extent limestone mixed with sand in pocket areas.

3. Sample Collection and Preparation

A total of eighteen (18) water samples were collected; nine (9) samples each from boreholes and hand-dug wells for the analysis. Since these sources of water are the major water supplies in the study area. The sampling locations were spread across various communities within Wudil town and subvert as shown in Figure 1. The samples were collected in 1-litre plastic containers with about 1%

air space left for thermal expansion [9].The water samples were immediately acidified with 20 ml of nitric acid per litre of sample collected for preservation and to minimize the absorption of the radionuclides onto the walls of the containers according to ISO standard (ISO, 9697 & 9698: 1992).The samples were then tightly covered and transferred to a laboratory for preparation.

The required volume of each of the samples was measured into a beaker and slowly evaporated on a hot plate at 60^0C, down to a volume of 50ml. This volume was transferred into a weighted petri-dish wish cleaned with acetone to avoid cross contamination and then evaporated to dryness using infra-red light. About 77 mg of the residue was washed with distilled water and then transferred to a stainless-steel planchet, dried and allowed to equilibrate with ambient temperature and weighed. The sample was evenly distributed using a syringe and some drops of vinyl acetate were added to the sample to act as a binder. It was kept in a desiccator for 28 days until it was ready for counting.

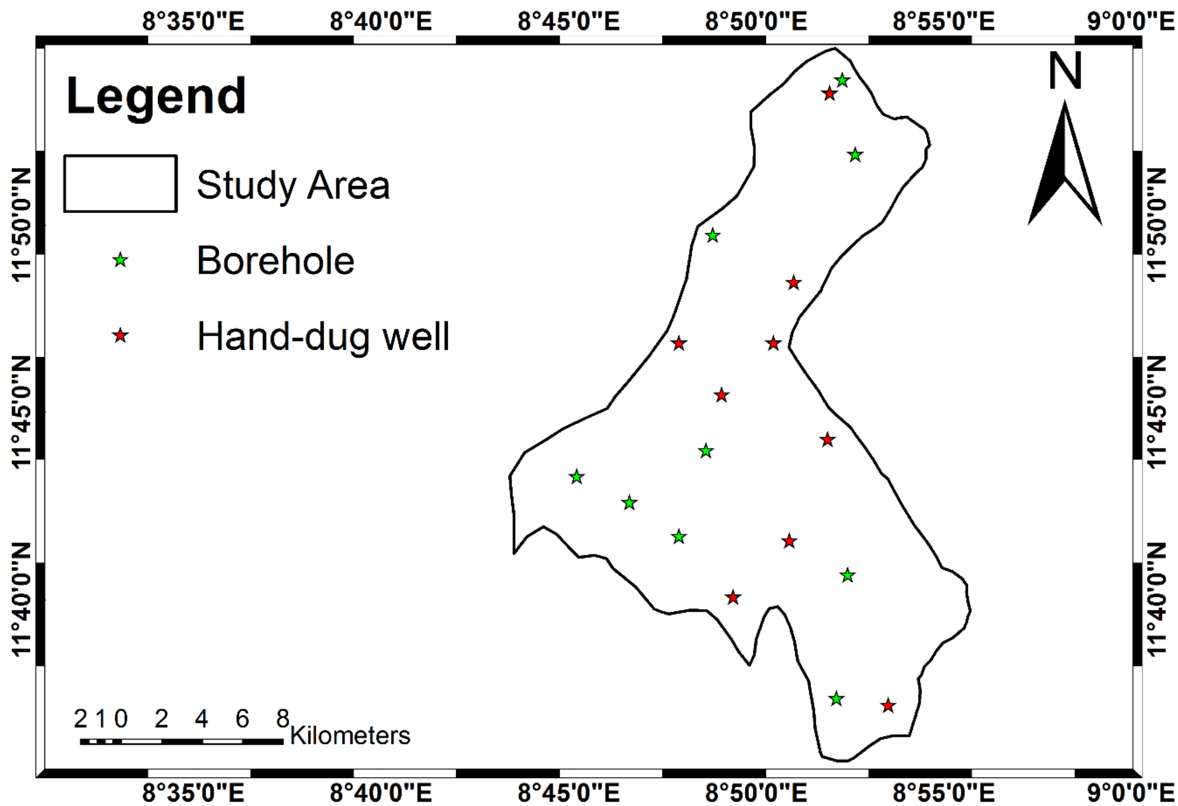

Fig. 1: Sampling Locations

These samples were analysed for gross alpha and beta activity using single channel gas-flow proportional counter, MPC2000B-DP model, at the Centre for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria. Each sample was counted for the time length of eight (8) hours. The MPC-2000-DP contains a custom designed detector with Zinc Sulphide layer bonded to a plastic scintillator. This combination is optically coupled to a photo-multiplier tube (PMT). The outermost layer detects alpha particles and the inner layer detects beta particles. The sample loader of the equipment is designed to require the least effort and range of motion from users. It also gives clear, unambiguous feedback to show that it is opened or closed.

4. Calibration of detector

For radioactivity measurement, sources of alpha (^{239}PU) and beta (^{90}Sr) with activities ranging from 133.29 to 185.51Bq and 105.1 Bq to 117.7 Bq, respectively, were used as standards. The radionuclide impurity in α source varied from 0.74 - 0.82% and less than 0.1% in β source. These standards were certified by CERCA LEA Laboratories in France with certification numbers CT 001/1285/001920-1927 and CT 1271/00/1778- 1783, respectively. This plateau test was run for 1800s for five cycles. The operational efficiencies of the channels of the counter were obtained [10].The alpha and beta specific activities were calculated using the following expression [1].

$$\text{Specific Activity } (\alpha/\beta)\ \text{Bq L}^{-1} = \frac{Counting\ rate\ (\alpha,\beta) \times - Background\ count\ rate\ (\alpha,\beta)}{Sample\ efficiency \times channel\ efficieny \times weight\ of\ the\ sample} \quad (1)$$

5. Results and discussion

The results for gross alpha and beta activity concentration in ground water for both hang-dug wells and boreholes are presented graphically. Activity concentration of α in boreholes water was found to range between 0.05±0.02 and 3.65±0.08 Bq L^{-1} with a mean value of 1.41±0.03 Bq L^{-1} while that of β ranged from 0.18±0.01 to 1.50±0.03 Bq L^{-1} with a mean value of 0.76±0.01 Bq L^{-1} as presented in Figure 2. Activity concentration of α in wells water ranged from 0.04±0.01 to 1.58±0.03 Bq L^{-1} with a mean value of 0.43±0.03 Bq L^{-1} and 0.02±0.004 to 0.85±0.008 Bq L^{-1} with a mean value of 0.23±0.03 Bq L^{-1} for β activity concentration as presented in Figure 3.

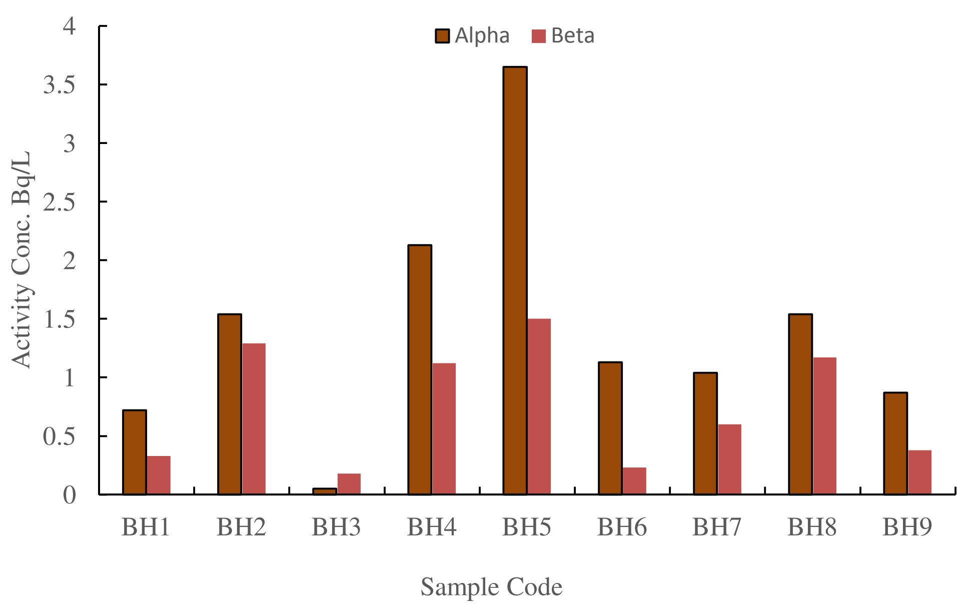

Fig. 2: Alpha and beta activity concentration in boreholes water.

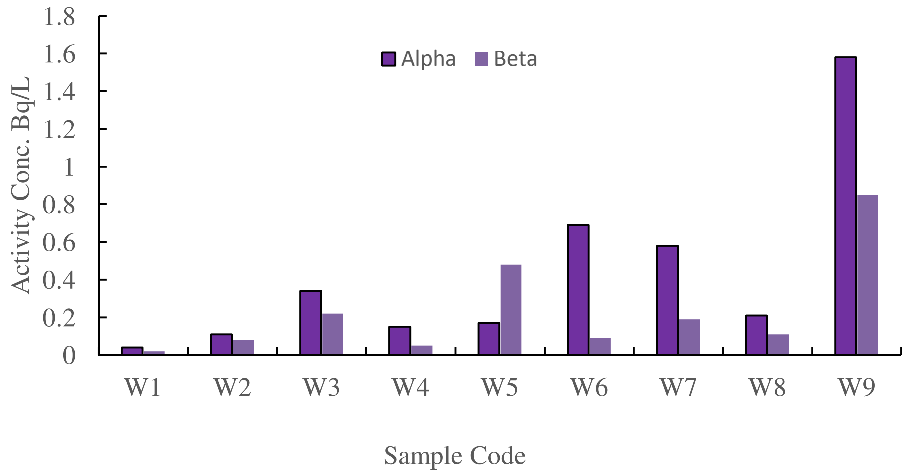

Fig. 3: Alpha and beta activity concentration in wells water.

Gross alpha and beta activity concentrations in borehole water have the highest values at location BH5 which might be due to rich Kaolin deposits in the area. Higher activity concentrations of ^{226}Ra and ^{232}Th as 82.0±37.3 Bqkg^{-1}, 94.8±47.2 Bqkg^{-1} in Kaolin, reported respectively [11]. This is because ^{226}Ra is an alpha emitter and ^{288}Ra which is a product of ^{232}Th is a beta emitter [1]. The least values of gross alpha and gross beta activity concentrations were measured in BH3 water sample, area underlie by sand mixed with limestone. It is reported that natural radioactivity of ^{238}U and ^{232}Th in limestone are considered to a typical of natural background [1, 12]. The highest activity concentrations of alpha and beta in well water were measured in water sample collected from location W9, area also endowed with Kaolin. The least activity concentrations of gross alpha and beta in well water were observed in water sample collected from W1, an area characterised with sedimentary formation.

There is good correlation between gross alpha and gross beta activities concentration with correlation coefficient of 0.7097 in borehole water as shown in figure 4. Perhaps, this might be due the deposits of Kaolin in the area. All the results obtained for borehole water in the communities sampled, except water sample BH3, were found to be higher than the safe limit of 0.1 Bq L^{-1} for gross alpha and higher than 1.0 Bq L^{-1} in BH2, BH4, BH5 and BH8 water samples for gross beta activity concentration in drinking water [13].

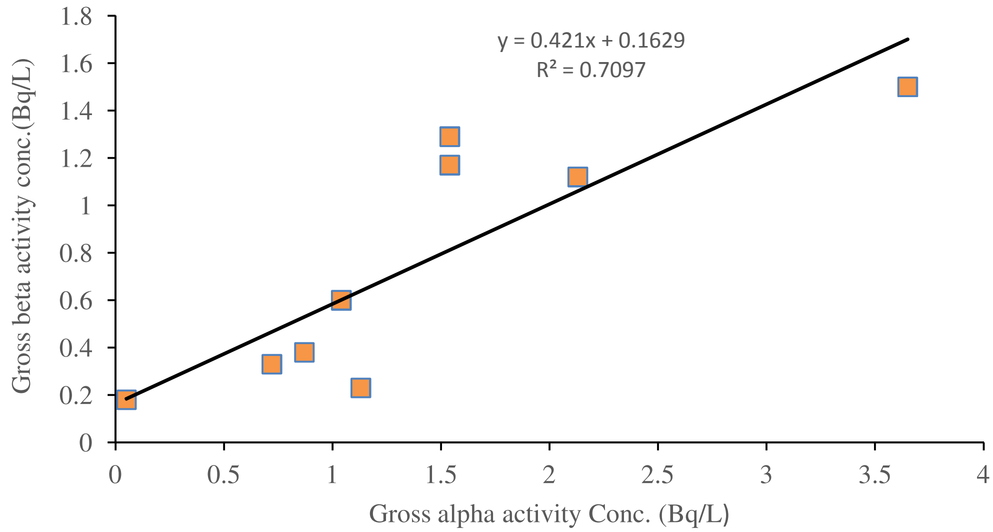

Fig. 4: Correlation of gross alpha and gross beta activity concentration in Borehole Water

Highest values of activity concentrations of gross alpha and gross beta in well water were measured in water sample collected from location W9 and the lowest values were found in water sample from W1. The activity concentrations of gross alpha in the well water samples were found to be lower than reference value, 0.1 Bq L^{-1}, only in W1 water sample. Gross beta activities concentration in all the water samples collected from the hand-dug wells were found lower than the recommended value of 1.0 Bq L^{-1} [13]. A good correlation (R= 0.6082) was also observed between gross alpha and gross beta activities concentration in well water samples collected from the communities of the study area as shown in figure 5. The reason stated for the borehole water could also be responsible for the good correlation observed in well water. Radionuclides (alpha and beta emitters) present in Kaolin underlying most communities might have led to the linear relationship in both cases.

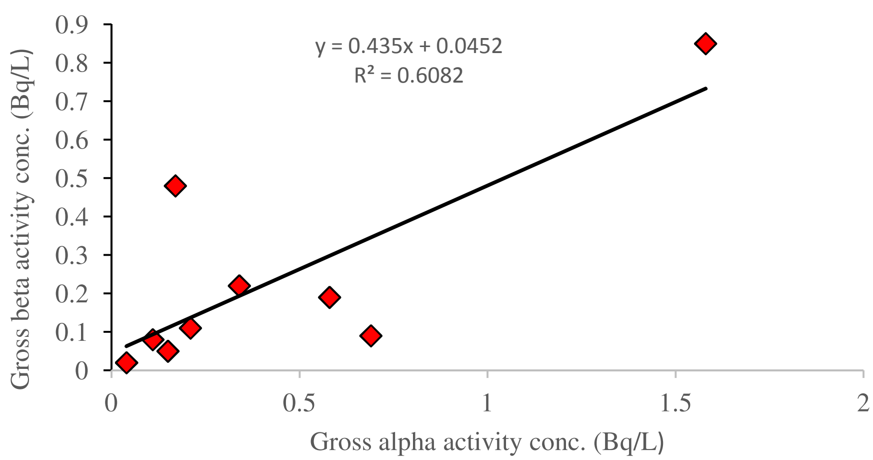

Fig. 5: Correlation of gross alpha and gross beta activity concentration in Well Water.

The mean gross alpha activity concentration in borehole water for this study is found to be higher than the corresponding mean values reported for other study areas as shown in figure 6 [1, 14, 15, 16, 17]. Mean gross beta radioactivity obtained in this work was higher than that obtained in Mangu, Benue and Enugu of Nigeria. This may be due to varying degrees of solid mineral deposits that constitute the geology of the areas studied.

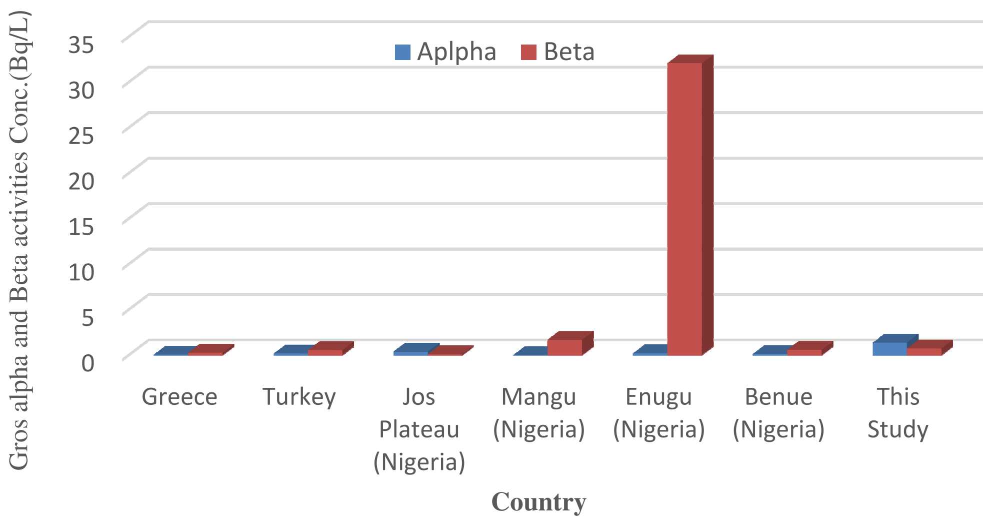

Fig. 6: Comparison of the gross α and β concentrations determined in drinking water samples with those reported in other countries.

6. Conclusion

Gross alpha and gross beta activity concentration in ground water (hand-dug wells and boreholes) from various communities of Wudil and environs were measured using gas flow proportional counter (MPC2000B-DP model). The gross alpha activity concentration exceeded the reference value of 0.1 Bq L^{-1} while beta activity concentration exceeded 1.0 Bq L^{-1} in four water samples as recommended by WHO [13]. Areas endowed with Kaolin recorded the highest value.

The results imply that, ground water from most communities within the study area pose radiological health risks due to consumption of groundwater. We therefore, recommend incorporation of reverse osmosis technology or ion exchange technology in water sources to remove the dissolved mineral radionuclides from drinkable water in order to reduce radiological burden to the populace.

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