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SURVEY OF GROSS ALPHA AND BETA RADIOACTIVITY CONCETRATION AND ESTIMATED COMMITTED EFFECTIVE DOSE TO THE GENERAL PUBLIC DUE TO INTAKE OF GROUNDWATER IN SOME PARTS OF CHIKUN AND KADUNA SOUTH LGAs OF KADUNA STATE, NIGERIA

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Abstract

Twenty eight samples of water fourteen each from hand-dug wells and boreholes in some parts of Chikun and Kaduna south LGAs were selected using a stratified random sampling. Twenty (20mils) of concentrated nitric acid were added to each two liters of the sampled water for preservation. The samples were then evaporated and counted for Gross Alpha and Beta activity using MPC-2000-DP model gas free proportional counter at Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria. The results showed that the range of alpha activity varied from (0.008-0.276)Bq/L with a geometric mean of 0.048 Bq/l for borehole samples and (0.001-0.413) Bq/L with a geometric mean of 0.124 Bq/l for well water samples. The range of beta activity varied from (0.009-0.338) Bq/l with a geometric mean of 0.099 Bq/l for borehole water samples and (0.003-0.808) Bq/L with the geometric mean of 0.183 Bq/l for well water samples. The overall results show that, the alpha and beta activity have their values below WHO recommended practical screening level of 0.5 Bq/L for alpha and 1.0 Bq/L for beta radioactivity for drinking water. The mean values of CED due to intake of borehole water for alpha activity are 0.019mSv/yr, 0.039mSv/yr and 0.078mSv/yr for infants, children and adult respectively. For beta activity the values are 0.032mSv/yr, 0.063 mSv/yr. and 0.127 mSv/yr. In the well water samples, the mean CED value for alpha activity are 0.048 mSv/yr, 0.095 mSv/yr. and o.146 mSv/yr for infants, children and adults respectively and for beta activity the mean values are 0.081 mSv/yr., 0.147mSv/yr. and 0.294 mSv/yr respectively. The results showed elevated values in few of the location above the ICRP acceptable standard of 0.1mSv/yr. These values show that the general public in few of the locations are committed to higher dose above the standard values and long term exposure could pose health threat.

Keywords: Gross Alpha; Gross Beta; Radioactivity; Geometric Mean. Well; Borehole; Committed Effective Dose.

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1. Introduction

Water is fundamental to life here on earth, and, therefore is one of our most valuable resources. The supply of clean, abundant water sources is a major challenge facing modern civilization, and as such, the topic of many research endeavors. The challenge includes the securing of water supplies in the face of climate changes and population growth, and the mitigation of ongoing detrimental effect of modern world. The use of water cuts across industrial, agricultural and domestic uses. The two main sources of water are rain and ground water sources. It is found in rivers, wells, dams, lakes and streams. Human activities and natural phenomenon constantly polluting the sources of water and affect water quality. Water pollution arises as a result of waste and sewage disposal into the environment and rivers by industries, hospitals and use of materials such as fertilizers by farmers. On the other hand, individuals also cause ground water contamination by improper disposal of wastes namely motor oil, detergents and cleaners can leak into water sources. These disposed materials often contain radioactive materials (solid, liquid, or gaseous) which contribute significantly to the background activity of the water bodies (Gondar, 2011). Another form of water pollution is as a result of Naturally Occurring Radioactive Materials (NORMS) that emits alpha, beta and gamma radiations. These usually have elements in the uranium and thorium series whose radioactive gaseous daughter (radon and thoron) in particular cause an appreciable airborne particulate activity and contribute to the radioactivity of rain and ground waters. They contaminate the water body directly with their radionuclide products; and indirectly, through the radon and thoron gaseous products which can solidify and attach themselves as aerosols to the air particles and are washed down by rain into water bodies. Furthermore, flowing water encounters shelves, sedimentary rocks, igneous rocks and phosphate rocks all of which are also radioactive (Santchi and Honeyman, 1989). All these contribute to the level of radioactivity in water. The activity concentration of natural radionuclides depends on the water sources. In the surface water, activity concentrations are typically low while drinking water sourced from deep wells and boreholes are usually expected to have higher concentration of radioactive nuclides. This is because they pass through fractures in bedrocks or within the soil which contains minerals deposits that might have radioactive constituents and thus leaking into the water ways. Also the concentration increase in summer due to the high evaporation rates and the increase of the solubility of the salts due to higher temperature of the water (Kehagia et al., 2007). In addition to radioactivity, it has a chemical toxicity that predominantly affects the kidneys (Auvinen et al., 2002; Kurttio et al., 2005). According to Arnold et al. (1992), some radionuclides are chemically similar to some minerals in the human body and so when they are taken into the body, they mimic those minerals in the organs. For instance 226Ra, 38Sr and 56Ba (Arnold et al., 1992) are found to have chemical similarity with 20Ca in the bone, when these radionuclides get into the body, they are deposited at the bone marrow, causing damage to bone cells through Osseo Sarcoma (bone cancer). Exposure to radiation is harmful to living tissues because of its ionizing power in matter. This ionization can damage living cells directly, by

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breaking the chemical bonds of important biological molecules like DNA, or indirectly, by creating chemical radicals from water molecules in the cells, which can chemically attack biological molecules (UNSCEAR, 1993). To some extent, these molecules are repaired by natural biological processes; however, the effectiveness of this repair depends on the extent of damage. Obviously, if the repair is faulty or not made at all, the cell may then suffer either of these possible fates (Cember, 1996): Death of the cell, an impairment in the natural functioning of the cell leading to somatic cell effects, i.e. physical effects suffered by the irradiated individual such as cancer and permanent alteration of the cell which is transmitted to later generations, i.e. a genetic mutation.

Radioactivity in drinking water is an important mode of transfer of radionuclides from environment to man. The most important natural radionuclides in drinking water are tritium, potassium-40, radium, radon and gamma emitters. Therefore, measuring the radioactivity in drinking water is of great interest in environment studies (Ajayi and Owolabi, 2008). A gross alpha test is the first step to determining the level of radioactivity in drinking water. This test serves as a preliminary screening device and determine whether additional is advisable (Ajayi and Owolabi, 2008). Gross alpha is more of concern than gross beta for natural radioactivity in water as it refers to the radioactivity of Th, U, Ra as well as Rn and daughters (USEPA, 1997). If the gross alpha and gross beta are less than 0.5 and 1.0Bq/L respectively, it can be assumed that the Total Indicative Dose (TID) is less than the parametric indicator value 0.1mSv/year and no further radiological investigation is needed. If the gross alpha activity exceed 0.5Bq/L or gross beta activity exceeds 1.0Bq/L, analysis for specific radionuclides is required (WHO, 1993). Parts of Kaduna south and environs, like many other parts in the country, due to portable water scarcity, people normally collect water from wells and boreholes (deep and shallow). The public water boards are generally ineffective in supplying portable drinking water; therefore most of the populations rely on untreated ground water sources (borehole and well) for domestic and industrial purposes. The ground water collected from dug wells and boreholes samples are not entirely free from radioactive pollutants which are hazardous to human health. Therefore, there is need to determine the concentration of gross alpha and gross beta particles in wells and boreholes water from these areas assess the radiological health risks due to consumption of water from wells water and boreholes sources on the area because communities from all parts of the country and beyond are involved. This research help in understanding a quantitative detection of gross alpha and beta radioactivity which is important for a quick survey of both natural and man-made radioactivity in dug-wells and boreholes water in the study area.

2. The Study Area

The area under study is some parts of Kaduna south and Environs and this research is limited to dug-wells and boreholes water sources used by people of the region for drinking, domestic activities irrigation and animal husbandry. The area is bounded by latitudes 100 25.28′ N and 100 35.53′ N and Longitudes 70 21.49′ E and 70 30.00′ E. It lies within parts of Kaduna South and Chikun Areas of Kaduna State. It covers an area of approximately 268.36Km2, in the Basement Complex of North Central Nigeria, the area is the Industrial layout and most of the industries are located there suggesting predominantly Industrial activities zone. The study area lies within the Guinea Savannah belt, which experiences the tropical Savannah climate with two distinct seasons. The area has a vast fertile land which is suitable for the cultivation of a wide

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range of cash and food crops. This condition makes agricultural activities the main backbone of the economy of the people. The major food crops grown in the areas are maize, soya beans, cassava guinea corn, cocoyam and yam are cultivated in the area. The main source of water in the communities is borehole. However, some residents of the communities depends on streams, rivers and wells as their water sources. The above reasons make it imperative for baseline study such as this to establish baseline radioactivity levels which will serve as reference data for future studies.

Twenty eight water samples were collected from dug-wells and boreholes within the fourteen areas namely: Kudenda, Nassarawa, Gonin Gora, Ungwan Romi, Kakuri, Narayi, Television, Sabon Tasha, Bagado, Karji, Kamazou, Barnawa, Mahuta and Ungwan Boro areas of Kaduna South, Kaduna state. The samples were collected in 2-litre of plastic containers and were taken to Centre for Energy Research and Training CERT, Ahmadu Bello University, Zaria for analyses.

3. Materials and Methods

The method used for the sampling is stratified random sampling (Williams, 1977). The sampling procedures include the following: The sample container was rinsed three times with the water being collected to minimize contamination from the original content of the sample container, The amount collected was such that an air space of about 1% of container capacity was created for thermal expansion was left, The water samples were immediately acidified with 20ml of nitric acid per 2liters of sample collected to reduce PH and to minimize the absorption of radioactivity into the walls of the containers (ISO, 1992) and the samples were tightly covered and kept in the laboratory for analysis.

For the purpose of analysis, an Acetone (a cleansing agent) was used to wash the equipment needed for the Sample preparation. About 600cm3 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 WB and the weight of the planchette plus sample after evaporation to 50ml, WB+S. The difference between WB+S and WB 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 (1.1)

$$Sample\ efficiency = \frac{w_{B+S} - w_B}{0.077} \ x\ 100\% \quad (1.1)$$

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The gross alpha and beta counting equipment used in this work was the MPC-2000-DP low background alpha/beta detector. The equipment is a non-gas proportional counter with an ultra-thin window. For the gross alpha counting, the desired weight of 0.0770g of residue on the planchette was transferred to the sample carrier of MPC-2000-DP model detector. The carrier was then placed on the sample drawer and closed. Counting was done automatically according to the selected count mode when the appropriate sample information was entered (The detector was operated in alpha and beta modes to obtain the count rates of alpha and beta in counts per minutes respectively). The activity concentration (C) in Becquerel's per Litre was calculated using the expression

$$\alpha_{A},\ \beta_{A}(Bq/l) = \frac{\alpha,\beta \text{ count rate (cpm)} - \text{BKG count rate (cpm)}}{\text{sample eff x sample size x detector eff}} \text{ x } 0.0167 \qquad 1.2$$

Determination of the Effective Dose Equivalent

The committed effective dose to an individual due to intake of alpha/beta emitting radionuclides from all the water samples over one year was estimated. Gross alpha and beta activity in natural water is mainly due to uranium and radium isotopes because thorium solubility is low (Osmond & Ivanoich, 1992). Principally, Ra-226 and occasionally Th-232, Po-210 or Ra-224 are the main contributors to the total alpha particle activity in water samples (Damla et al., 2006).
Dose Conversion Factor used to calculate the internal exposure by ingestion of radionuclides of radionuclides of radiological significance in drinking water for members of the public is 2.2 x10-3 mSv/Bq (DMP, 2010)
The Estimated additional Equivalent Effective Dose derived from water consumption was calculated using the procedure of (Onoja, 2011)

$$CED = A \text{ x } IW \text{ x } DCF \qquad 1.3$$

Where,
DCF = Dose conversion Factor (mSv/Bq), A = Activity (Bq/L)
IW = Intake of water for a person in one year (2L/day) = 730Litres, For an infant (≤1yr) in a year is 182.5L, For a child (1-12yrs) in a year is 365L and For teenagers/adults (>12yrs) in a year (730L).

Table 1: Gross Alpha and Beta Radioactivity Concentration (Bq/L) of Well and the Committed Effective Dose in some parts of Chikun and Kaduna South LGAs of Kaduna State.

S/N	Sample Location	Activity concentration in Bq/L		α-Annual Committed Effective Dose mSv/yr			Beta-Annual Committed Effective Dose mSv/yr		
		Alpha	Beta	≤1yr	1-12yrs	Teenager/Adult ≥12yrs	≤1yr	1-12yrs	Teenager/Adult ≥12yrs
1.	Kakuri	0.068± 0.042	0.068± 0.084	0.027	0.056	0.109	0.026	0.051	0.103
2.	Kudenda	0.225± 0.097	0.382± 0.197	0.090	0.181	0.361	0.153	0.307	0.613
3.	Nassarawa	0.413± 0.049	0.808± 0.100	0.166	0.334	0.066	0.324	0.649	1.298
4.	Ungwan Romi	0.097± 0.028	0.093± 0.064	0.039	0.078	0.156	0.037	0.075	0.149

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5.	Television	0.083± 0.043	0.283± 0.104	0.034	0.067	0.135	0.114	0.227	0.454
6.	Narayi	0.001± 0.003	0.006± 0.006	0.000	0.000	0.001	0.001	0.002	0.005
7.	Sabon Tasha	0.073± 0.049	0.118± 0.100	0.029	0.059	0.117	0.002	0.005	0.010
8.	Ungwan Boro	0.028± 0.017	0.006± 0.003	0.011	0.022	0.045	0.002	0.005	0.010
9.	Gonin Gora	0.090± 0.043	0.088± 0.083	0.036	0.072	0.145	0.035	0.071	0.141
10.	Barnawa	0.090± 0.045	0.099± 0.042	0.036	0.072	0.145	0.040	0.079	0.159
11.	Kamazou	0.038± 0.020	0.25± 0.039	0.015	0.031	0.061	0.010	0.020	0.040
12.	Mahuta	0.276± 0.097	0.300± 0.106	0.118	0.222	0.443	0.120	0.241	0.482
14.	Karji	0.013± 0.005	0.029± 0.011	0.005	0.010	0.021	0.116	0.023	0.047
15.	Bagado	0.149± 0.049	0.380± 0.064	0.060	0.120	0.239	0.153	0.305	0.610

Table 2: Gross Alpha and Beta Radioactivity Concentration in Borehole water and the Committed Effective Dose in some parts of Chikun and Kaduna South LGAs of Kaduna State

Sample ID	Sample Location	Activity Concentration in (Bq/L)		α-Annual Committed Effective Dose mSv/yr			Beta-Annual Committed Effective Dose mSv/yr		
		Alpha	Beta	≤1yr	1-12yrs	Teenager/ Adult ≥12yrs	≤1yr	1-12yrs	Teenager/Adult ≥12yrs
1.	Kakuri	0.020± 0.010	0.009± 0.018	0.008	0.016	0.032	0.004	0.007	0.014
2.	Kudenda	0.023± 0.012	0.081± 0.028	0.009	0.018	0.037	0.033	0.065	0.130
3.	Nassarawa	0.009± 0.003	0.011± 0.007	0.004	0.007	0.014	0.004	0.009	0.018
4.	Ungwan Romi	0.034± 0.005	0.066± 0.011	0.013	0.027	0.055	0.026	0.053	0.106
5.	Television	0.076± 0.020	0.112± 0.039	0.031	0.061	0.122	0.045	0.090	0.180
6.	Narayi	0.024± 0.014	0.042± 0.029	0.010	0.019	0.039	0.017	0.034	0.067
7.	Sabon Tasha	0.080± 0.025	0.087± 0.048	0.032	0.064	0.128	0.035	0.070	0.140
8.	Ungwan Boro	0.042± 0.025	0.080± 0.051	0.017	0.034	0.067	0.032	0.064	0.128
9.	Gonin Gora	0.042± 0.012	0.051± 0.022	0.017	0.034	0.067	0.020	0.041	0.082
10.	Barnawa	0.043±	0.054±	0.017	0.035	0.069	0.022	0.043	0.087

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		0.015	0.026						
11.	Kamazou	0.008± 0.003	0.021± 0.022	0.003	0.006	0.013	0.008	0.017	0.034
12.	Mahuta	0.060± 0.022	0.097± 0.034	0.024	0.048	0.096	0.039	0.078	0.156
13.	Bagado	0.040± 0.009	0.055± 0.018	0.016	0.032	0.064	0.022	0.044	0.088
14.	Karji	0.176± 0.039	0.338± 0.079	0.071	0.141	0.283	0.136	0.271	0.543

Tables 1 and 2 present the summary of the results of the gross Alpha and Beta Activity Concentrations and annual Committed Effective Dose (CED) to infants, children and adults due to intake of Borehole and well water in the study area. The results showed that the range of alpha activity varied from (0.0.008-0.276)Bq/L with a geometric mean of 0.048 Bq/l for borehole samples and (0.001-0.413) Bq/L with a geometric mean of 0.124 Bq/l for well water samples. The range of beta activity varied from (0.009-0.338) Bq/l with a geometric mean of 0.099 Bq/l for borehole water samples and (0.003-0.808) Bq/L with the geometric mean of 0.183 Bq/l for well water samples. All the samples show lower concentration below the WHO guideline value of 0.5Bq/l for alpha activity and 1.0Bq/l for beta activity.

The annual Committed Effective Dose (CED) to infants, children and adults were estimated. The results showed elevated values in some of the locations above the ICRP acceptable standard of 0.1mSv/yr. The mean values of CED due to intake of borehole water for alpha activity are 0.019mSv/yr, 0.039mSv/yr and 0.078mSv/yr for infants, children and adult respectively. For beta activity the values are 0.032mSv/yr, 0.063 mSv/yr. and 0.127 mSv/yr. In the well water samples, the mean CED value for alpha activity are 0.048 mSv/yr, 0.095 mSv/yr. and o.146 mSv/yr for infants, children and adults respectively and for beta activity the mean values are 0.081 mSv/yr., 0.147mSv/yr. and 0.294 mSv/yr respectively. These values show that the general public in some of these locations are committed to higher dose above the standard values and long term exposure could pose health threat

4. Conclusion

Our survey and study of gross alpha and beta radioactivity indicates that the water samples under investigation has a low concentration of both alpha and beta emitters and the activity was less than 0.5Bq/l for alpha and 1.0Bq/L for beta. We conclude that the radioactivity of water samples from all the selected locations is well below the limit set by the WHO. To the best of our knowledge, this is the first detailed study of gross alpha and gross beta activity concentration in well water samples in the study area. However, more research has to be done in order to identify the individual radionuclides contributing to the total gross radioactivity. This is a matter of further research work.

The estimated committed effective dose to the different age groups in some of the locations is above 0.1mSv/yr (ICRP, 1997) guideline value. Although immediate health implication for the present level, long term accumulated health side effects are highly probable in the affected communities. Thus, long term accumulated effects should be guided especially in the locations where elevated activity values are observed.

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