International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor (2018): 7.426

Determination of Radioactivity Levels in Borehole Water at Adenta Municipality in the Greater Accra Region of Ghana

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Abstract: ***Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in twenty selected borehole water samples randomly collected from the Adenta municipality in the greater Accra region of Ghana were measured.The analysis was carried out in the Gamma Spectrometry Laboratory at Radiation Protection Center of Ghana Atomic Energy Commission by using gamma spectrometry system to quantify the radionuclides of interest in the water samples. The investigation revealed a recorded measured activity concentration of ^{226}Ra, ^{232}Th and ^{40}K ranged from 0.27 ±0.05Bqkg-1to 1.83 ±0.55Bqkg-1, 0.11±0.06Bqkg-1 to 4.29±0.27Bqkg-1 and 1.24 ±0.16Bqkg-1 to 28.75 ±4.82Bqkg-1 respectively. The average activity concentration values were 0.77±0.42Bqkg-1, 0.93±0.62Bqkg-1 and 9.77 ±4.55 Bqkg-1 for ^{226}Ra, ^{232}Th and ^{40}K respectively. The committed annual effective due to intake of natural radionuclides in the borehole water was calculated to be 40.29±10.45 µSvy-1.The total annual effective is far below the World Health Organization recommended limit of 100 µSvy-1 as well as the average injection dose of 0.29 mSvy-1. The results indicate that the inhabitants in the Adenta municipality are not exposed to any significant radiological health hazard due to drinking water from boreholes in the municipality. The data from this will serve as baseline data for future studies in the study area. This research will provide some useful data (base –line radiometric values) to be used by the regulatory authority to evaluate possible changes in the future. <u>Introduction</u>: Water is essential for the survival of all organisms, including humans; hence the need for adequate safe water cannot be overemphasize. [1] The rise of human internal exposure through inhalation and ingestion are link to the existence of radionuclides in the water bodies. [2]The measurement of radioactivity in borehole water allows the determination of population exposure to radiation due to the habitual consumption of water. The increasing fear on radiological status from borehole drinking water from Adenta in Accra has necessitated the need to evaluate the potential radiological risk.The public is unaware of the potential hazards associated with drinking water contaminated with natural radioactivity. Hence, the need for this study; to evaluate the natural radioactivity levels in borehole water is necessary to ensure radiological quality of drinking watercould serve as preliminary and baseline report, for ensuring public protection from radiation exposure .subject to further investigations. <u>Method</u>: The study employed experimental research design to address the statement of the problem and achieve the aim and objectives of the study. A total number of twenty (20) water samples were randomly taken from boreholes in the Adenta Municipality where the water sources are used for domestic purposes, prepared and counted for 36000secs using a high pure germanium detector to acquire spectral data. Appropriate mathematical modeling/equations were used to obtain reliable data sets.The analytical expression used in the calculation of the activity concentrations in Bql-1 and committed annual effective dosein (SvBq-1).for the water samples are as shown below.*** $A_{sp} = \frac{N_{sam}}{P_E . \varepsilon . T_c . M}$ ***where; Nsam- background corrected net counts of the radionuclide in the sample, PE - gamma ray emission probability (gamma yield), ε - total counting efficiency of the detector system, Tc - sample counting time, and M - mass of sample (kg) or volume (L) .[6]. Committed annual effective dose, ET =*** $\sum(A_w * DCF_w) * I_w$.

Where, I_w is the water consumption rate which is 730 Ly-1, At is the activity concentration of radionuclide in the water (Bql-1), and DCF_w is the dose conversion factor (SvBq-1). <u>Results</u>: The committed annual effective dose to an adult individual due to intake of natural radionuclides in the borehole water from Adenta was estimated to be 40.29±10.45 µSvy-1 which is far below the World Health Organization [8] recommended limit of 100 µSvy-1 as well as the average radiation dose of 0.29 mSvy-1 received per caput worldwide due to ingestion of natural radionuclides reported in [2] report. <u>Conclusion</u>: The results indicate that the inhabitants in the Adenta municipality are not exposed to any significant radiological health hazard due to drinking water from boreholes in the municipality.

Keywords: Borehole, Radionuclides, Activity concentration, Annual effective and Recommended limit

1. Introduction

Water is essential for the survival of all organisms, including humans, hence the need for adequate safe water cannot be overemphasize. [1]The rise of human internal exposure through inhalation and ingestion are link to the existence of radionuclides in the water bodies. [2]The measurement of radioactivity in borehole water allows the determination of population exposure to radiation due to the habitual consumption of water. Radioactivity as the name implies is the term used to describe the decay of an excited atomic nucleus. Some of the exacted nucleus has existed since time began on earth. Radiation exposure Occur from two main types namely (I) naturally occurring radioactive materials (NORM), which are present in soils, rocks, the floors and walls of dwellings, offices or schools, in the food humans eat and drink, in the air humans breathe and in human bodies and (ii) man-made or artificial sources.

Naturally occurring radioactive materials enter the human body through two main pathways – by inhalation of radioactive gases like radon and dust, and ingestion of primordial radionuclides ^{40}K, ^{232}Th and ^{238}U as well as their radioactive progenies. The decay of inhaled or ingested radionuclides gives rise to internal exposure of the tissues and organs in the human body.The United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR) has reported that the average worldwide exposure to natural sources in foods and drinking water (ingestion exposure) is 0.29 mSvy-1 (about 0.17 mSvy-1 from ^{40}K and about 0.12 mSvy-1 from Uranium and Thorium).[2]

Exposure to ionizing radiation/particles at low doses for a long time may result to delayed deterministic effects, stochastic effects and genetic effects. A lot of research has been conducted to determine the radioactivity levels in borehole in many parts of the world. In Ghana, some studies have been carried out in some mining areas of the country to determine the radioactivity levels in ground water [3], [4]. However, no study has been carried out to establish data on the radioactivity levels in borehole waters in the Adenta Municipality in the Greater Accra region of Ghana.Until now, there is no similar work done on the radioactivity levels in borehole water at the Adenta municipality. The public is unaware of the potential hazards associated with drinking water contaminated with natural radioactivity. Hence, the need for this study; to evaluate the natural radioactivity levels in borehole water is necessary to ensure radiological quality of drinking watercould serve as preliminary and baseline report, for ensuring public protection from radiation exposure .subject to further investigations.

2. Materials and Method

2.1 The study Area

The location is Accra; it is located within one of the six districts of the Greater Accra Region of Ghanaand lies between longitude 0^0 00^1 W and $0^0 15^1$ E and latitudes 0^0 45^1 N and 6^0 15^1 N respectively. It is bounded on the North and West by the Akwapem -Togo ranges and Ga district respectively. The city of Accra is the biggest city in Ghana, with a total area of 173km^2 and a population of about 1.6 million people.The vegetation is mainly coastal grassland and scrub [5].

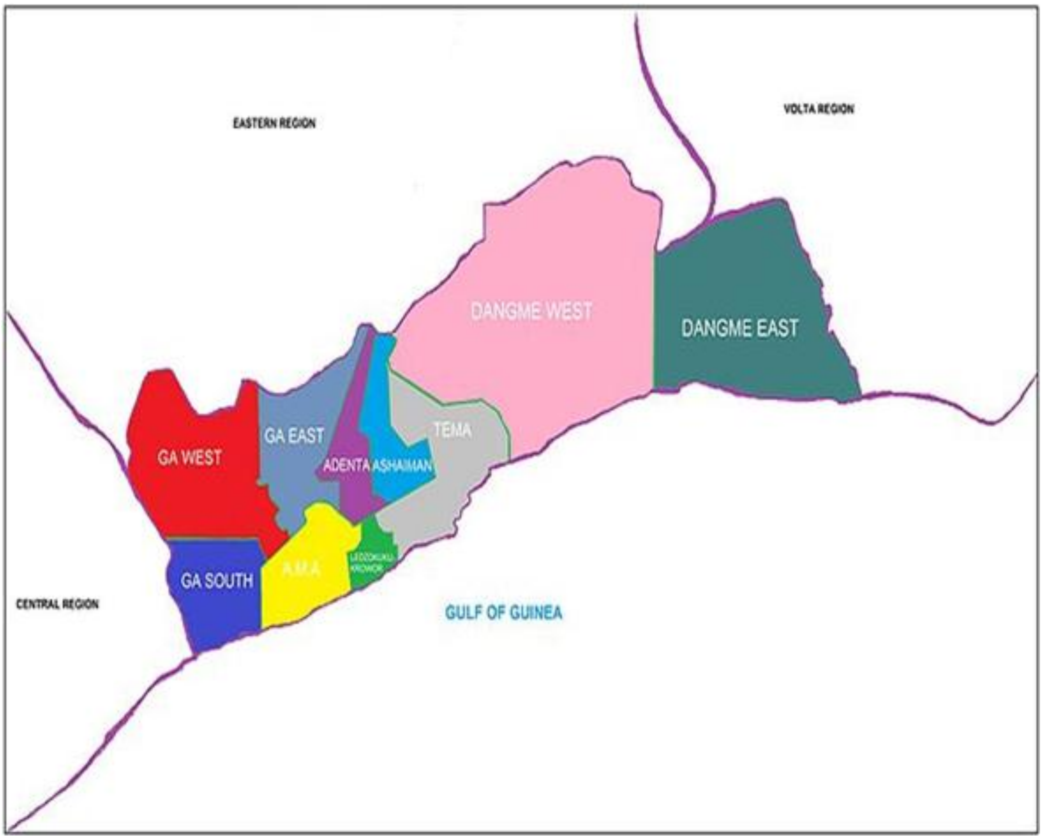

Figure 1: Map of study area

2.2 Sample Collection and Preparationfor Gamma Spectrometry

A total number of twenty (20) water samples were randomly taken from boreholes in the Adenta Municipality where the water sources are used for domestic purposes. The samples were collected in the morning (8am – 10am) when the weather conditions were fairly stable. The pH, temperature, total dissolve solids and conductivity of the water samples were measured on-site during the sampling period using a portable water-analysis kit. The water samples were collected into 5 L polyethylene gallons and a few drops of nitric acid added to prevent adherence of the radionuclides to the walls of the containers, tightly covered with the lids, and labeled appropriately. 1L of each sample was transferred into a Marinelli beaker and labeled. The shape of the Marinelli beaker allows for a relatively larger surface area of the water sample. The beakers were covered with a lid and tightly seal with plastic tape and placed on a stand for three to four weeks to established daughter radionuclides established with the parent before analysis. Samples were weighed and the mean mass recorded. Each sample was analyzed using the gamma spectrometry system with the counting assembly.

2.3 Description of the gamma spectrometry setup

The gamma spectrometry is made up of a multichannel analyzer, software connected to a computer for spectrum analysis and evaluation and a high purity germanium detector. The detector has coaxial closed window geometry with vertical dipstick. Liquid nitrogen at 196ºC and (77k) is use to cooled the system. The system is an n-type with the following specifications: the detector has a relative efficiency of 25% and an energy resolution of 1.8KeV at gamma ray of 1332 KeVof 60.

2.4 Calibration of the Gamma Spectrometry Setup

A standard reference solution supplied by the International Atomic Energy Agency was used to calibrate to ascertain the quantification and identification of radionuclides. To achieve accurate results, Genie-2000 software was used to acquire quantitative result of the radionuclides and gamma ray energies were used to identify individual radionuclides. Proper calibration ensures that the gamma ray spectra generated are accurately described in terms of energy and specific activity (activity per unit mass or litre, i.e. Bq/ kg or Bq/ L). Distilled water were filled in six clean Marinelli beakers and counted for 36,000 secs.

2.5 Counting Procedure for Gamma Spectrometry

The samples were counted for 36000secs on the high pure germanium detector to acquire spectral data. The activities were determined using the gamma energies.

2.6 Calculation of Activity Concentrations from Spectral Data

For all the water samples, the activity concentration of ^{238}U was determined from the peak of 609.31 keV of ^{214}Bi. Similarly, the activity concentration of ^{232}Th was determined from the average energies of 238.63 keV of ^{212}Pb and 911.2 keV of ^{228}Ac. The activity concentration of ^{40}K was determined from the energy of 1460.83 keV.

The analytical expression used in the calculation of the activity concentrations in Bql-1 for the water samples is as shown in below.

$$A_{sp} = \frac{N_{sam}}{P_E . \varepsilon . T_c . M}$$

where; Nsam- background corrected net counts of the radionuclide in the sample, PE - gamma ray emission probability (gamma yield), ε - total counting efficiency of the detector system, Tc - sample counting time, and M - mass of sample (kg) or volume (L) .[6]

2.7 Estimation of Committed Annual Effective Dose

The committed annual effective dose (Sv/year) from ingestion of radionuclide consumed in water was calculated on the basis of the mean activity concentrations of the radionuclides. The daily water consumption rate was taken to be 2 liters per day. The dose conversion factors used for ingestion of naturally occurring radionuclides for adult members of the public were 4.5 x 10-5 mSv Bq-1 for ^{226}Ra, 2.3 x 10-4 mSvBq-1 for ^{232}Th and 6.2 x 10-6 mSvBq-1 for ^{40}K [7]. The committed annual effective dose owing to ingestion of Ra, Th and K in water was then estimated using the equation shown below

Committed annual effective dose, ET =

$$\sum (A_w * DCF_w) * I_w .$$

Where, Iw is the water consumption rate which is 730 Ly-1, At is the activity concentration of radionuclide in the water (Bql-1), and DCFw is the dose conversion factor (SvBq-1).

3. Results

Table 1: Average activity concentrations and annual effective doses due to ^{226}Ra, ^{232}Th and ^{40}K in water samples in the study area

Sample ID	Activity concentration, Bq/l			Committed effective dose, μSvyear^{-1}
	^{226}Ra	^{232}Th	^{40}K	
BHW$_1$	0.27±0.05	0.63±0.09	1.33±0.11	6.24
BHW$_2$	1.10±0.18	0.40±0.05	5.87±0.26	26.76
BHW$_3$	1.79±0.16	1.16±0.15	6.29±0.67	28.95
BHW$_4$	1.24±0.18	0.34±0.07	10.0±0.05	6.50
BHW$_5$	0.43±0.06	0.43±0.07	1.24±0.16	5.75
BHW$_6$	0.55±0.23	0.14±0.02	4.10±0.11	3.00
BHW$_7$	0.13±0.08	0.40±0.15	1.30±0.21	6.03
BHW$_8$	0.91±0.18	0.12±0.05	28.75±4.82	130.21
BHW$_9$	0.61±0.02	0.11±0.06	3.88±4.53	17.65
BHW$_{10}$	0.90±0.21	0.15±0.07	12.53±3.56	56.84
BHW$_{11}$	0.25±0.02	1.24±0.18	1.57±0.38	7.18
BHW$_{12}$	1.83±0.55	0.10±0.06	19.99±4.73	90.67
BHW$_{13}$	0.43±0.19	1.16±0.17	3.19±0.33	14.85
BHW$_{14}$	0.64±0.15	2.61±0.68	31.73±4.73	144.48
BHW$_{15}$	0.29±0.15	4.29±0.27	23.72±1.14	108.74
BHW$_{16}$	0.52±0.15	0.31±0.05	7.30±0.06	3.44
BHW$_{17}$	1.64±0.16	0.41±0.06	26.11±4.23	118.43
BHW$_{18}$	0.33±0.29	0.65±0.15	1.62±0.27	7.58
BHW$_{19}$	0.82±0.14	2.35±0.45	2.50±0.38	11.57
BHW$_{20}$	0.71±0.28	1.67±0.12	2.35±0.42	10.88
Average	0.77	0.93	9.77	40.29
Standard deviation	0.42	0.62	4.55	10.45
Range	0.27-1.83	0.11-4.29	1.24-28.75	3.00-144
Guideline levels WHO, 2004)	10.00	1.00	N/A	100.00

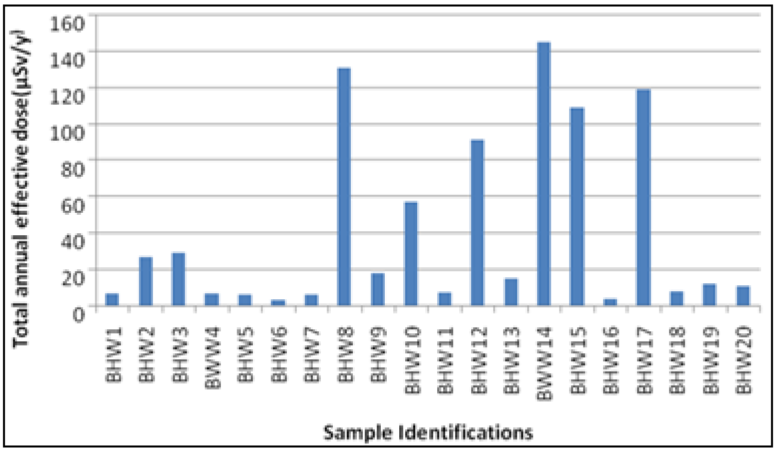

Figure 2: Shows a bar graph of total annual effective dose of the selected borehole waters in Adenta

4. Discussion

4.1 The measured activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the water samples collected from boreholes in the Adenta Municipality are presented in Table 1. The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K ranged from 0.27±0.05 to 1.83±0.55 Bqkg-1, 0.11±0.06 to 4.29±0.27 Bqkg-1 and 1.24±0.16 to 28.75±4.82 Bqkg-1 respectively. The borehole water sample with the identification BHW1 had the lowest concentration of ^{226}Ra of 0.27BqKG-1while that of BHW12 had the highest concentration of 1.83BqKG-1. The highest and lowest activity concentration values of ^{232}Th were found in samples with identifications BHW15 and BHW9 respectively. While the highest concentration of ^{40}K was found in sample with identification BHW8 and the lowest was found in BHW5. These variations are attributable to the different locations of the boreholes at the Adenta municipality.

The variations in the levels of the radionuclides observed are due to the different depths of the boreholes and the underlying bed rock at the various locations. The average activity concentration values were 0.77±0.42, 0.93±0.62 and 9.77±4.55 Bqkg-1 for ^{226}Ra, ^{232}Th and ^{40}K respectively. Thus ^{40}K contributed the largest activity concentration while ^{226}Ra contributed least activity in the water samples. The ± values associated with the mean values represent the variability (standard deviation) in the activity concentration values of the radionuclide.

The committed annual effective dose was calculated from intake of these radionuclides as a consequence of direct consumption of the borehole water and the results are also presented in Table 1. The annual effective dose due to ingestion of ^{226}Ra, ^{232}Th and ^{40}K in the borehole water varied from 3 to 114 µSv/year with an average value of 40.29±10.45 µSv/year.

It can be seen that within the locations where the samples were taken, water sample with the identification BHW14 recorded on the average the highest annual effective dose whilst that of BHW6 gave the lowest effective dose. This shows that water from the borehole with identification BHW14 gives the highest internal exposure than that of BHW6 to consumers.

The calculated annual effective dose, as a result of ingestion of radionuclides in water to any individual's organ or tissue in the population group is far below the World Health Organization [8] recommended limit of 100 µSvy-1 as well as the average radiation dose of 0.29 mSvy-1 received per head worldwide due to ingestion of natural radionuclides. [2]

Figure 2.Shows a bar graph comparison of the total annual effective dose from each of the sampled borehole water with their respective identification codes. The figure shows that water from the boreholes with identification BHW14 gave the highest internal exposure, followed by BHW8, BHW7 and BHW15. Water from the boreholes with identifications BHW6 and BHW6 gave the least internal exposure to consumers.

5. Conclusion

Natural radioactivity in water samples collected from boreholes in the Adenta Municipality in the greater Accra region of Ghana has been measured using gamma-spectrometry system. The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K ranged from 0.27±0.05 to 1.83±0.55 Bqkg-1, 0.11±0.06 to 4.29±0.27 Bqkg-1 and 1.24±0.16 to 28.75±4.82 Bqkg-1 respectively. The average activity concentration values were 0.77±0.42, 0.93±0.62 and 9.77±4.55 Bqkg-1 for ^{226}Ra, ^{232}Th and ^{40}K respectively. The committed annual effective dose to an adult individual due to intake of natural radionuclides in the borehole water was estimated to be 40.29±10.45 µSvy-1 which is far below the World Health Organization [8] recommended limit of 100 µSvy-1 as well as the average radiation dose of 0.29 mSvy-1 received per caput worldwide due to ingestion of natural radionuclides reported in [2] report.

The results indicate that the inhabitants in the Adenta municipality are not exposed to any significant radiological health hazard due to drinking water from boreholes in the municipality.This research would provide some useful data (base –line radiometric values) to be used by the regulatory authority to evaluate possible changes in the future.

6. Acknowledgement

The authors would like to acknowledge the Radiation Protection Institute and Graduate School of Nuclear and Allied Sciences for their kind support given during the preparation of the manuscript.

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