Activity and Corresponding Mass Concentrations of ^{40}K and ^{238}U in Well Waters from Ago-Iwoye, Ogun State, Nigeria

Alausa S.K[1*] Fasunwon O. O[2]. & Odunaike Kola[1]
1 Department of Physics, Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria
2.Department of Physics, University of Regina, Regina, Saskatchewan, Canada
* E-mail of corresponding author: alausakunle@yahoo.com

Abstract
Ago-Iwoye, situated on the basement complex has similar geological setting to Abeokuta which had been reported to be significantly high in radioactivity when compared to the world's average. The major source of water for the populace in Ago-Iwoye was from the wells dug at different locations across the town. The ^{238}U and ^{40}K concentrations in the water samples were measured using gamma-ray spectroscopy method and the health risks due to consumption of the waters were determined. The mean activity concentrations were 25.1±10.7 Bql^{-1} for ^{40}K and 3.1±2.9 Bql^{-1} for ^{238}U. The corresponding mean mass concentrations for ^{40}K and ^{238}U were 462.02±217.47 μgl^{-1} and 52.6±53.18μgl^{-1} respectively. The mean cancer mortality and morbidity risks due to ^{238}U in the well water samples were respectively (1.09±1.11) x 10^{-4} and (1.68±1.69) x 10^{-4}. The cancer mortality and morbidity risks were less than the reported world average of 1.0x10^{-3}.
Keywords: Ago-Iwoye, radiological effects, well waters, cancer mortality, basement complex

1. Introduction

Water is most essential to all forms of lives; it makes up of about 50- 97% of the weight of all plants and animals; and about 70% of human body (Phiri et al, 2005).Water resources is abundant in the entire surface of the earth, yet water resources is most poorly managed in the world (Fakayode, 2005). Indeed safe water is found to be very scarce despite its large volume on the entire earth surface (Olayinka, 2004). WHO (2003) reported that about 20% of world population in about 30 countries faced shortage of safe drinking water in 2000. This figure was predicted to climb to 30% in 50 countries by 2025 (Agbola and Adedeji, 2007). The scarcity is attributed to contamination of water bodies from various sources, including industrial effluents discharged into rivers that later pollute underground water (Olayinka, 2004) and natural radionuclides in the earth crust. Poor water quality and scarcity would not only prevent safe drinking but also adversely affect food security, livelihood choice, and health for poor families across the world. Water sustains life and its scarcity can mar the health status of any nation, so it is very pertinent to provide portable water for drinking in every nation (Ezomo and Akujieze, 2011).
The earth crust that contains various elements is also the reservoir of water resources. Among the elements (radionuclides) in the earth crust include ^{40}K, ^{226}Ra and ^{232}Th radionuclides. Potassium is an essential biogenic element found in all living organisms and plants tissues (ICRP, 1976, Lan and Weng, 1989). Potassium occurs in the environment, including all natural waters (WHO, 2009) and widely distributed in nature with an abundance of about 0.1% in limestone, 0.1% in sandstones as much as 3.5% in granite (NCRP, 1991). ^{40}K, a non- series natural occurring radioactive element is present in the natural potassium in the earth crust with an abundance of 0.018% and half-life of 1.3x10^{9} years (Sabol and Weng, 1995). The ^{40}K radionuclide constitutes a small fraction in the natural potassium but makes a significant contribution to radioactivity in the environment and all the living tissues.
Uranium salt in the earth crust bonds easily with oxygen to form uranly ion or uranium dioxide which is highly soluble in ground water under aerobic condition (Amakom and Jibiri 2010). The average crustal abundance of uranium salt reported in literature ranged between 2 and 3ppm (IAEA-TECDOC, 2003).
However one of the primary goals of World Health Organization (WHO) and its Member States is that 'all people' whatever their stage of development, social and economic conditions, should have the right to access adequate supply of safe drinking water (WHO, 2009). In addition the United Nation Millennium Summit in September 2000, declared steps to reduce the proportion of people without sustainable access to safe drinking water to one-half by year 2020 (UN, 2003).
Although the Nigerian government, over the years, has put in place various policies on provision of clean and portable water, but lack of political will has been the obstacle hampering their implementation. The rural dwellers mostly depend on ground and surface waters that may have been contaminated by several sources. Safe and portable waters are only available to rich people in the cities and urban centers. The poor people in the rural areas mainly depend on well or spring water that is rarely treated for drinking. The high poverty level of about 54.6% in Nigeria (NLSS, 2005; NBS, 2008) is the bane of insufficient portable and drinkable water in the country (NLSS, 2005; NBS, 2008). This motivated the current investigation of well waters used for both domestic and drinking in Ago-Iwoye with an estimated population of over 40,000 (FRNOG, 2007).
Ago-Iwoye (Lat. 6^{0} 56' N, Long 3^{0} 55' E), the study area covers a mass area of 246sq km is the second largest

populated town in Ijebu North Local Government of Ogun State. It is situated on the basement complex (Fasunwon et al, 2010), similar to Abeokuta (Figure1) that has been reported to be significantly high in radioactivity (Farai and Jibiri, 2000; Jibiri, 2001; Farai and Vincent, 2006; Jibiri et al, 2009). The popular University formerly known as Ogun State University now known as Olabisi Onabanjo University was established in Ago-Iwoye in 1982. The University population alone (staff and students) as at the time of carrying out the study was estimated at 25,000.

The investigation of activity and corresponding mass concentrations and cancer mortality/morbidity risks of ^{40}K and ^{238}U in the well water samples from Ago-Iwoye is in furtherance to the earlier study (Fasunwon et al., 2010). The mass concentration and cancer mortality/morbidity risks measurements further reveal the state and safety of the well waters.

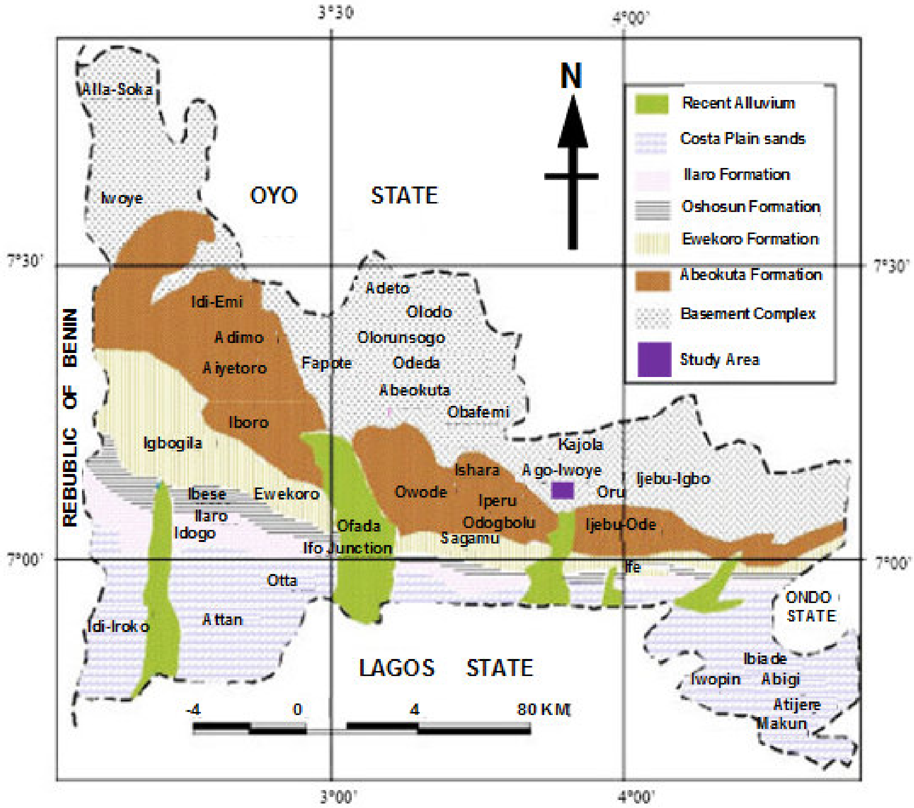

Figure 1: Geological Map of Ogun State showing the study area (After Kehinde-Phillips, 1992)

2. Material and Methods

2.1 Sampling and Preparation

The study area was divided into four grids and five well water samples were randomly collected from each of the grids giving a total of twenty water samples. At each well location, the water sample was collected into a 1 litre-size container, earlier rinsed with 0.1M diluted hydrochloric acid (HCl). The water samples were acidified with 1.0M concentrated hydrochloric acid (HCl) to obtain pH<2 in order to avoid absorption of radionuclides from the wall of the container (Amakom and Jibiri, 2010). In the laboratory, 250ml of each water sample were measured with measuring cylinder and transferred into uncontaminated and radon-impermeable cylindrical plastic containers of uniform sizes (60mm height by 60mm diameter). The containers were then sealed for about 30 days to allow for secular equilibrium between ^{226}Ra and ^{228}Ra and their respective gaseous progenies prior to gamma spectroscopy.

2.2 Radioactivity Measurements

The radioactivity levels in the water samples were measured by gamma-ray spectrometry method using 76 x76mm^2 NaI (Tl) detector (model no 802 series, Canberra Inc.) couple to a Canberra series 10 plus multichannel analyzer (MCA) (model no 1104) through a pre-amplifier base. The detector has a resolution of about 8% at energy 0.662Mev (^{137}Cs) which is enough to distinguish the gamma ray energies of interest. The energy calibration of the spectrometer was carried out using certified standard radioactive solutions of Cs-137 (Ref No: R$_o$/319/7) U-238 (RGU-1) and Eu-152 (Ref No: EA3/1496/20866) supplied by the Radiochemical Center Amersham, England through the technical aid of International Atomic Energy Agency (IAEA) Vienna, Austria.

The activity concentration of ^{214}Bi at γ-ray energy of 1.76Mev photo peak was chosen to determine the concentration of ^{238}U. The concentration of ^{40}K was determined from its own energy of 1.46Mev photo peak. The water samples were counted for 18,000 seconds. The net area under each photo peak, after background correction, was used to calculate the activity concentration of each radionuclide in the water sample.
The activity concentrations of the radionuclides in each water sample was calculated using Jibiri and Mabawonku (1999)

$$C = \frac{A}{VT\varepsilon_P I_\gamma} \tag{1}$$

where C is the activity concentration of the radionuclide in Bql^{-1},
V is the volume of water in litre,
A is the area under the photo peak of each radionuclide,
T is the counting time,
ε_p is the efficiency at the gamma-ray energy in $cpsBq^{-1}$ and
I_γ is the gamma- yield defined as absolute transition probability of the specific gamma-ray energy.
The detection limits (DLs) of the radionuclides (^{40}K and ^{226}Ra) were determined using Kitto et. al, (2006)

$$DL(Bq/kg) = 1.96\frac{\left(B/T + SD_b^2\right)^{\frac{1}{2}}}{k \times \varepsilon \times m} \tag{2}$$

where SD_b is the estimated standard error of the net background count in the peak;
T is the counting time (sec);
ε is the counting efficiency (cps/Bq);
m is the mass of the sample;
k is the factor that converts cps (count per second) to Bq;
B is the background count and 1.96 represent the 95% confidence level.
Using equation 2, the detection limits for ^{40}K was obtained as $14.2Bql^{-1}$ and for ^{226}Ra (^{238}U) was obtained as $4.6Bql^{-1}$. Whenever the concentration of the radionuclide in the sample was below the detection level, a value equal to one-half of the BDL value was considered for calculating the average activity concentration and other radiological assessment (Mlwilo, et al., 2007).

3. Results and Discussion

3.1 Activity and mass concentrations

The activity and mass concentrations of potassium and uranium in the well water were presented in Table 1. The activity concentrations of ^{40}K ranged from BDL-50.9 Bql^{-1} with mean concentration of 25.1±10.7 and the ^{238}U concentrations ranged from BDL-15.0 Bql^{-1} with mean concentration of 3.1±2.9.

Using conversion factors $1Bql^{-1} = 27pCil^{-1}$ and $\frac{1}{0.67}pCil^{-1} = 1\mu gl^{-1}$, the mass concentrations M, (μgl^{-1}) were determined using (Amakom and Jibiri, 2010)

$$M = 0.67 \times 27 \times A \tag{3}$$

where A is the activity concentration in Bql^{-1}.
The mass concentrations of potassium ranged from 156.48-920.78 μgl^{-1} with a mean value of 462.02±217.47 μgl^{-1} and uranium ranged from 37.99-271.35 μgl^{-1} with a mean value of 52.6±53.18 μgl^{-1}. The potassium mass concentrations in the drinking well water in the study was significantly low when compared to the value of 2500 μgl^{-1} reported for United Kingdom (Powell et al, 1987) and within the range of <1000 to 8000 μgl^{-1}reported in Canada (WHO, 2009). The uranium mass concentrations obtained in the study were higher than the World Health Organisation (WHO, 2003) recommended safe limit value of 15.0 μgl^{-1} in drinking water; United States Environmental Protection Agency(USEPA, 2003) recommended value of 30$\mu gl^{-1}$and the value of 20 μgl^{-1} recommended by both Health Canada (1999) and the Health Australia(1998) respectively for safe drinking water. The high concentrations of uranium may be attributed to the basement complex on which the study area is situated and the high solubility of uranium salt among the long-lived radionuclides (Amakom and Jibiri, 2010).

Table 1: Activity of ^{40}K, ^{238}U, and ^{232}Th radionuclides; and mass concentrations of K, U and Th elements in the well water samples from the study area

	Activity concentration			Mass concentration		
	^{40}K (Bql^{-1})	^{238}U (Bql^{-1})	^{232}Th (Bql^{-1})	K (μgl^{-1})	U (μgl^{-1})	Th (μgl^{-1})
Range	BDL-50.9	BDL-15.0	BDL-6.2	156.48-920.78	37.99-271.35	47.03-112.16
Mean	25.1	3.1	2.93	462.02	52.6	53.00
S Dev	10.7	2.9	1.33	217.47	53.18	24.04

3.2 Cancer mortality and morbidity risks

The carcinogenicity radionuclide slope factors by United States Environmental Protection Agency (EPA, 2000) were used to determine the life time cancer mortality and morbidity risks R, associated with intake of ^{238}U radionuclide. The mortality and morbidity cancer risks were determined using Amakom and Jibiri, (2010)

$$R = rACT \tag{4}$$

Where r (Bq^{-1}) is the applicable risk coefficient;

A (Bql^{-1}) is the activity concentration; C ($l\ y^{-1}$) is the consumption rate and

T (yr.) is the average life expectancy.

The average life expectance at birth in Nigeria is 45.5 years (WHO, 2008) and the water consumption rate for an individual is about 730 litre/yr. Using Equation 4, the cancer mortality and morbidity risks due to ^{238}U over the life time consumption of well water from the study area were evaluated and presented in Table 2. The cancer mortality and morbidity risk coefficients, r for ^{238}U were respectively $1.13x10^{-9}$ and $1.73\ x10^{-9}\ Bq^{-1}$ (EPA, 1999, UNSCEAR, 2000). The mean cancer mortality and morbidity risks were $1.09\ x10^{-4}$ and $1.68\ x10^{-4}$ respectively. These cancer risks at a factor of 10^{-4} are low compared to the acceptable limit of $1.0x10^{-3}$ (Ye-Shin et al., 2004, Amakom and Jibiri, 2010) for radiological health risks.

Table 2: Cancer risks due to ^{238}U in the well water samples from the study area

	Cancer risk mortality ($x10^{-5}$)	Cancer risk morbidity ($x10^{-4}$)
Range	7.88-56.40	1.21-8.62
Mean	10.93	1.68
S Dev	11.06	1.69

4. Conclusion and Recommendation

Although the results from the present study shows that both the chemical and the radiological health risks are respectively low when compared to the UN and USEPA reported values, yet it is necessary to be cautious of the ingestion of radionuclides as it is important to note that no matter how small, the radiation exposure (internal or external) is dangerous to human health. However the low values in the results still permits both domestic and economic use of the available well waters but the inhabitants should be duly educated on the dangers of excessive ingestion of radionuclides.

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