RADIOACTIVITY LEVEL OF DRILLED WELL WATER ACROSS SELECTED CITIES IN ONDO AND EKITI STATES, SOUTHWESTERN NIGERIA AND ITS RADIOLOGICAL IMPLICATIONS.

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Abstract

The increasing health effects of nuclear radiation occasioned by the enhanced human activities in the environment necessitated the need for constant evaluation and assessment of radiological impact on the general populace within a confined developmental area. In response to this need, Ten (10) drilled well water samples were collected from various cities distributed across Ondo and Ekiti states and analyzed for gamma-emitting radiations using n-type coaxial High Purity Germanium Detector (HPGe) detector: with ORTEC multichannel Analyzer and Maestro-32 for spectrum analysis and processing. The measured activity concentrations ranged from 2.25 ± 0.39 to 35.61 ± 6.22 Bq l^{-1} ^{232}Th, 45.42 ± 2.98 to 467.61 ± 31.69 Bq l^{-1} ^{40}K, 7.08 ± 1.71 to 56.68 ± 12.50 Bq l^{-1} ^{226}Ra and 1.66 ± 0.46 to 25.55 ± 5.76 Bq l^{-1} ^{232}Th, 41.50 ± 2.89 to 558.82 ± 31.69 Bq l^{-1} ^{40}K, 4.90 ± 1.08 to 54.18 ± 13.34 Bq l^{-1} ^{226}Ra respectively for Ondo and Ekiti states. The age dependent annual effective dose and committed effective dose were calculated using the measured activity concentration and ingested dose conversion factor for three different age groups (i.e 0-1yrs, 7-12yrs and $\geq$ 17yrs). The total annual effective dose was found to be above the international Commission for Radiation Protection (ICRP) and the World Health Organization (WHO) values. Hence, the drilled well are recommended for water screening to remove radionuclides.

Key Words: Dug well, HPGe, Annual effective dose, committed effective dose.[1]

1.0 Introduction

The quest for quality water supply has been a challenge to many public and private water suppliers in spite of advances in science and technology. Water purity is directly linked to the level of its contaminants i.e. physical, chemical, biological etc [1]. Diseases associated with water are also linked to the presence of these contaminants. Bottled and sachet water are usually labelled in terms of its chemical composition but no account of the level of its biological and physical contaminants. Water supply has been found to contain some physical contaminants such as ^{232}Th, ^{226}Ra, and the non-decay series ^{40}K which pose serious health risk for human use. ^{226}Ra and ^{228}Ra are known to be very hazardous [2]. When ingested into the human system, radium behaves like calcium and its accumulation over a long time can result into bone or sinus cancer [3]. Higher concentrations of radioactivity in environmental media are connected with risk of health challenges to humans such as kidney damage, mutagenicity, leukemia as well as cancer of bladder, kidney, testis and lung [4]. While many developed nations of the world have set up agencies to regulate its water supply, it is not certain whether developing nations have toed this line [5].

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There is need therefore to assess the physical contaminants and or radionuclides present in various water sources and ascertain whether this is above or below the minimum permissible dose due to exposure. The World Health Organization (WHO) and the United States Environmental Protection Agency (EPA) have issued regulations and guidelines on the quality of drinking water [5]. Water supply generally whether in the form of dug or drilled well is sourced from the soil, which is the product of weathering from the parent rock. The distribution of radionuclides in any water supply is a function of the local geology of the parent rock or soil [6, 7]

[8] Investigated the physical parameters and the total radioactivity concentrations in some borehole water in Zaria, Northwestern Nigeria. They noted that some of the samples met the requirements of good water supply, while some had the alpha and beta radioactive concentrations above the set values recommended by the World Health Organization and the US Environmental Protection Agency (EPA). [9] also assessed the radionuclides concentrations in some public water in Markudi Metropolis of Benue State, Nigeria using a Geiger Muller Counter. It was reported that there exist highest radiation concentration in Borehole water ranging from 2.86×10^{-1} Bq to 3.69×10^{-1} Bq and the least in bottled water in the range 0.55×10^{-1} – 0.77×10^{-1} Bq. It is evident that physical contaminant in drinking water should not be under estimated as it poses a great risk to human health.

Dug and drilled well are the major sources water available for human use in town and cities of Nigeria. Hence, this work is intend to assess the level of physical contaminants (i.e. radionuclides) present in Eleven drilled well distributed across selected cities in Ondo (5^0 48'N, 4^0 45'E) and Ekiti States (8^0 15'N, 6^0 05'É), South Western Nigeria using high resolution gamma ray Spectrometry. The age dependent annual effective dose accrued to individual due to exposure will also be calculated.

2.0 Material and Method

2.1 `Collection and Preparation of Samples

Water samples were collected from the selected well using very clean container [fetcher] whereby the usual manual procedure for collecting water from wells which involved the dipping of the containers which has been firmly tied to a rope long enough to reach the water level in the well was employed. The collected water was then emptied into a one litre keg and labeled based on the alphabet ascribed to each city. Table 2.1 gives the samples code and interpretation. Water samples collected from the various dug wells across the two states using a one liter plastic keg were acidified with 11M of HCl at the rate of 10ml per liter of samples as soon as possible, to avoid absorption of radionuclide onto the wall of container [10]. Marinelli beaker of 1L volume capacity previously washed, rinsed with a dilute sulphuric acid (H_2SO_4) and dried to avoid contamination was filled with sample from the container used for sampling. This was later sealed for at least four weeks to ensure that no loss of radon and to achieve secular equilibrium between the daughters and the parents nuclides.

2.2 Sample Analysis

The activity Concentrations of the dug well water samples were measured using an N-type coaxial HPGe gamma-ray detector at the laboratory of Ghana Atomic Energy Commission Accra with ORTEC Multichannel Analyzer (MCA) and MAESTRO-32 evaluation software for spectrum acquisition and processing. The relative efficiency of the detector was 28.5 % with energy resolution of 1.8 keV at gamma ray energy of 1332 keV of ^{60}Co. The gamma lines 609.31 and 1764.49 keV of ^{214}Bi were used to determine ^{226}Ra. The gamma lines 583.19 of ^{208}Tl were used to determine ^{232}Th and that of ^{40}K was determined from the gamma line of 1460.83 keV. The samples were counted for 18,000 seconds (5 hours).

The energy and efficiency calibrations were performed using mixed radionuclide calibration standard in the form of solid water, serial number NW 146 A with approximate volume 1000 mL and density 1.0 gcm^{-3} in a 1.0 L Marinelli beaker. The standard was supplied by Deutscher Kalibrierdienst (DKD-3), QSA Global GmBH, Germany. Background measurements were made for the same period. Density corrections were also made where appropriate.

The specific activity concentrations (A_{sp}) of ^{226}Ra, ^{232}Th, and ^{40}K were determined in Bq l^{-1} for the water samples using the following expression [11, 12, 13] after decay correction.

$$A_{sp} = \frac{N_{sam}}{P_E.\varepsilon.T_c.M} \quad (1)$$

where; N_{sam} is net counts of the radionuclide in the sample, P_E is gamma ray emission probability (gamma yield), ε is total counting efficiency of the detector system, T_c is sample counting time and M is mass or weight of the Sample.

The specific activity obtained using equation (1) coupled with appropriate dose conversion factors form the basis for the evaluation of the radiological health hazards posed by the analysed samples from the study area.

2.2 **Calculation of Annual Effective Dose and Committed Effective Dose**

Estimation of annual effective dose E_d (Sv/y) to an individual due to the ingestion of the natural radionuclides present in the dug well water samples was carried out using the following relation by [14].

$$E_d = A_c A_i C_f \quad (2)$$

where A_c is the activity concentration of the radionuclide in the dug well (Bq/l), A_i is the consumption per annum or annual intake of drinking water and C_f is the ingested dose conversion factor for radionuclides (Sv/Bq). The ingested dose conversion factor and the consumption per annum vary with both radionuclides and the age of the individual ingesting the radionuclides. The ingested dose Conversion factor C_f used for ^{40}K, ^{232}Th and ^{226}Ra in this work and the corresponding consumption per annum in l y^{-1} are (6.2×10^{-8}, 1.3×10^{-8}, 6.2×10^{-9}) , (4.6×10^{-6}, 2.9×10^{-7}, 2.3×10^{-7}), (4.7×10^{-6}, 8.0×10^{-7}, 2.8×10^{-7}) and (2.0×10^{2}, 3.5×10^{2}, 7.3×10^{2}) respectively for the three different age group [15, 16].The total effective dose D (Sv/y) to an individual was established by summing contributions from all radionuclides present in the water samples, i.e.

$$D = \sum A_c A_i C_f \quad (3)$$

The annual effective dose values were calculated for three different age groups (0-1yr, 7-12yr, >17yr) i .e babies, Children and Adult. The committed effective dose C_d , which is a measure of the total effective dose received over an average life time of 50 years was calculated for the age >17 years due to the ingestion of radionuclides using the relation

$$C_d = 50 \times D \quad (4)$$

Where D is the total effective dose to an individual

3.0 Result and Discussion

The measured activity concentration of ^{232}Th, ^{40}K and ^{226}Ra in the drilled well water samples of the two states revealed that ^{137}Cs was not detected in all the samples. The activity concentrations were found to be within the range 2.25 ± 0.39 to 35.61 ± 6.22 Bq l^{-1} ^{232}Th, 45.42 ± 2.98 to 467.61 ± 31.69 Bq l^{-1} ^{40}K, 7.08 $\pm$ 1.71 to 56.68 ± 12.50 Bq l^{-1} ^{226}Ra for Ondo state drilled well water samples. While Ekiti state drilled

well water samples lie within the range 1.66 ± 0.46 to 25.55 ± 5.76 Bq l^{-1} ^{232}Th, 41.50 ± 2.89 to 558.82 ± 31.69 Bq l^{-1} ^{40}K, 4.90 ± 1.08 to 54.18 ± 13.34 Bq l^{-1} ^{226}Ra . ^{40}K had the highest concentration, followed by ^{226}Ra and the least activity was found in ^{232}Th for the two states. The highest activity concentration of the three radionuclides (^{232}Th, ^{40}K and ^{226}Ra) was recorded in the sample taken from Erinmope-Ekiti and the least was found in the sample taken from Ise-Ekiti with the exception of Ado-Ekiti that had the least activity concentration for ^{40}K. Ondo state had its highest concentration in the sample taken from Ikare-Akoko and the least concentrations, for ^{232}Th, ^{40}K and ^{226}Ra in the sample taken from Owo, Ondo and Okitipupa . The mean activity concentrations of ^{232}Th, ^{40}K and ^{226}Ra are 8.43 ± 1.47 Bq/l, 129.67 ± 8.27 Bq/l, 15.83 ± 3.39 Bq/l and 7.25 ± 1.69 Bq/l, 156.57 ± 9.05 Bq/l, 15.92 ± 3.68 Bq/l respectively for both Ondo and Ekiti drilled Well water samples. The result obtained in both cases for ^{226}Ra exceeds the recommended limits of 1.00 Bq/l [10] and 0.185 Bq/l [17]. This result corroborates the 7.15 ± 6.94 Bq l^{-1} reported for ^{226}Ra by [17] in private dug well in Akure Southwestern Nigeria. The mean measured activity concentrations of ^{232}Th and ^{40}K for Ondo state (8.43 ± 1.47 Bq/l and 129.67 ± 8.27 Bq/l) and Ekiti state (7.25 ± 1.69 Bq/l and 156.57 ± 9.05 Bq/l) were above the values reported in other part of the world.

The age dependent annual effective dose was calculated using using equation (2) and the total annual effective dose using equation (3). The annual effective dose and the total annual effective dose were calculated. Generally, the mean total annual effective dose for each of the age groups (Babies 0-1y, Children 7-12y, and Adult >17y) resulting from the radionuclides in the drilled Well water samples of both Ondo and Ekiti States is (26.91 ± 5.11, 6.52 ± 1.25, 6.56 ± 1.29) mSv/y and (23.58 ± 5.12, 5.90 ± 1.24, 5.18 ± 1.08) mSv/y respectively. This is above the ICRP and WHO recommended limits of 1mSv/y and 0.1mSv/y respectively. Total Annual effective dose resulting from the ingestion of the three radionuclides (i.e. ^{232}Th, ^{40}K, ^{226}Ra) among the three age groups ranged from 6.65 ± 1.48 to 81.40 ± 18.20 mSv/y, 1.73 ± 0.36 to 20.30 ± 4.46 mSv/y, 1.47 ± 0.31 to 17.90 ± 3.84 mSv/y and 10.50 ± 1.77 to 91.80 ± 17.90 mSv/y, 2.68 ± 0.44 to 21.60 ± 4.28 mSv/y, 2.36 ± 0.38 to 19.70 ± 3.74 mSv/y respectively for Ekiti and Ondo states. In both states, Babies (i.e. 0-1y) are most Susceptible to radiation followed by Children (i.e. 7-12y) and the least was found in Adult (> 17y). The variation of total annual effective dose and the three age groups considered is shown in figures 1.0 and figure 2.0 for the sampled drilled well across the two states. In all the samples taken from Ondo state the annual effective dose ingested from ^{226}Ra is above the recommended limits of 1.0 mSv/y by ICRP for all ages. The annual effective dose resulting from the ingestion of ^{232}Th in the drilled well water samples of Ondo State is below the recommended limits of 1.0 mSv/y set by ICRP except for the Babies age group (0-1 y) and the adult group (>17y) only in the sample taken from Okitipupa. Annual effective dose resulting from the ingestion of ^{40}K in the dug well water samples of Ondo state is below the recommended limits of 1.0 mSv/y set by ICRP for the three age groups considered in all the samples with the exception of the one taken from Ikare-Akoko. Similarly, in Ekiti State the annual effective dose resulting from the ingestion of ^{232}Th in its dug well water samples is above the recommended limits of 1.0 mSv/y in all the drilled water samples taken for the babies age group (0-1y) and below in all the other age groups (children and Adult). The only exception is the sample taken from Erinmope for the Children and Adult groups. Annual effective dose resulting from the ingestion of ^{40}K in the drilled well of Ekiti is above the recommended limits of 1.0 mSv/y set by ICRP for the age groups considered in Erinmope Ekiti drilled well water samples and below for all the other samples. The ingestion of ^{226}Ra and its annual effective dose from the drilled well of Ekiti State is above the limits set by ICRP of 1.0 mSv/y for all the samples and for the age groups considered. It is however within the limit of 1.0 mSv/y in the sample taken from Ise-Ekiti for the adult and Children age groups. Hence the drilled well waters from Ikare –Akoko in Ondo state and that of Erinmope Ekiti should be screened for ^{226}Ra, because its accumulation in the bone of Babies and Children may result in bone or Sinus Cancer. The high activity concentrations of ^{226}Ra in Ikare-Akoko drilled well water samples from Ondo State may be as result of emerging industries coupled with local geology and that of Erinmope Ekiti may be as a result of its closeness to Guinea Savannah where the soil type (Clay-sandy) needs huge application of Potash fertilizer to grow crops and the presence of granite rock in the terrain. This result is

in tandem with the findings of [18, 19, 20]. The committed effective dose which is a measure of the radiation received over a lifetime of 50y is also presented for the Adult age group.

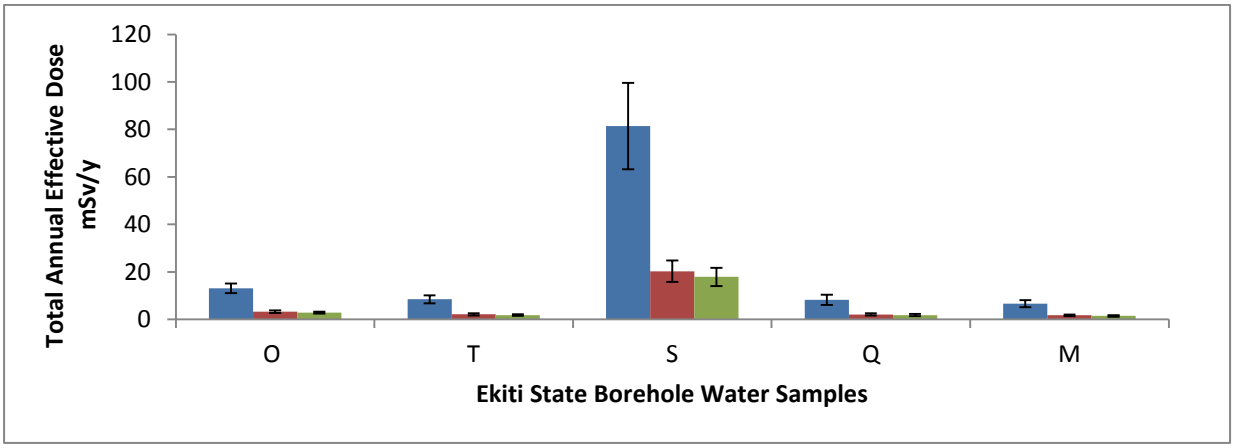

Figure 1.0: Total annual Effective Dose D (Sv/yr) variation in the dug well water samples of Ekiti State

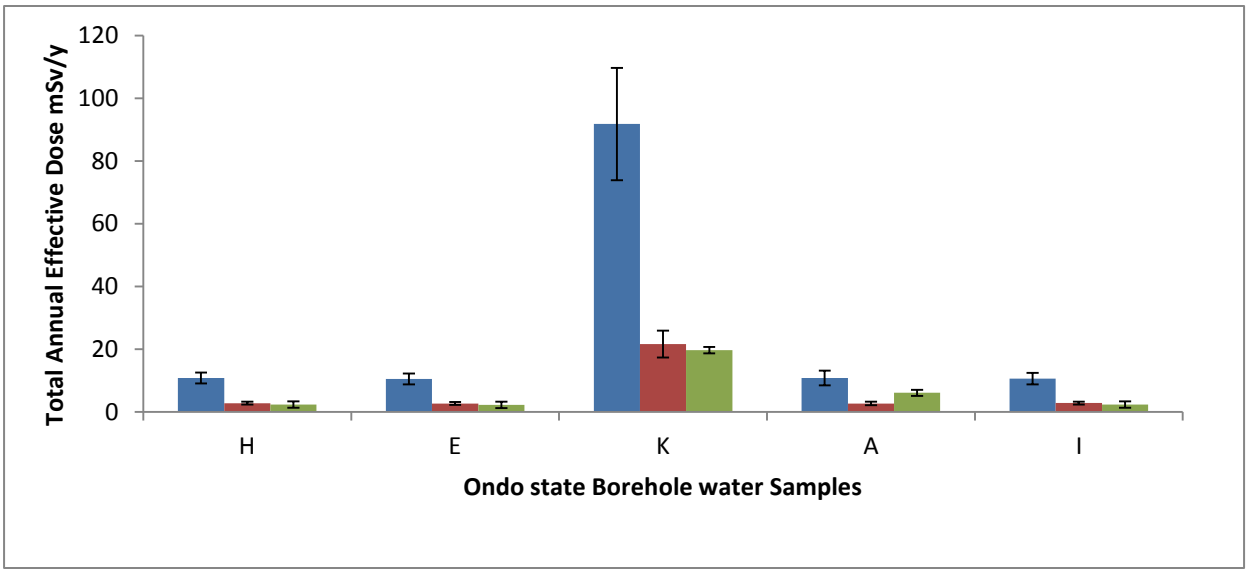

Figure 2.0: Total annual Effective Dose (Sv/yr) in the dug well water Samples of Ondo State

4.0 Conclusion

The activity concentrations of ^{232}Th, ^{40}K, and ^{226}Ra in the dug well water samples distributed across ten (10) notable Cities in Ondo and Ekiti States had been determined. The activity concentration of gamma emitters in the drilled well water ranged from 2.25± 0.39 to 35.61± 6.22 Bq l^{-1} ^{232}Th, 45.42± 2.98 to 467.61± 31.69 Bq l^{-1} ^{40}K, 7.08± 1.71 to 56.68± 12.50 Bq l^{-1} ^{226}Ra and 1.66± 0.46 to 25.55± 5.76 Bq l^{-1} ^{232}Th, 41.50± 2.89 to 558.82± 31.69 Bq l^{-1} ^{40}K, 4.90± 1.08 to 54.18± 13.34 Bq l^{-1} ^{226}Ra respectively for Ondo and Ekiti states. The age dependent total annual effective dose due to the ingestion of these radionuclides from the drilled well of Ondo and Ekiti States was found to be above the recommended limits of 1.0 mSv/y and 0.1 mSv y^{-1}set by ICRP and WHO respectively for the samples taken from Erinmope Ekiti and Ikare-Akoko. Hence the affected drilled are recommended for screening for radionuclides to prevent the outbreak of radiation induced diseases. In all the samples considered across the two the two states, Babies were most susceptible to radiation followed by Children and the

least was Adult.

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