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Radiation Hazard Indices due to Intake of Radionuclides in Drinking Water in Gombe, Nigeria

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Abstract:*The water samples collected from local boreholes in Gombe metropolis, Nigeria have been evaluated for radiation hazard indices and excess lifetime cancer risk (ELCR). The samples were evaporated to dryness and obtained the residues which were later counted for gross alpha and beta activity using EURISYS MEASURE IN20 low Background multiple (eight) channels alpha and beta detector. It is a gas flow proportional counter. The mean activity obtained were 1.03 and 18.69 Bq/l for gross alpha and beta respectively. The radiation hazard indices and excess lifetime cancer risk due to intake of alpha radionuclides were computed and their mean values are 0.00027 mSv/yr, 0.00017 mSv/yr and 0.00094 for annual effective dose equivalent (AEDE), annual gonadal equivalent dose (AGED) and ELCR respectively while beta emitting radionuclides had the mean of 0.00489 mSv/yr, 0.06106 mSv/yr and 0.0171 for AEDE, AGED and ELCR respectively. Even though, the computed radiation hazard indices were less than the maximum permissible limit, care need to be taken to prevent excess accumulation of doses over time. Therefore, it could be concluded that further studies need to be carried out to ensure the safety of the general public in the sampling regions.*

Keywords:*Drinking water, Radioactivity, Radiation hazard indices, Excess lifetime cancer risk, Gombe State.*

I. Introduction

Water is necessity to man and his environment, the existence of radionuclides in drinking water causes a numerous health concerns to human and other life. Natural radioactivity comes from the primordial radionuclides, such as ^{40}K, ^{238}U, ^{232}Th and their decay products, which are present in trace levels in all ground formations. But anthropogenic activities continuously affecting level of these radionuclides in drinking water such as mining, milling, processing of uranium ores, mineral sands, production of fertilizers, drilling, transportation, burning of fossil fuels have been the factors that affect the levels of naturally occurring radioactive minerals concentrations in the environment. This enhancement of the radionuclides in the environment due to human activities might subsequently increase the level of radioactivity in surface and ground water sources[1, 2].All living things require water that is temperately pure, human and other life cannot survive if the water contains toxic chemicals or other harmful substances. Obviously, water wash-downs gases from atmosphere, dissolve minerals and soluble substances from the soil through it flows. As a results many contaminantsfind their way into it thus polluting the water[3]. Continuous intake of ground water with higher concentration of natural radionuclides may increase the radiological consequences and internal exposure to radiation instigated by the deterioration of the natural radionuclides taken into the body via ingestion as well as inhalation. The deterioration process may results in the discharge of various alpha and beta particles which are accountable for the total dose received from natural radioactivity as well as artificial radioactivity[4].

Radioactivity in drinking water is defined as the sum of gross alpha and gross beta activity. Gross alpha activity is the total activity of all alpha emitters such as 210Po, 226Ra, 238U, when radon has been removed while gross beta activity is the total activity of all beta emitters excluding tritium, 14C and other weak beta emitters. Radioactivity in drinking water is an important mode of transfer of radio nuclides from the environment to man. The most important natural radionuclides in drinking water are tritium, potassium-40, radium and their decay products, which are in essence beta and gamma emitters[5, 6].Some literatures reveal that the levels of some water constituents in drinking water abuse the action levels for various parameters, particularly, the level of natural radionuclides and trace metals. The continuous concern on the level of radioactivity in water anticipated for human intake has force the World Health Organization (WHO) and the European Union to institute maximum permissible concentrations for radionuclides and trace metals in drinking water bodies. The level of tritium and total indicative dose had been established in the European Community (EC) directive 98/83. The WHO guidelines for drinking water recommend an indirect assessment of committed effective dose by evaluating gross alpha and beta activity and observing the agreement to derived limit values; the recommended limit values are 0.5 Bq/l for gross alpha and 1.0 Bq/l for gross beta activity. The level of radioactivity in drinking water depends on many factors namely; the time intervals between sample collection, sample preparation and analysis, the radionuclides used in the calibration standards, the counting efficiency and so on[7].

There is a great concern for the quality of drinking water as it is critical to overall socio-economic development of any society and involves individuals, groups, government and non-governmental organizations. Since the public utilities are simply unable to cope with the demand for qualitative water, alternative source (s) of water must be devised. Consequently, the frustrated citizen of Gombe town in north-western Nigeria seek realistic solutions by digging local wells and boreholes as well as other water sources that are clean, clear, odorless, apparently pure and safe to drinking. Available statistics show that urban centers are better off than the rural areas in terms of access to safe drinking water sources. This is so perhaps where large population resides, as a result of that most of the national and international aids are directed to these centers. Moreover, the conditions are just as dreadful in the cities as in rural localities, since there is no boundary between the rural and cities centers. To justify the situation evidently, UNICEF in 2010 joint monitoring program for water supply and sanitation, reported that only 58% of Nigerian population has access to improved drinking water supply and only 32% have sanitation coverage. This translates into about 64 millions of Nigerians without access to improved drinking water and over 100 million people do not have access to improved sanitation, all out a total population of about 150 million[8, 9].The critical water shortage forced people of Gombe to drink untreated water obtained from surface and underground sources, thus, exposing themselves to hazardous chemicals and infectious agents. This has drawn the attention of many researchers to examine the radioactivity, physicochemical and microbial characteristics of water sources[8]. Assessing the radiological impact to the general public can be carried out by measuring thelevel natural radioactivity in our environment. The level of radionuclides in drinking water depends on the source of the water and anthropogenic activity in the area. The activities that affect the level of radioactivity in water include the geological activity, tin mining, industrial activity and use of fertilizers in agriculture[10].The knowledge of the radioactivity concentration in drinking water provides an opportunity to evaluate any possible health hazards to human and the environment. Therefore, the objectives of this study are to investigate the gross alpha and beta activity concentration in drinking water and to estimate the radiation hazard indices such as Annual Effective Dose Equivalent (AEDE), Annual Gonadal Equivalent Dose (AGED) and Excess Lifetime Cancer Risk (ELCR) in the study locations. This work will ascertain the quality of the local borehole water sources in Gombe metropolis. The study will also provide further information in the monitoring of environmental radioactivity.

II. Research Methodology

2.1 Sampling Frame

The area under study is Gombe metropolis and limited to underground water sources drawn from local boreholes used by the people of Gombe metropolis for drinking, domestic's activities, irrigation and animal husbandry. A stratified random sampling was adopted.

2.2 Sampling Procedure

The sampling procedure involves 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. One sample was collected per sampling point which gives the total of 8 samples, air space of about 2% of the container was left for each sample to give room for thermal expansion. The sample containers were marked indicating one liter corresponding to the air gap. A concentrated nitric acid of 10 ml volume was added to each sample at the sampling point to reduce the pH and to minimize precipitation and absorption on the container walls. The samples were tightly covered with container cover and masking tape and kept in the laboratory for analyses.

Fig. 1: Map of Gombe Metropolis and Within the Map Bold dots indicates the Sampling Points[11].

Figure 1: shows the map of Gombe metropolis and various sampling points which were marked on the figure using bold dots. The sample sites were selected based on the population and highly dependence on local water boreholes for drinking and other domestic activities. The area under study includes: Yalan-guruza, Manawachi, Gabukka, Bolari, Jekada-fari, Tudun-wada, Malam-inna and Herwagana.

2.3 Sample Preparation

The calculated volume of each sample was measured into a beaker and evaporated on a hot plate to almost dryness and transferred to a clean dry planchet, the samples were still taken back to the hot plate to complete the evaporation until a dry residues were obtained. Hence, the residues obtained were then transferred onto to another clean, dry and previously weighed planchet. The difference between the mass of empty planchet and that of the empty planchet plus residue gives the mass of the residue. The residue was uniformly spread and stick on the planchet by dropping a few drops of vinyl acetate. The residue was allowed to dry and then covered with Mylar film ready for counting.

$$\text{Sampling efficiency} = \frac{(w_2 - w_1) - (w_3 - w_1)}{w_2 - w_1} \times 100\% \quad (1)$$

The sampling efficiency was obtained by measuring the weight of the empty beaker, w_1, and weight of empty beaker plus the sample obtained after evaporation, w_2, the difference between w_2 and w_1 gives the total weight of the sample obtained after evaporation. The sample is then transferred to a planchet and the weight of the beaker was measured again, w_3. The difference between w_3 and w_1 gives the total weight of sample loss from the beaker.

2.4 Counting and Analysis

The gross alpha and beta counting equipment used in this study is a EURISYS MEASURE IN20 low Background multiple (eight) channels alpha and beta detector. It is a gas flow proportional counter. The counting gas is an argon-methane mixture at the ratio of 90% and 10% respectively. The protocol involves entering preset time, counting voltage and number of counting cycles. Also the necessary parameters to be entered are the counter characteristics (efficiency and background), volume of sample used and sample efficiency. Results are displayed as raw count, (count/min) count rate, activity, and standard deviation. Acquisition was made in α-only and β (+α) mode. The selection of mode of counting was arbitrary[11]. The calculation formulae for count rate, activity and other parameters for a given sample are shown below:

$$\text{Rate } (\alpha,\beta) = \frac{Raw\ (\alpha,\beta)\ Count}{CountTime} \quad (2)$$

In all modes except mode alpha then beta:

$$\text{Activity } (\alpha,\beta) = \frac{Rate\ (\alpha,\beta) - Bgd\ \ (\alpha,\beta)}{Sample\ Efficiency\ \times ChannelEfficiency\ \ \times Volume} \times \frac{1}{60} \quad (3)$$

The statistical precision was calculated for each channel, on each measurement and it depends only on the preset count whose value is declared indirectly. Assume N measurements were made during a time T, the average is given by $x = \frac{\sum xi}{N}$, and standard deviation (σ). To determine the radioactivity measured, statistical analysis employed are estimation of the central tendencies and correlation analysis[12]. Pearson regression coefficient (r) and the geometric mean are given in equations (6) and (7) below:

$$\sigma = \sqrt{\left[\frac{R_s}{t_s} + \frac{R_b}{t_b}\right]} \quad (4)$$

Where:
R_s = Sample counting rate
R_b= Background counting rate
t_s= Sample counting time
t_b = Background counting time

$$CR = 1.96\sigma \quad (5)$$

Where CR = Counting Error

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \quad (6)$$

$$\text{Geometric Mean (GM)} = \sqrt[n]{(x_1, x_2 \ldots x_n)} \quad (7)$$

All statistical analysis were carried out using Microsoft Excel.

2.5 Radiation Hazard Indices Calculation

2.5.1 Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent to an individual due to consumption of alpha emitting radionuclides and beta emitting radionuclides from the water samples were estimated using the relation below[3]:

$$AEDE = MA \times WI \times IDEF \quad (8)$$

Where AEDE = Annual Effective Dose Equivalent, MA = Measured Activity in Bq/l, IW = intake water in liters, IDEF = Ingestion dose equivalent factor given by 3.58×10^{-7}mSv/Bq

- Annual water consumption for teenagers/adults is 730 liter/year

2.5.2 Annual Gonadal Equivalent Dose (AGED)

The AGED is a measure of the threat and stomach from exposed to a particular level of radiation.
The AGED for members of the public for a given activity is given by[4]

$$AGED = \frac{AEDE}{W_R \times W_T} \quad (9)$$

Where W_R= Radiation weighing factor, for alpha activity is equal to 20 and for beta activity is equal to 1 while W_T = Tissue weighing factor, for gonads is equal to 0.08[13]

2.6 Excess Lifetime Cancer Risk (ELCR)

This deals with the probability of developing cancer over a lifetime at a given exposure level considering 70 years as the average duration of life for human beings. It is given by[4]

$$ELCR = AEDE \times DL \times RF \quad (10)$$

Where AEDE = Annual Effective Dose Equivalent, DL = Average Duration of Life (70 years), RF = Risk Factor (Sv^{-1}) for stochastic effects ICRP used RF as 0.05 for public.

III. Results And Discussion

The drinking water collected from local boreholes in Gombe town were studied and analyzed using EURISYS MEASURE IN20 low Background multiple (eight) channels alpha and beta detector. The mean activity obtained were 1.03 and 18.69 Bq/l for gross alpha and beta respectively.

3.1 Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent (AEDE) due to intake of alpha and beta emitting radionuclides are presented in the figures 1 and 2 respectively:

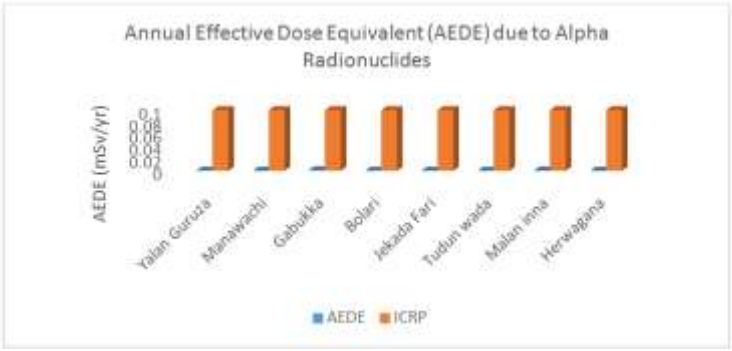

Fig. 1: Annual Effective Dose Equivalent due to Alpha Radionuclides and WHO Standard

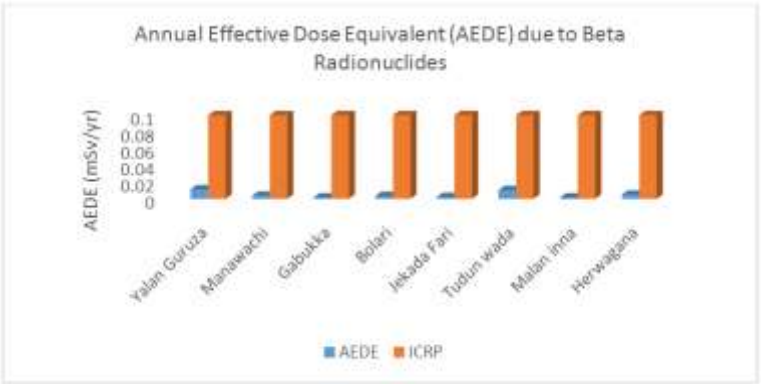

Fig. 2: Annual Effective Dose Equivalent due to Beta Radionuclides and ICRP Standard

Figures 1 and 2: show the comparison between the annual effective dose equivalent due to alpha and beta emitting radionuclides and maximum permissible limit set by International Commission on Radiological Protection (ICRP). It was observed that all the sample locations were below the maximum permissible limit set by ICRP.

3.2 Annual Gonadal Equivalent Dose due to Alpha and Beta Radionuclides

The annual gonadal equivalent dose (AGED) due to intake of alpha and beta emitting radionuclides and comparison with ICRP standard are presented in the figures 3 and 4 below.

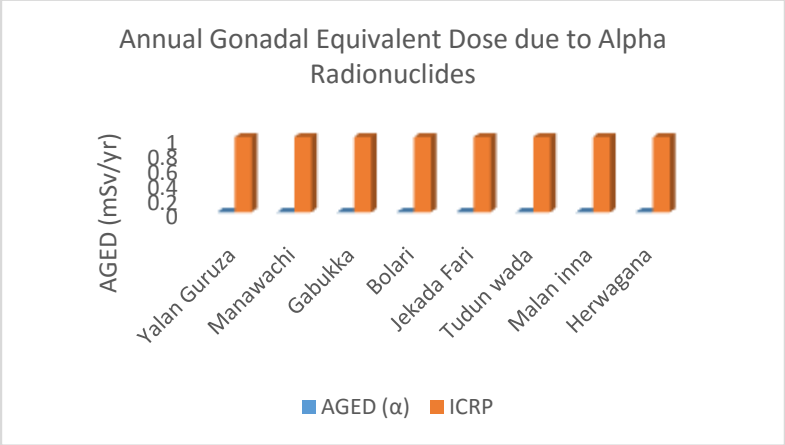

Fig. 3: Annual Gonadal Equivalent Dose due to Alpha Radionuclides and ICRP Standard

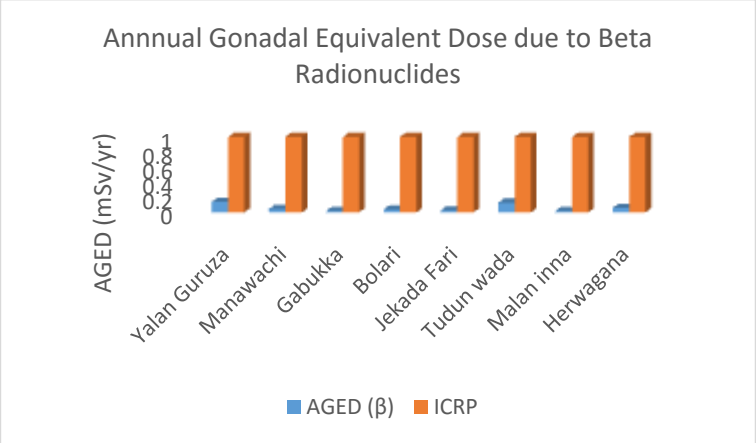

Fig. 4: Annual Gonadal Equivalent Dose due to Beta Radionuclides and ICRP Standard

Figure 3 and 4: show the annual gonadal equivalent dose due to intake of alpha and beta emitting radionuclides in drinking water collected from local boreholes in Gombe metropolis. It was observed that all the locations were below the maximum permissible limit set by ICRP as in the figures above.

3.3 Excess Lifetime Cancer Risk (ELCR)

The excess lifetime cancer risk were estimated using equation (10) and compared with the world average value (WAV) as shown in the figures 5 and 6 below:

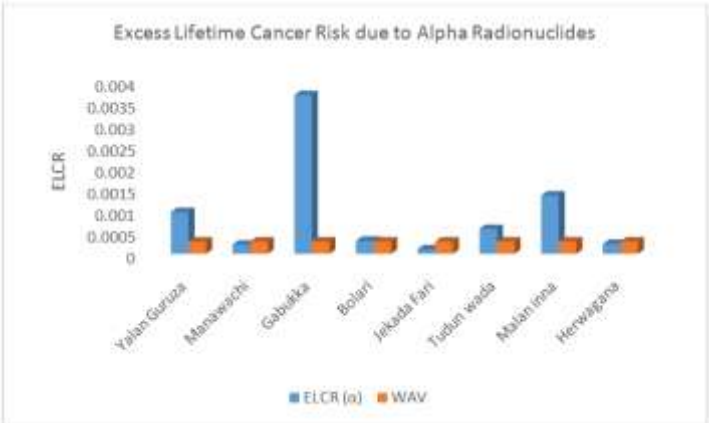

Fig. 5: Excess Lifetime Cancer Risk due to Alpha Radionuclides and World Average Value

Figure 5: shows the comparison of the estimated ELCR due to intake of alpha emitting radionuclides and world average value (WAV) from drinking water collected in Gombe metropolis, Nigeria. It was observed that only three locations including Manawachi, Jekadafari and Herwagana were below the WAV while the rest of the locations were above the WAV. The maximum and minimum ELCR were observed at Gabukka and Jekadafari of values 0.00371 and 0.00011 respectively.

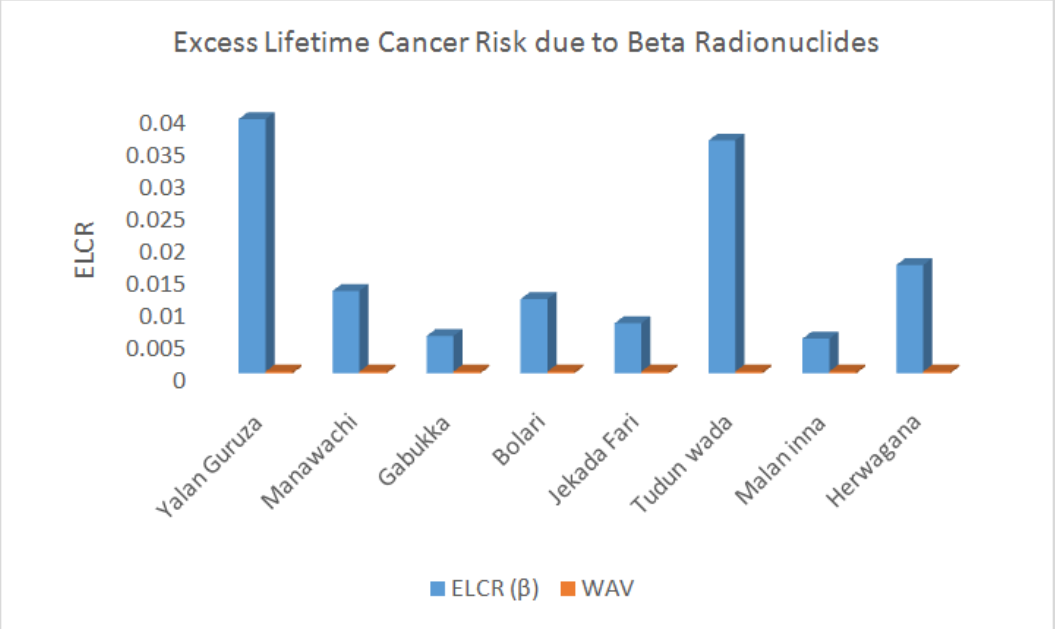

Fig. 6: Excess Lifetime Cancer Risk due to Beta Radionuclides and World Average Value

Figure 6: shows the comparison of the estimated ELCR due to intake of beta emitting radionuclides and world average value (WAV) from drinking water collected in Gombe metropolis, Nigeria. It was observed that all the locations were extremely exceeded the WAV. The maximum and minimum ELCR observed at Yalanguruza and Malan inna of values 0.03977 and 0.00542 respectively.

Table 1: Comparison of AEDE, AGED and ELCR Obtained with the one Estimated in Plateau State[4]

Locations	AEDE (α)	AGED (α)	ELCR (α)
Plateau	0.157	0.039	0.000548
Gombe	0.00027	0.00017	0.00094
Locations	AEDE (β)	AGED (β)	ELCR (β)
Plateau	0.134	0.668	0.000468
Gombe	0.00489	0.06106	0.0171

Table 1: shows the comparison of the result obtained in Gombe with one estimated in Plateau State. The estimated AEDE and AGED due to alpha emitting radionuclides in Gombewere extremely smaller than the one estimated in Plateau while ELCR estimated was greater than the one estimated in Plateau. The estimated AEDE and AGED due to intake of beta emitting radionuclides in Gombe were smaller than the one estimated in Plateau, similarly, the ELCR computed in Gombe was greater than the one computed in Plateau.

IV. Conclusion

The radioactivity concentration and radiation hazard indices due to intake of radionuclides had been evaluated using EURISYS MEASURE IN20 low Background multiple (eight) channels alpha and beta detector. The mean activity measured were 1.03 and 18.69 Bq/l for gross alpha and beta respectively. The radiation hazard indices due to alpha emitting radionuclides were computed and varied from 0.00003 to 0.00106mSv/yr and 0.00002 to 0.00066 mSv/yr for AEDE and AGED respectively while the radiation hazard indices due to beta emitting radionuclides varied from 0.00155 to 0.01136 mSv/yr and 0.01937 to 0.14204 mSv/yr for AEDE and AGED respectively. Further studies were also carried out to determine the excess lifetime cancer risk (ELCR). The result obtained due to alpha and beta emitting radionuclides ranged from 0.00011 to 0.00371 and 0.00542 to 0.03977 respectively. It was further observed that results obtained for radiation hazard indices were

below the maximum permissible limit set by ICRP of values 0.1 and 1.0 mSv/yr for AEDE and AGED respectively. However, the ELCR results obtained indicated that most of the locations were above the world average value of 0.29×10^{-3}. Even though, the computed radiation indices were less than the maximum permissible limit, care need to be taken to prevent excess accumulation of doses over time. Therefore, it could be concluded that further studies need to be carried out to ensure the safety of the general public in the sampling regions.

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