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Assessment of Radioactivity Concentration from Borehole and Well Water in Konshisha, Benue-Nigeria

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Abstract: ***In this study, radioactivity concentration of water samples collected from boreholes and wells in Konshisha, Benue State, Nigeria was measured and an average annual effective dose derived from drinking water ingestion was calculated. Ten (10) samples were collected for the purpose of this analysis. The samples were studied for gross alpha and beta radioactivity using a low background proportional counter (MPC-2000DP). The arithmetic mean for alpha activity was found to be 0.0298Bq/l and 0.1010Bq/l for borehole and well water samples, and that of beta activity was 0.0335Bq/l and 0.1941Bq/l for borehole and well water samples respectively. Results from this research showed that the gross alpha and beta activities measured from the water samples were below the WHO recommended values (0.5Bq/l for gross alpha and 1.0Bq/l for gross beta) and the annual effective dose derived from drinking water ingestion was at a safe level.***

Keywords*:* gross alpha, gross beta, drinking water, Konshisha

1. Introduction

Water is essential to human life as it's a major constituent of the human body. In developing countries, people rely on ground water mostly for drinking, bathing and other domestic use. One of the major challenge of civilization today is the supply of clean and abundant water [6]. Water source is from either rain or ground and its use cuts across industrial, agricultural and domestic.

Ground water is gotten from sources such as; wells, boreholes, rivers, lakes, dams and streams. Water quality can be affected by pollution of this ground water source either directly or indirectly. Water pollution in the environment occurs as a result of waste and sewage disposal. Also, use of fertilizers by farmers, improper disposal of motor oil, detergents and cleaners can leak into water sources and cause pollution [6]. These materials disposed often contain radioactive materials which significantly contribute to the background activity of the water bodies [4,6]. Estimation of the radiation dose distribution is vital in assessing the health risk to a population and serves as a reference for documenting changes in environmental radioactivity due to anthropogenic activities [9].

Water can be polluted through Naturally Occurring Radioactive Materials (NORMs) [11]. NORMs are materials containing radionuclides that exist in the natural environment, such as; Uranium and Thorium, and any of their radioactive decay products such as radium and radon, elements that have always been present in the earth's crust and within the tissues of all living species. Although the concentration of NORMs in most natural substances is low, almost any operation in which any material is extracted from the earth and processed can concentrate NORMs in product, by-product, residue or waste streams. Naturally occurring radionuclides in drinking water usually give radiation doses higher than those provided by artificially produced radionuclides and are therefore of greater concern [16]. It has been noted that radiation is part of the natural environment and it is estimated that about 80% of all human exposure comes from naturally occurring radioactive materials [2].

Humans are exposed to natural radiation by contamination of the food chain which occurs as a result of direct deposition of radio- nuclides on plant leaves, root uptake from contaminated soil, sediment or water [3], and from direct ingestion of contaminated water [10]. An important mode of transfer of radionuclides from environment to man is through radioactivity in drinking water [6]. Higher concentrations of radioactivity in environmental media are connected with risk to humans and higher radiation damage such as kidney damage, mutagenicity, leukemia as well as cancer of bladder, kidney, testis and lung [5]. Therefore, monitoring for radioactive materials is of primary importance for humans, organisms and for environmental protection [8]. Radionuclides are atoms with unstable nuclei. With the release of energy or radiation, the decay of unstable parent atoms produces daughter atoms. During radioactive decay, alpha particles, beta particles and gamma rays are types of radiation released. In measuring radioactivity in drinking water, gross alpha test is the first step to determining the level of radioactivity, because, it refers to the radioactivity of Thorium, Uranium, Radium, as well as Radon and daughters [13].

In view of determining quality of drinking water, a more practical approach is to use a screening procedure, where the total radioactivity present in the form of alpha and beta radiation is first determined, then the identity of specific radionuclides are also found if either of the screening level is exceeded [16]. The specific radionuclides should be identified and their individual activity concentrations measured if either of the screening levels is exceeded. This will allow the contribution from each radionuclide to the individual dose criterion, IDC (IDC of 0.1mSv/year represents a very low level of risk that is not expected to give rise to any detectable adverse health effect) to be calculated. In the WHO (World Health Organization) guidelines for drinking water quality the recommended screening levels for drinking-water are 0.5 BqL^{-1} for gross alpha and 1BqL^{-1} for gross beta so as to guarantee an exposure lower than 0.1 $mSvy^{-1}$. The United Nations Scientific Committee on the Effects of Atomic Radiation [14] has estimated that the global average annual dose per person from all sources of radiation in the environment is approximately 3.0mSv/year. Of this, 80% (2.4mSv) is due to naturally occurring sources of radiation, 19.6% (almost 0.6mSv) is due to the use of radiation for medical purpose and the remaining 0.4% (around 0.01mSv) is due to other sources of human-made radiation. Natural radionuclides can be found in water as a result of either natural process such as absorption from the soil or technological process involving naturally occurring radioactive materials such as; the mining and processing of mineral sands or phosphate fertilizer production. Drinking water in this area is obtained from sources such as hand dug wells and boreholes. These sources of drinking water pose great risk to human health due to contamination by pollutants which could be radioactive and consist of microorganisms, fertilizers and other toxic organic compounds [11]. The accumulation of radionuclides in the body can instigate the growth of lumps that can lead to any kind of cancer in the body no matter how small or long the dosage might be. The immune system might be weakened at a stage and might combine with other factors to instigate uncontrollable cells in the body (Cancer). Hence, the need for assessment of drinking water quality in Konshisha Local Government Area, Benue State, through measurement of activity concentration.

This study investigated the level of radioactivity concentration in drinking water sources. The work gives the level of radioactivity concentration. The results from this investigation gives us an estimate on the average annual dose per person from ingestion of drinking water from the study area and if found to be above reference levels, then, sensitization will be made to the appropriate authority for necessary action.

This work was carried out in the three (3) districts of Konshisha Local Government Area, Benue State. This study is limited to underground water sources (boreholes and hand dug wells) used by people for drinking, domestic activities and animal husbandry. Measurement of activity concentration and heavy metals concentration is done and annual effective dose for adults was calculated.

2. Materials and Methods

The materials used for the purpose of this research work are listed below;

MPC-2000Dual Phosphur Proportional Counter, Radiation Alert Meter, Beakers, Desiccator, Planchette, Petri-dish,Volumetric flask,Hot plate,HNO_3 (nitric acid), Acetone, 2litre Plastic Containers, Permanent Maker, Cello Tape.

Proportional Counter: A low background alpha and beta proportional counter, MPC-2000DP was used for counting of the gross alpha and beta radioactivity concentration. The equipment is a gasless proportional counter.

Radiation Alert Meter: The Inspector radiation survey meter has an internal GM detector and is microprocessor controlled. The Inspector Survey Meter is a general purpose Geiger counter for low levels of alpha, beta, gamma and x-rays. The digital readout, red count light and audible beep, provide instant indications of the radiation level. Other benefits include scaler function with an adjustable timer and external calibration controls.

Collection of Samples: A stratified random sampling method was adopted for the purpose of this work (Williams, 1977). A total of 10 samples spread across the three districts of Konshisha Local Government Area, Benue State were collected.

The sample container was rinsed three (3) times with the water to be collected, to minimize contamination from the original content of the sample container. There was an air space of about 2% left in the container of water collected to give room for thermal expansion. 10ml of HNO_3 (nitric acid) was added to the samples immediately after collection to minimize absorption on the walls of the container [7]. The samples were tightly covered and labeled and taken to the laboratory for analyses.

Measurement of Background Radiation: A Radiation Alert Meter was used in the cause of collecting samples to measure background radiations around the source of water collected for sampling. The meter was held 30cm from the source of water supply and the meter was put on after which, values were recorded concurrently for 30seconds and arithmetic mean calculated to get a value of background radiation from each drinking water source.

Counting and Analysis: Acetone (a cleansing agent) was used to wash the equipment needed for the sample preparation. A specified volume of each sample was poured into a beaker and evaporated on a hot plate at a regulated temperature below boiling point to 100 ml volume and then transferred to a clean dry Petri-dish. Few drops of Vinyl acetate were added to the solvent to aid even distribution on the planchette. The samples were then evaporated to dryness on hot plate. The residues were then transferred onto a clean, dry and previously weighed planchette and the difference between the mass of empty dish and that of the empty dish plus residue gave the mass of the residue. The residues were uniformly spread on the planchette by dropping a few drops of ethanol. The residues were allowed to dry in a desiccator and then ready for counting. The sample residue placed on a planchette was later placed on a sample carrier and closed for the purpose of gross alpha and beta counting [11].

The counting equipment is calibrated such that the counter efficiency, background and limit is known and specified [12]. The formulae for count rate and activity are shown below;

i. Count Rate (R)

$$R(\alpha,\beta) = \frac{Counts\ (\alpha,\beta)}{ElapsedMinutes} \qquad (2.1)$$

ii. Activity (A)

$$A\ (\alpha,\beta) = \frac{R(\alpha,\beta) - BKGCountrate}{SE \times SS \times DE} \times 0.0167 \qquad (2.2)$$

Where A is the Activity, R is the Count Rate, BKG is the background count rate of the detector, SE is the Sample Efficiency, SS is the Sample Size and DE is the Detector Efficiency.

Annual Effective Dose: According to WHO, a reference dose level of committed effective dose, equal to 0.1mSv per year ingestion of drinking water is recommended (WHO, 2011). To assess the health risk on the public from the study area, the annual effective dose (AED) associated with radiation exposure through ingestion of drinking water from boreholes and wells was calculated using the equation below;

$$AED = A \times V \times C \qquad (2.3)$$

Where AED is the annual effective dose, A is the activity of gross alpha, V is the annual ingested volume of drinking water for adults (730L/yr by WHO) and C is the dose coefficient for ingestion by adults (3.58×10^{-4}mSv/Bq for the gross alpha) [17].

3. Result

The water samples drawn from boreholes and hand-dug wells were studied and analyzed for radioactivity concentration.

Activity Measurements for Borehole and Well Water Samples: The activity for borehole and well water samples were measured and tabulated below;

Table 1.0: Result of Gross Alpha and Beta Activity Concentration in Boreholes

Sample ID	Alpha CONC. (Bq/L)	Beta CONC. (Bq/L)
MB2	0.04873±0.01184	0.04367±0.01546
MB4	0.01446±0.00709	0.02573±0.01022
IB1	BDL (Below Detection Limit)	0.06412±0.02119
SB1	0.01245±0.00860	0.03397±0.01308
SB5	0.07331±0.01688	BDL (Below Detection Limit)
Mean Value	0.02979±0.01110	0.03350±0.0149875

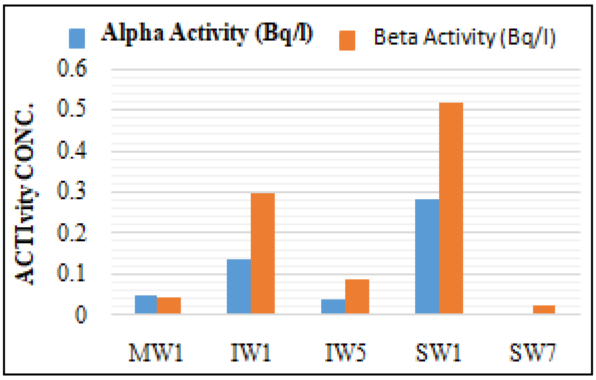

Figure 1: Gross Alpha and Beta Activity of Borehole Water Samples in Konshisha, Benue State.

Table 1.1: Results of Gross Alpha and Beta Activity Concentration in Wells

Sample ID	Alpha CONC. (Bq/L)	Beta CONC. (Bq/L)
MW1	0.05065±0.01207	0.04539±0.01576
IW1	0.13500±0.01621	0.29714±0.02409
IW5	0.03692±0.01333	0.08749±0.02001
SW1	0.28254±0.02267	0.51555±0.03188
SW7	BDL	0.02515±0.01073
Mean Value	0.101022±0.01607	0.194144±0.020494

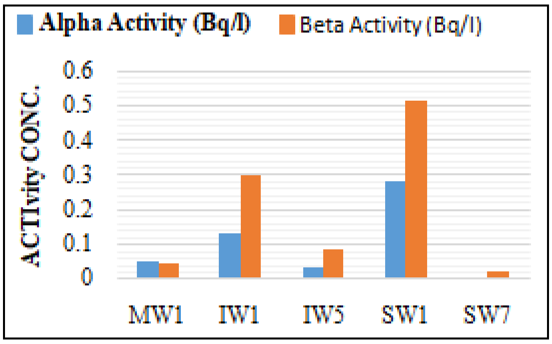

Figure 1.1: Gross Alpha and Beta Activity of Well Water Samples in Konshisha, Benue State.

Table 1.2: Comparison of Measured Activity in Konshisha and Other Places

	Alpha (Bq/l)	
Locations	Min.	Max.
Nassarawa	-	-
Zaria	0.035	0.01
Turkey	0.08	0.38
Makurdi	0.15	0.68
Konshisha	0.013	0.283
Locations	Beta (Bq/l)	
Nassarawa	0.020	7.620
Zaria	0.06	0.91
Turkey	0.12	3.47
Makurdi	0.37	1.22
Konshisha	0.025	0.516

Table 1.3: Background Radiation around Boreholes

Sample ID	Location	RAD (mSv/hr)	ICRP (mSv/hr)
MB1	Tse Iber1	0.012	0.1
MB2	Tse Iber2	0.011	0.1
MB3	Agberagba1	0.018	0.1
MB4	Agberagba2	0.012	0.1
MB5	Mbatsen1	0.014	0.1
MB6	Mbatsen2	0.011	0.1
IB1	Penda Yainjo	0.008	0.1
IB2	Mbanor 2	0.01	0.1
IB3	Mbake 2	0.008	0.1
IB4	GSS Korinya	0.011	0.1
IB5	Mbakugh	0.016	0.1
SB1	Gungul1	0.008	0.1
SB2	Mbakyase3	0.023	0.1
SB3	Mbakyase4	0.008	0.1
SB4	Mbagusa2	0.009	0.1
SB5	Gungul4	0.015	0.1
SB6	Iwarnyam2	0.013	0.1

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Table 1.3: Background Radiation around Wells

Sample ID	Location	RAD(mSv/hr)	ICRP (mSv/hr)
MW1	Tse Iber3	0.014	0.1
MW2	Tse Iber4	0.016	0.1
MW3	Agberagba3	0.014	0.1
MW4	Agberagba4	0.013	0.1
MW5	Mbatsen3	0.018	0.1
MW6	Mbatsen4	0.01	0.1
IW1	Mbake 1	0.008	0.1
IW2	Mbanor 1	0.016	0.1
IW3	Chia Agba	0.015	0.1
IW4	RCM Alyewan	0.011	0.1
IW5	Ikyer	0.014	0.1
SW1	Gungul2	0.011	0.1
SW2	Gungul3	0.016	0.1
SW3	Mbakyase1	0.013	0.1
SW4	Mbakyase2	0.012	0.1
SW5	Iwarnyam1	0.017	0.1
SW6	Mbagusa1	0.02	0.1
SW7	Ikurav	0.019	0.1

4. Discussion

The arithmetic mean for alpha activity was found to be 0.0298Bq/l and 0.1010Bq/l for borehole and hand-dug well water samples, and that of beta was 0.0335Bq/l and 0.1941Bq/l for borehole and well water samples respectively.

Figure 1.0 shows a chart of gross alpha and beta activity concentration for borehole water samples in Konshisha, Benue State. It is observed that values of gross alpha activity of samples were below the maximum contamination level in drinking water set by WHO of 0.5Bq/l. it was further observed that the measured beta activity of samples for all sample locations were also below the guidelines set by WHO of 1.0Bq/l.

Figure 1.1 shows a chart of gross alpha and beta activity concentration of well water samples in Konshisha, Benue State. It is observed from the measured results shown on the chart that the values of gross alpha activity are below the maximum contamination level of 0.5Bq/l set by WHO with concentration value for sample SW7 been beyond detection limit. It was further observed for beta activity concentration for all samples that values were also below maximum contamination level of 1.0Bq/l.

The alpha activity recorded in borehole water samples were lower than the activity recorded in well water samples. The difference might be from the absorption of radionuclides by the wall of the pipes unlike that of wells which was fetched directly from its source.

Comparison of Obtained Results with other research: The results obtained for radioactivity concentration analysis in water samples from Konshisha, Benue State were compared with results from other research works in different locations.

Table 1.2 shows the comparison between activity measured in Konshisha and other places such as Nassarawa, Zaria, Turkey and Makurdi. It was observed that the minimum measured alpha activity in Konshisha (0.013Bq/l) was lower than those of Makurdi (0.15Bq/l), Zaria (0.035Bq/l) and Turkey (0.08Bq/l). Also, the maximum measured alpha activity in Konshisha (0.283Bq/l) is higher than that of Zaria (0.01Bq/l) but lower than that of Makurdi (0.68Bq/l) and Turkey (0.38Bq/l).

Similar comparisons were made for measured beta activity; the measured minimum beta activity in Konshisha (0.025Bq/l) is higher than that of Nassarawa (0.020Bq/l) but lower than that of Makurdi (0.37Bq/l), Zaria (0.06Bq/l) and Turkey (0.12Bq/l). The measured maximum beta activity in Konshisha (0.516Bq/l) was lower than those of Makurdi (1.22Bq/l), Zaria (0.91Bq/l), Turkey (3.47Bq/l) and Nassarawa (7.620Bq/l) respectively.

Generally, one could say that the results obtained in Konshisha, Benue, Nigeria, are in agreement with other studies carried out in different locations within and outside the country. The higher value of gross beta activity could be as a result of the geological formation of the area whose land is highly invaded with phosphorus, a by-product of phosphate that has potassium-40 which is a beta and gamma emitter whose source is fertilizer used by farmers.

Also, using equation 2.3, the Annual Effective dose for adults was calculated. It was discovered that the AED for adults was 0.0078mSv/yr for borehole water samples and 0.0264mSv/yr for well water samples respectively. This gives values below the Individual Dose Criterion (IDC) value of 0.1mSv/yr recommended by WHO.

5. Conclusion

The gross alpha and beta activity concentration was measured using MPC-2000DP, a low background alpha and beta proportional counter stationed at Center for Energy Research and Training (CERT), Ahmadu Bello University, Zaria, Nigeria.

The gross alpha and beta activity concentration for boreholes ranged from BDL to 0.07331Bq/l and BDL to 0.06412Bq/l respectively while the activity for wells was found to range from BDL to 0.28254Bq/l and 0.02515 to 0.51555Bq/l for alpha and beta respectively. The arithmetic mean was computed and compared with maximum recommended level set by WHO (0.5Bq/L for gross alpha and 1Bq/l for gross beta) and also compared with other locations within and outside Nigeria. It can be said from the result that the gross alpha and beta activity concentrations in the study area were below reference level.

The Annual effective dose value calculated for borehole and hand-dug well water samples were 0.0078 and 0.0264mSv/yr respectively and were both below the Individual Dose Criterion value 0.1mSv/yr set by WHO. Thus, we can say the annual effective dose is at a safe level.

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