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Natural Radionuclide Concentrations and Radiological Impact Assessment of Soil and Water in Tanke-Ilorin, Nigeria.

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Abstract

Radioactivity measurement of water and soil samples from Tanke-Ilorin, Nigeria was carried out using a thallium activated Canberra vertical high purity 3″×3″ Sodium iodide [NaI(Tl)] detector connected to ORTEC 456 amplifier. The results were used to estimate all the radiological impact parameters in order to effectively ascertain the level of the radiological health hazard to Human life by the use of such materials in that area. The mean Absorbed Dose Rate for the soil and water samples was found to be 59.45 and 8.33 nGy/h. The estimated mean Annual Effective Dose (AED) for the ingested radionuclide in drinking water from the area for infants, 1year, 5 years, 10 years, 15years and adult were 1.9395, 2.0087, 1.2487, 0.9009, 0.7019, and 1.1688 mSv/y respectively. This reveals that children within 1year are more susceptible to radiation hazards in the area followed by the infants, 5 years, adults, 10 years and then 15 years respectively. The mean $AED_{outdoor}$ for the soil is 0.07291 mSv/y and mean AED_{indoor} is 0.29165 mSv/y. These mean values are within the safe limit of 1mSv/y for the general public. The mean Ra_{eq} for the soil and water samples is 114.50 Bq/kg and 17.53 Bq/l respectively. These estimated average values were lower than the recommended maximum value of 370 Bq/kg. The estimated hazard indices H_{in} and H_{ext} for the soil is 0.35 and 0.31 respectively. While that of water is 0.065 and 0.047. These values of H_{in} and H_{ext} in soil and water are less than unity which follows that hazardous effects of these radionuclides and their short-lived progenies are negligible. The estimated Excess Lifetime Cancer Risk (ELCR) for the soil and water samples is 1.02078×10^{-3} and 0.14301×10^{-3}. The estimated value of ELCR for soil is high which implies that the probability of developing cancer over a lifetime considering seventy years as the average life span of humans is high. The estimated mean values for the Annual Gonadal Equivalent Dose (AGED) in the soil and water is 0.43797 mSv/y and 0.05844 mSv/y. The estimated mean I_γ for the soil and water samples was 0.9410 mSv/y and 0.1297 mSv/y respectively. These values are within the safe limit of less than the universal standard of unity. The results showed trends that are generally low for most of the radiological impact parameters calculated except for few indices whose values are above the UNSCEAR recommended thresholds. Therefore, there may be no serious immediate radiological effects to the populace in this area.

Key Words: Radioactivity, Gamma Spectrometry, Specific Activity, Absorbed Dose, Effective Dose, Radiation Hazard Indices.

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1. INTRODUCTION

Life on earth is being inevitably exposed (internally and externally) to ionizing radiations which are of both natura and anthropogenic oroigins. (UNSCEAR, 1993). Exposure to excess level of background ionizing radiation can cause somatic and genetic effects that are damaging to critical and/or radiosensitive organs of the body, and can even lead to death (Ajayi and Ajayi, 1999).

Natural radioactivity is widespread in the earth's environment and exists in soils, rocks, plants, sand, water, and air as background radiations. Knowledge about the distribution of these radionuclides present in natural materials enables one to assess any possible radiological hazard to human life by the use of such materials. Activitiy of radionuclides in the soil is one of the main determinants of the natural background radiation. When rocks are disintegrated through natural process, radionuclides are carried to soil by rain and flows (Taskin, et al., 2009). In addition to the natural sources, soil radioactivity is also affected by human-made activities. The presence of radioactive elements in the erth's crust is also responsible for the level of radioactivity in ground water.

The quality of these ground water sources are affected by the characteristics of the media through which the water passes on its way to the ground water zone of saturation (Adeyemi et al., 2007). Groundwater is most favored as a source of drinking water in Africa (International Atomic Energy Agency/Water Resources Program (IAEA/WRP, 2010). It is often thought to be cleaner and easier to treat compared to surface water and as a result, many wells have been either sunk or drilled. However, groundwater can be contaminated by anthropogenic activities while naturally it contains several chemical components, which can lead to different kinds of health problems. According to Karanth (1987) a groundwater source can potentially contain several naturally occurring chemical and radioactive elements, many of which are not tested routinely as indices of water quality despite their known toxicity. Uranium and other radionuclides in water can lead to chronic health problems if present in high concentrations. In Nigeria today, ground water has become the major source of water supply in both the rural and urban areas as a result of the inability of the government to meet the ever increasing demand for water by the teeming population (Ajadi, 1996; Sule and Olu 1994).

Several authors have studied the level and impact of radioactivity in water, food and soil in different parts of the world including Nigeria. For example, Meindinyol and Agbalagba (2012) conduct radioactivity concentration and heavy metal assessment of soil and water, in and around Imirigin oil field, Bayelsa state, Nigeria. Avwiri et al*.,* 2014 evaluates the radiation hazard indices for selected dumpsites in Port Harcourt, Rivers State, Nigeria. Oni et al*.,* 2011 study the natural radionuclide concentrations and radiological impact assessment of river sediments of the coastal areas of Nigeria. Radiation hazard indices and excess lifetime cancer risk in soil, sediment and water around mini-okoro/oginigbacreek, Port Harcourt, Rivers State, Nigeria was carried out by Avwiri, Ononugbo and Nwokeoji in 2014. Similarly, the study of the radionuclide concentration levels in soil and water samples in Eagle, Atlas and rock cement companies in Port Harcourt was carried out by Avwiri (2005). In Results from all these studies revealed that the level of human exposure to radiological hazards are lower than the International Commission on Radiological Protection (ICRP, 1979, 1991, 1992) maximum permitted limit and therefore, have no significant radiological health burden on the environment and the populace. However, Nwankwo, 2013 in his study of the radioactivity in groundwater from Tanke-Ilorin, Nigeria, discovered that the activity concentration values range from 0.81 ± 0.08 to 7.4 ± 2.2 Bq/l for ^{226}Ra and from 1.8 ± 0.3 to 5.6 ± 2.6 Bq/l for ^{228}Ra. Consequently, the Annual Effective Dose received, as a result of the combined ingestion of ^{226}Ra and ^{228}Ra, was found to range from 0.81 to 1.74 mSv/y with an average of 1.30 mSv/y. This means that the mean contribution of both ^{226}Ra and ^{228}Ra activities to the committed effective dose from a year's consumption of drinking water in the study area is higher than the tolerable level of 1 mSv/y to the general public for prolonged exposure as recommended by ICRP, and much more than the WHO recommended level of 0.1 mSv/y for drinking water. These findings ultimately call for detail radiological monitoring to be conducted in the area and estimation of all the radiological impact parameters to effectively ascertain the level of the radiological health hazard. Hence the objective of this study is to measure and use the activity concentrations of the radionuclides from Gamma spectrometry of the soil and water samples from Tanke area of Ilorin to estimate all the radiological impact parameters to effectively ascertain the level of the radiological health hazard to human life in that area.

2. MATERIAL AND METHODS

2.1 The study area

The area of the study lies entirely within the basement rocks in the western part of central Nigeria and bounded by longitudes 4º36'–4º39' E and latitudes 8º27'–8º30' N. This area falls within the northwestern part of Ilorin, a semi-arid region of Nigeria. The geology of Ilorin consists of Pre-Cambrian basement complex with an elevation that varies from 273 m to 333 m in the West having an isolated hill (Sobi hills) of about 394 m above sea level and 200 m to 364 m in the East. Oyegun, 1985 asserted that a large part of Ilorin town is laid by sedimentary rock, which contains both primary and secondary laterites and alluvial deposits. The variety of basement complex rocks gives rise to a large number of ferruginous groups of soils. Thus, the main soil type in Ilorin is ferrallitic type, usually deep red in colour with high clay content. The major river in Ilorin is Asa, which flows North-South direction dividing the plain into two, Western and Eastern parts. The eastern part is generally steeper than the western part with height ranging from 900 – 1200 feet in some part and peaking at isolated landforms. The Nigeria basement complex (Fig. 1) consists of at least four main groups of rocks: the migmatite gneiss complex, the metasediment (composed of schist, calcgneiss, quartizite and meta-conglomerate), the porphyritic older granite and the miscellaneous rock types, which are mostly post orogenic rocks like aplite, pegmatites, and dolerites dykes (Rahaman, 1973).

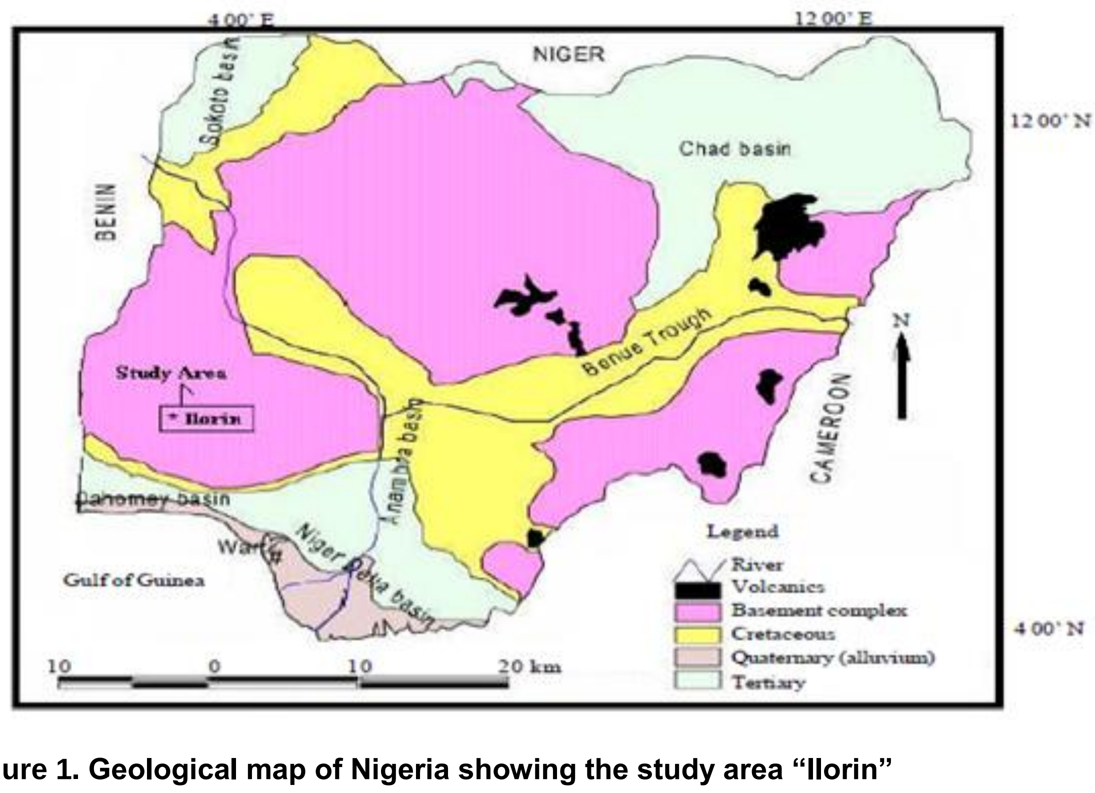

Figure 1. Geological map of Nigeria showing the study area "Ilorin"

2.2 Sample collection and preparation

Before samples were collected, a collection protocol was established which was strictly followed. This involves establishing a collection procedure, obtaining appropriate containers, and utilizing the appropriate methods of preservation in order to reduce the effect of adsorption or biodegradation. Measurements carried out *insitu* include conductivity, pH and temperature. A total of

20 samples were collected from the study area, 10 samples each of soil and water. The water samples were collected using 2 litre plastic bottles. They were acidified with 0.1 M HCl, at a rate of 10 ml per litre to minimize the precipitation of the radionuclide present in the water samples (Avwri et al., 2014). Soil samples were collected in black nylon bags about 2kg each. They were spread in trays and air dried. The samples were crushed and made to pass through 2 mm mesh sieve. They were weighed, sealed and stored in the laboratory for four weeks before being analyzed to allow for radon and its short-lived progenies to reach secular equilibrium prior to gamma spectroscopy (Avwri et al., 2014).

2.3 Measurements and Analysis.

The experiments for radioactivity measurement of the water and soil samples were carried out at the National Institute of Radiation Protection and Research (NIRPR) university of Ibadan using a thallium activated Canberra vertical high purity 3″×3″ Sodium iodide [NaI(TI)] detector connected to ORTEC 456 amplifier. The detector was connected to a computer program MAESTRO window that matched gamma energies to a library of possible isotopes. The detector was shielded by 15cm thick lead on all four sides and 10cm thick on top. The energy resolution of 2.0kev and relative efficiency of 33% at 1.33Mev was achieved in the system with the counting time of 27000 seconds. The standard International Atomic Energy Agency (IAEA) sources were used for calibration (IAEA, 2003). From the counting spectra, the activity concentrations of ^{238}U, ^{232}Th and ^{40}K were determined using computer program. The peak corresponds to 1460 kev (40K) for ^{40}K, 1764.5 Kev (Bi-214) for ^{238}U and 2614.5 kev (Ti-208) for ^{232}Th were considered in arriving at the activity levels (Bq/kg). The activity concentration (C) of the radionuclide was calculated after subtracting decay correction using the following expression (Avwri et al., 2014);

$$C_s = \frac{C_a}{P_\gamma\left(\frac{M_s}{V_s}\right)\varepsilon_\gamma t_c} \text{ (Bq/kg or Bq/l)} \quad (1)$$

Where C_s = Sample concentration, Ca = net peak area of a peak at energy, ε_γ= Efficiency of the detector for a γ-energy of interest, M_s/V_s = Sample mass/volume for soil/water, t_c = total counting time, P_γ= is the abundance of the γ-line in a radionuclide.

2.4 Evaluation of Radiological Hazard Parameters

Calculating the absorbed dose rate is the first major step for evaluating the health risk. With regard to biological effects, the radiological and clinical effects are directly related to the absorbed dose rate (Ramasamy et al., 2011).

2.4.1 Absorbed Dose Rate

The absorbed dose is a measure of the energy deposited in a medium by ionizing radiation per unit mass. It may be measured as joules per kilogram and represented by the equivalent S.I. unit, gray (Gy) or rad. The absorbed dose rate D (nGy/h), due to activity concentration of ^{238}U, ^{232}Th and ^{40}K was calculated using;

$$D = C_U A_U + C_{Th} A_{Th} + C_K A_K \quad (2)$$

Where A_U, A_{Th}, A_K are the radioactivity concentration in Bq/L and C_U, C_{Th}, and C_k are dose conversion factors which are 0.462, 0.604 and 0.0417 for ^{238}U, ^{232}Th and ^{40}K respectively. Average value is given as 57nGy/h (Avwiri et al., 2014; Issa, et al., 2013; Ononugbo et al., 2013; Avwiri and Ononugbo, 2012; Avwiri et al., 2012; Al-Hamameh and Awadalla, 2009; Farai and Ejeh, 2006; Farai and Isinkaye, 2002; UNSCEAR, 2000, 2008).

2.4.2 Annual Effective Dose (AED)

The Effective Dose is a dose quantity defined by the International Commission on Radiation Protection to monitor and control human exposure to ionizing radiation. It is the tissue-weighted sum of the equivalent doses in all specified tissues and organs of the body and represents the stochastic health risks to the whole body. It takes into account the type of radiation and the nature of each organ or tissue being irradiated, and enables summation of organ doses due to varying levels and types of radiation, both internal and external, to produce an overall calculated effective dose. This combines both internal and external exposures. The Annual Effective Dose (AED) is the sum of the effective dose over a year.

2.4.2.1 Annual Effective Dose for Ingested Radionuclide ($AED_{Internal\ Exposure}$)

The annual effective dose rate for all the ingested radionuclides from water was calculated using equation (3).

$$AED_{Internal\ Exposure} = \sum_i I_i \times 365 \times D_i \quad (3)$$

Where I_i is the daily intakes of radionuclide. Intake (Bq/d) = (concentration of radionuclide in food or water in Ci/lb or Bq/kg) × (consumption rate of water or food in lb/day or kg/day) and the ingestion dose coefficient (dose conversion factor) *Di* for adults for ^{40}K, ^{232}Th and ^{238}U is 6.2×10^{-9}, 2.3×10^{-7} and 4.5×10^{-8} Sv/Bq, respectively (UNSCEAR, 2000; ICRP, 2012). The annual effective dose resulting from the ingestion of water was estimated based on the assumption that a daily intake of water per person is 2 l/d for adults and 1 l/d for lower ages and 0.5 l/d for infants (Avwiri, et al., 2014; WHO, 2011). The Dose Conversion Factors for ingestion of radionuclides for members of the public for all ages provided by ICRP, 2012 is given in Table 1.

Table 1. Dose Conversion Factors for ingestion of radionuclides for members of the public up to 70 years of age (ICRP, 2012).

Radio Nuclides	$T_{1/2}$ (years)	Dose Conversion Factors (Sv/Bq)					
		Infants	1 year	5 years	10 years	15 years	Adults
^{40}K	1.2×10^{9}	5.2×10^{-8}	4.2×10^{-8}	2.2×10^{-8}	1.3×10^{-8}	7.6×10^{-9}	6.2×10^{-9}
^{232}Th	1.405×10^{1}	1.6×10^{-6}	4.5×10^{-7}	3.5×10^{-7}	2.9×10^{-7}	2.5×10^{-7}	2.3×10^{-7}
^{238}U	4.468×10^{9}	1.4×10^{-7}	1.2×10^{-7}	8.0×10^{-8}	6.8×10^{-8}	6.7×10^{-8}	4.5×10^{-8}

2.4.3 Annual Effective Dose for External Exposures ($AED_{external\ Exposure}$)

The annual effective dose received outdoor and indoor by a member of the public is calculated from the absorbed dose rate by applying dose conversion factor of 0.7Sv/Gy and occupancy factor for outdoor and indoor was 0.2 and 0.8 respectively (Avwiri, et al., 2014). AED is determined using the following equations (Issa, et al., 2013; Avwiri, et al., 2014).

$$AED_{outdoor}\ (\mu Sv/y) = D(nGy/h) \times 8760h \times 0.7\ (Sv/Gy) \times 0.2 \times 10^{-3} \quad (4)$$

$$AED_{indoor}\ (\mu Sv/y) = D(nGy/h) \times 8760h \times 0.7\ (Sv/Gy) \times 0.8 \times 10^{-3} \quad (5)$$

The AED_{indoor} occurs within a house whereby the radiation risks due to use of the soil as building material is taken into consideration. $AED_{outdoor}$ involves a consideration of the absorbed dose emitted from radionuclide in the environment such as ^{238}U, ^{232}Th and ^{40}K.

2.4.4 Radium Equivalent Activity Index (Ra_{eq}):

The radium equivalent (Ra_{eq}) activity represents a weighted sum of activities of ^{238}U, ^{232}Th and ^{40}K. It is based on the estimation that 1 Bq/kg of ^{238}U, 0.7 Bq/kg of ^{232}Th and 13 Bq/kg of ^{40}K produce the same radiation dose rates. This allows a single index or number to describe the gamma output from different mixtures of ^{238}U, ^{232}Th and ^{40}K in a material. It was calculated using the formula (Issa, et al., 2013):

$$Ra_{eq} = C_U + 1.43C_{Th} + 0.077C_K \quad (6)$$

Where C_U, C_{Th}, C_K are the radioactivity concentration in Bq/Kg of ^{238}U, ^{232}Th and ^{40}K.

2.4.5 Radiation Hazard Indices:

The external radiation hazard (H_{ext}) and the internal radiation hazard (H_{int}) was calculated as follows:

$$H_{ext} = \left(\frac{C_U}{370}\right) + \left(\frac{C_{Th}}{259}\right) + \left(\frac{C_K}{4810}\right) \quad (7)$$

$$H_{int} = \left(\frac{C_U}{185}\right) + \left(\frac{C_{Th}}{259}\right) + \left(\frac{C_K}{4810}\right) \quad (8)$$

H_{int} should be less than unity for the radiation hazard to be negligible. Internal exposure to radon is very hazardous which can lead to respiratory diseases like asthma (Avwiri, et al., 2014). Natural radionuclide in soil, sediment and rocks produce an external radiation field to which all humans are exposed. H_{ext} must be less than unity for this external radiation hazard to be negligible. H_{ext} equal to unity corresponds to the upper limit of radium equivalent dose (370 Bq/kg) (Avwiri et al., 2014; Ononugbo et al., 2013; Issa, et al., 2013; Avwiri and Ononugbo, 2012; Avwiri et al., 2012; Oni et al., 2011; WHO, 2011; Al-Hamameh and Awadalla, 2009; Farai and Ejeh, 2006; Avwiri, et al., 2005; Farai and Isinkaye, 2002; UNSCEAR, 2000, 2008).

2.4.6 Excess Lifetime Cancer Risk (ELCR):

The Excess Lifetime cancer risk (ELCR) was calculated using the following equation (Avwiri, et al., 2014):

$$ELCR = AED \times DL \times RF \quad (9)$$

Where, AED is the Annual Equivalent Dose Equivalent, DL is the average duration of life (estimated to 70 years), and RF is the Risk Factor (Sv^{-1}), i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for public (Avwiri, et al., 2014). Average value of ELCR is given as 0.2×10^{-3} (UNSCEAR 2000, 2008).

2.4.7 Annual Gonadal Equivalent Dose (AGED)

The gonads, the bone marrow and the bone surface cells are considered as organs of interest by UNSCEAR (2000) because of their sensitivity to radiation. An increase in AGED has been known to affect the bone marrow, causing destruction of the red blood cells that are then replaced by white blood cells. This situation results in a blood cancer called leukemia which is fatal. The AGED for the resident using such material for building was evaluated by the following equation;

$$AGED\ (\mu Sv/y)\ C = 3.09C_U + 4.18C_{Th} + 0.314C_K \quad (10)$$

Where, C_U, C_{Th}, and C_K are the radioactivity concentration of ^{238}U, ^{232}Th and ^{40}K in soil and water samples.

2.4.8 Representative Gamma Index (I_γ)

This is used to estimate the gamma radiation hazard associated with the natural radionuclide in specific investigated samples. The representative gamma index was estimated as follow (Avwiri,et al.,2014):

$$I_\gamma = C_U/150 + C_{Th}/100 + C_K/1500) \leq 1 \quad (11)$$

Where, C_U, C_{Th}, and C_K are the radioactivity concentration of ^{238}U, ^{232}Th and ^{40}K in soil and water samples. The I_γ is correlated with the annual dose rate due to the excess external gamma radiation caused by superficial material. An increase in the representative gamma index greater than the universal standard of unity may result in radiation risk leading to the deformation of human cells thereby causing cancer. Values of I_γ = 1 corresponds to an annual effective dose of less than or equal to 1 mSv, while I_γ = 0.5 corresponds to annual effective dose less or equal to 0.3 mSv (Avwiri and Olatunbosun, 2014; Turham et al., 2008). Thus, I_γ should be used only as a screening tool for identifying materials that might be of concern to be used as construction materials, though materials with $I_\gamma > 1$ should be avoided (Ravisankar et al., 2012) since these values correspond to dose rates higher than 1 mSv/y (Avwiri and Olatunbosun, 2014; Turham et al., 2008), which is the highest value of the dose rates recommended for humans (UNSCEAR, 2000).

3. RESULTS AND DISCUSSIONS

The results of the gamma ray spectrometry of the soil and water samples are presented in Table 2. The radionuclide observed with reliable regularity belonged to the decay series chain headed by ^{238}U and ^{232}Th as well as the non- series ^{40}K. The ^{40}K activity concentration dominated over the ^{238}U and ^{232}Th elemental activities as expected. The activity concentration of ^{40}K ranges between 511.93 ± 26.86 and 1492.30 ± 77.83 (Bq/kg) with a mean of 1136.58 ± 59.68 (Bq/kg) in the soil samples and ranges between 25.42±2.57 and 93.95±9.65 (Bq/l) with a mean of 72.25±5.52 (Bq/l) in the water samples. Activity concentrations of ^{238}U ranges between 3.08 ± 0.45 – 54.14 ± 2.69 (Bq/kg) and 3.66 ± 0.23 – 8.97 ± 1.94 (Bq/l) in the soil and water samples respectively, with means 16.64 ± 1.04 (Bq/kg) and 6.66 ± 1.27 (Bq/l) in the soil and water samples. While the activity concentration of ^{232}Th in the soil and water samples ranges between 2.67±0.12– 12.87±0.83 (Bq/kg) and 1.18±0.78–5 .63±2.52 (Bq/l) respectively with means 7.237±0.35 (Bq/kg) and 3.71±1.52 (Bq/l) in the soil and water respectively (Table 2, Fig. 1 a and Fig. 1 b). The activity concentrations of ^{238}U and ^{232}Th in all the samples were within the world safe limit of 10.0 and 1.0 Bq/l respectively for water and 35.0 and 30.0 Bq/kg respectively for soil samples by UNSCEAR, 2000 and WHO, 2008 standards. ^{40}K on the hand was observed to exceed the safe limits of 10.0 Bq/l and 500.0 Bq/kg for water and soil in all the samples.

As said earlier, knowledge about the distribution of these radionuclides present in natural materials enables one to assess any possible radiological hazard to humankind by the use of such materials. That is, the knowledge of radionuclide distribution levels in the environment is important in assessing the effects of radiation exposure due to natural and human-made sources. Figures 2a to 2c give the contour map of these radionuclides in the study area. Fig. 2a reveals that ^{40}K has less concentration around the Southwestern part of Tanke-area. This area represents an area with less population in Tanke. This follows that the high concentrations observed in the areas with more population (i.e the North-central part of the area) is an indication that the ^{40}K in the area is more from anthropogenic inputs than due to local geology of the study area. Fig. 2b and 2c shows that ^{238}U and ^{232}Th have similar distribution. Their maps reveal higher concentrations along the South-central spreading towards the Southern part the area. It follows that the concentrations of ^{238}U and ^{232}Th is likely due to the local geology of the study area.

Table 2. Physico-chemical parameters, location and specific activity of ^{40}K, ^{238}U and ^{232}Th in the soil and water samples.

SOIL SAMPLES							
Sample code	pH	[a]EC **µS/cm**	[b]LONG °E	[c]LAT °N	^{40}K (Bq/kg)	^{238}U (Bq/kg)	^{232}Th (Bq/kg)
SOIL1	8.00±0.2	56.50±2.5	4.6204	8.4783	584.98 ±31.41	54.14±2.69	12.87±0.83
SOIL2	8.60±0.1	50.00±3.0	4.6197	8.4798	1263.08 ±65.99	5.48±0.72	6.02±0.26
SOIL3	8.00±0.2	61.20±2.5	4.6172	8.4790	1273.69 ±66.93	16.81±1.05	7.98±0.17
SOIL4	7.00±0.1	62.60±2.0	4.6105	8.4896	911.09 ±48.03	13.66±0.86	6.89±0.24
SOIL5	7.50±0.1	56.30±2.0	4.6412	8.4687	1201.52 ±63.03	4.47±0.63	3.44±0.12
SOIL6	7.00±0.1	56.50±3.5	4.6226	8.4888	1492.30 ±77.83	19.56±1.22	8.55±0.23
SOIL7	8.60±0.2	54.20±2.0	4.6149	8.4744	511.93 ±26.86	14.67±0.89	7.89±0.46
SOIL8	7.72±0.2	58.20±2.8	4.6075	8.4694	1475.64 ±77.79	3.08±0.45	2.67±0.17
SOIL9	7.50±0.2	52.50±2.0	4.6228	8.4671	1361.03 ±71.49	18.05±0.98	8.05±0.64
SOIL10	7.60±0.2	47.64±3.3	4.6279	8.4995	1290.53 ±67.41	16.45±0.86	8.01±0.41
MIN					511.93 ±26.86	3.08±0.45	2.67±0.12
MAX					1492.30 ±77.83	54.14±2.69	12.87±0.83
MEAN					1136.58 ±59.68	16.64±1.04	7.237±0.35
WATER SAPMLES							
Sample code	pH	EC **µS/cm**	LONG °E	LAT °N	^{40}K (Bq/l)	^{238}U (Bq/l)	^{232}Th (Bq/l)
WATER1	6.7±0.1	360.0± 2.0	4.6165	8.4821	25.42±9.65	3.66±1.03	1.18±0.78
WATER2	6.8±0.3	380.0±3.2	4.6180	8.4833	77.86±4.03	4.92±1.25	2.01±1.92
WATER3	7.5±0.1	386.0±3.0	4.6179	8.4794	37.21±3.75	8.97±0.23	5.63±1.63
WATER4	7.0±0.2	384.0±3.1	4.6155	8.4783	91.86±6.28	4.82±1.38	1.91±1.14
WATER5	7.2±0.1	385.0±3.0	4.6221	8.4760	85.60±6.80	8.78±1.47	5.25±2.52
WATER6	6.7±0.1	370.0±2.0	4.6134	8.4751	47.28±4.04	6.94±1.72	4.54±1.67
WATER7	7.5±0.3	386.0±3.2	4.6261	8.4793	84.49±3.89	6.36±1.94	4.16±1.39
WATER8	7.0±0.2	381.0±2.9	4.6343	8.4776	93.95±2.57	5.61±1.82	2.79±1.94
WATER9	7.0±0.1	384.0±3.0	4.6136	8.4871	87.56±8.07	8.67±0.68	5.53±0.94
WATER10	6.5±0.1	374.6±0.5	4.6195	8.4866	91.22±6.15	7.82±1.22	4.12±1.26
MIN					25.42±2.57	3.66±0.23	1.18±0.78
MAX					93.95±9.65	8.97±1.94	5.63±2.52
MEAN					72.25±5.52	6.66±1.27	3.71±1.52

[a]EC – electrical conductivity [b]Long – longitude [c]Lat - lattitude

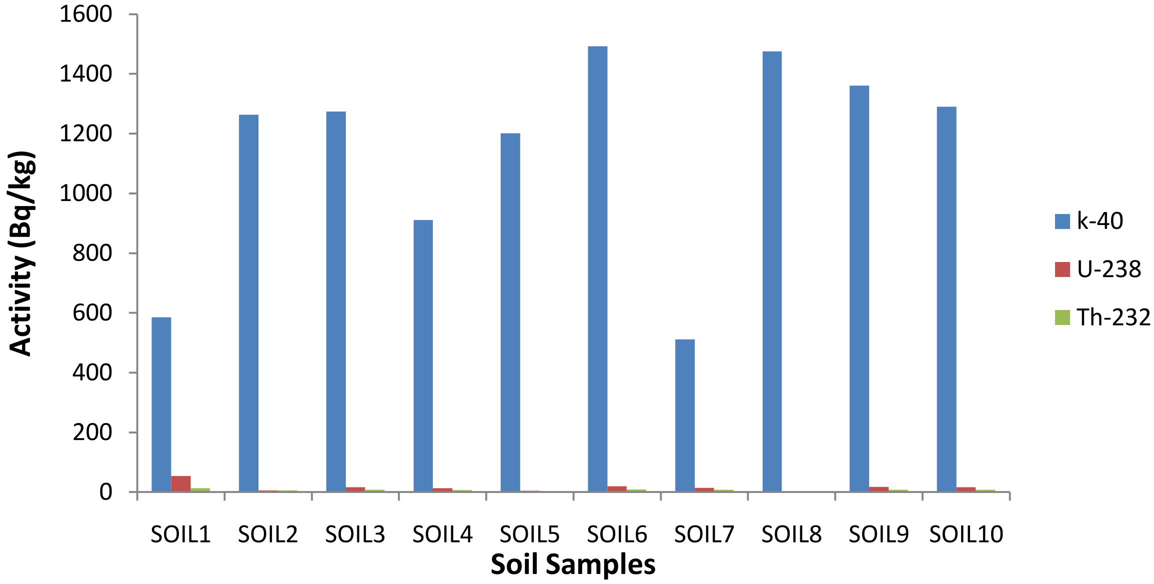

Figure 1a. Specific activity of ^{40}K, ^{238}U and ^{232}Th in the soil samples

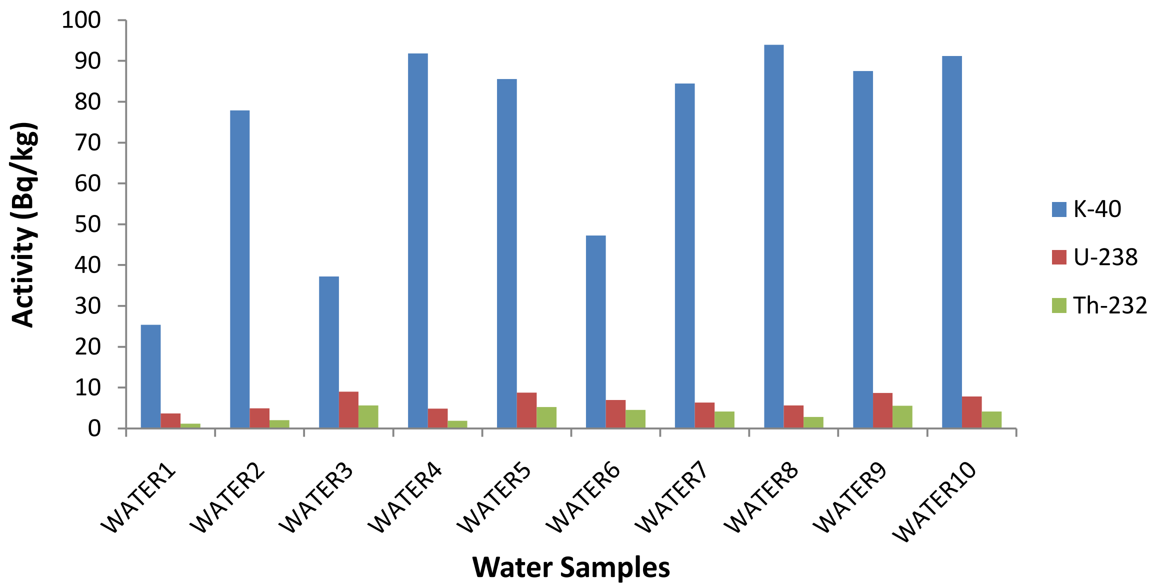

Figure 1b. Specific activity of K-40, U-238 and Th-232 in the water samples

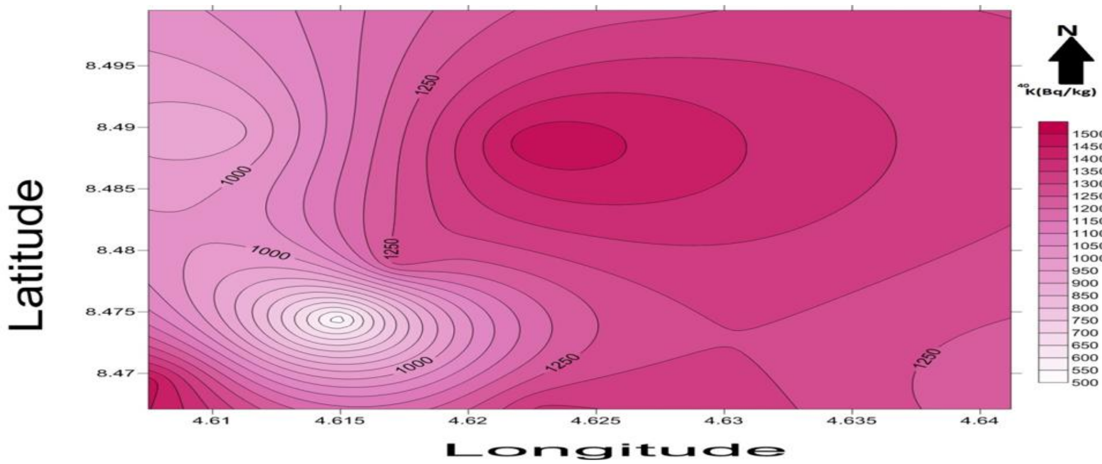

Figure 2a. Contour map of the Activity concentration of ^{40}K of the soil in the study *area.*

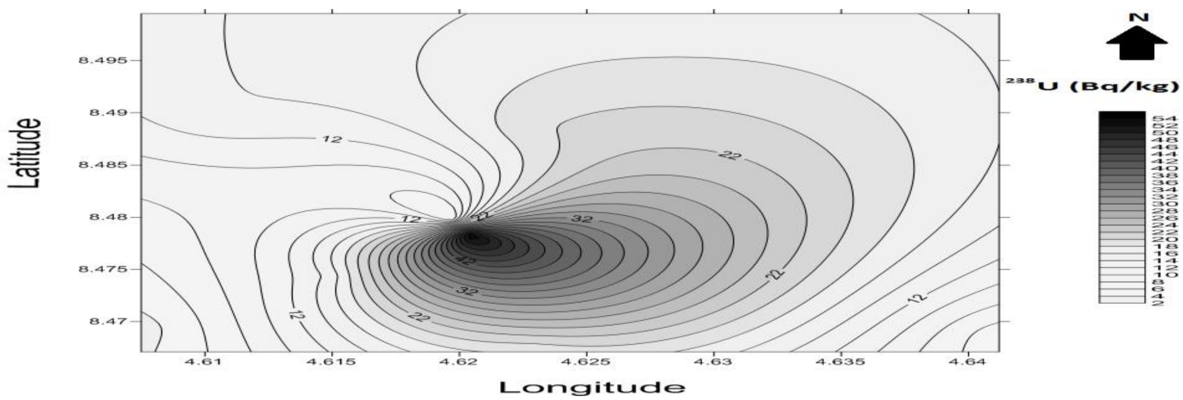

Figure 2b. Contour map of the Activity concentration of ^{238}U of the soil in the study area.

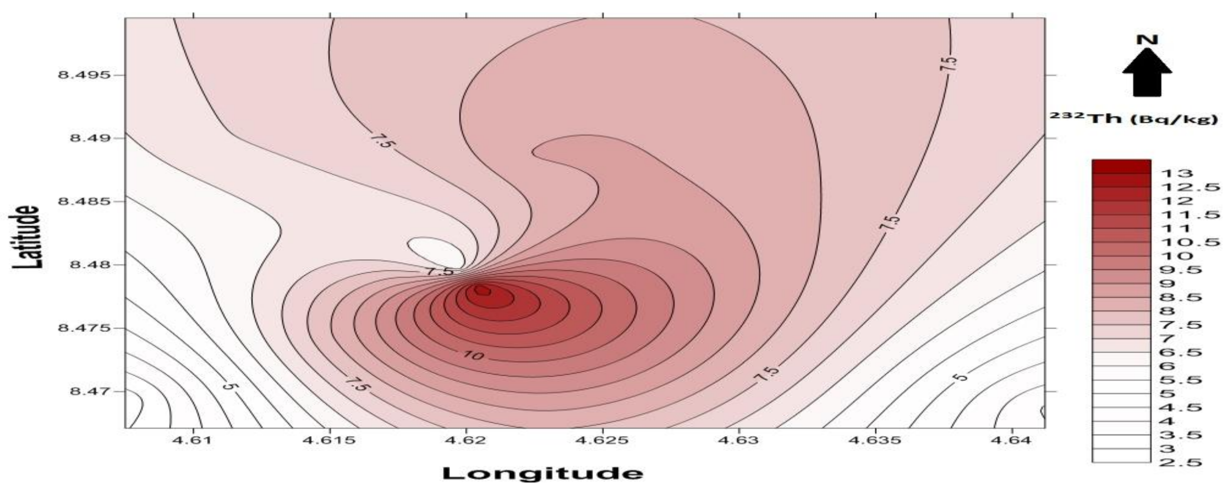

Figure 2c. Contour map of the Activity of ^{232}Th of the soil in the study area.

The mean Absorbed Dose Rate for the soil and water samples is 59.45 and 8.33 nGy/h respectively (see Tables 3 and 4). The mean Absorbed Dose Rate for the soil is slightly above the general average value of 57nGy/h.

Table 3. Annual Effective Dose (mSv/year) for different age category/group for members of the public in the study area

SAMPLE CODE	Annual Effective Dose (mSv/year)					
	ADULTS	INFANTS	1YEAR	5YEARS	10YEARS	15YEARS
WATER1	0.4334	0.6793	0.7438	0.4617	0.3364	0.2677
WATER2	0.8515	1.4515	1.7392	1.0256	0.7043	0.5197
WATER3	1.4084	2.2263	1.8880	1.2799	0.9951	0.8363
WATER4	0.8948	1.5526	1.9330	1.1224	0.7577	0.5470
WATER5	1.5573	2.5697	2.5591	1.6144	1.1798	0.9312
WATER6	1.2042	1.9517	1.7745	1.1623	0.8771	0.7151
WATER7	1.2898	2.1790	2.2571	1.3956	0.9991	0.7695
WATER8	1.0779	1.8496	2.1442	1.2746	0.8803	0.6524
WATER9	1.6096	2.6672	2.6303	1.6627	1.2160	0.9595
WATER10	1.3615	2.2685	2.4176	1.4872	1.0630	0.8202
MEAN	1.1688	1.9395	2.0087	1.2487	0.9009	0.7019

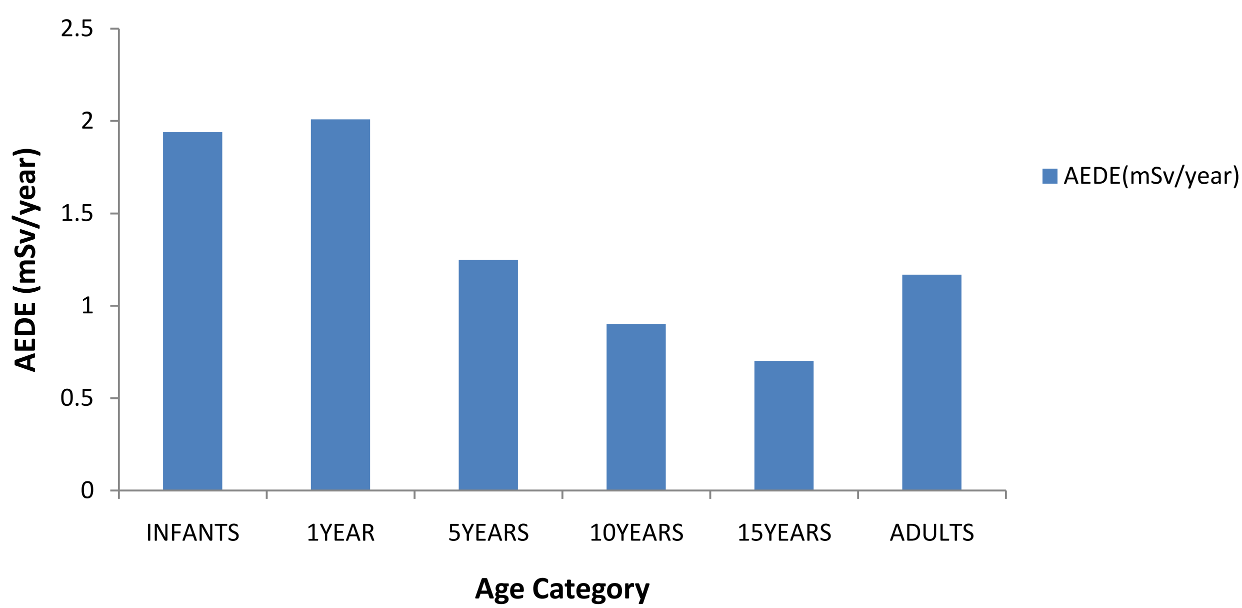

Figure 3. Annual Effective Dose (mSv/year) for different age category/group for members of the public in the study area

The mean AED for the ingested radionuclide in drinking water from the area for Infants, 1year, 5years, 10years, 15years and Adults is 1.9395, 2.0087, 1.2487, 0.9009, 0.7019, and 1.1688 mSv/y respectively (Table 3 and Fig. 3). These average values for the AED for the different age groups are higher than the acceptable limits of 1mSv/y for the general public except for 10years and 15years which are within the safe limits. Although it should be noted that daily intake of water per person of 2 l/d for adults, 1 l/d for lower ages and 0.5 l/d for infants was used as against the 1 liter per day for adults used by Nwankwo, 2013 in his determination of natural radioactivity of groundwater in the study area. From Fig. 3, it is clear that children within 1year are surprisingly more susceptible to radiation hazards in the area followed by the infants then 5years, adults, 10years and 15years respectively. Although 15 years and 10 years are within the safe limit of 1 mSv/y.

The mean $AED_{outdoor}$ for the soil is 72.91 µSv/y (= 0.07291 mSv/y) and the mean AED_{indoor} is 291.65 µSv/y (= 0.29165 mSv/y) (see Tables 4 and 5). Expectedly,these mean values are within the safe limit of 1 mSv/y for the general public.

The mean Ra_{eq} for the soil and water samples is 114.50 Bq/kg and 17.53 Bq/l respectively. The estimated average values were lower than the recommended maximum value of 370 Bq/kg for the safe use of materials in the construction of buildings (Avwiri et al., 2014; Issa, et al., 2013; Farai and Ademola, 2005; UNSCEAR, 2000). This means that soil from this area can safely be used as building materials without much fear of.

Table 4. Radiation hazard parameters for the soil samples.

Sample code	**D** (nGy/h)	**AED** (µSv/year)		**AGED (µSv/y)**	**Ra_{eq}** (Bq/kg)	**H_{in}**	**H_{ext}**	**ELCR (x 10^{-6})**	**I_γ (mSv/y)**
		outdoor	**Indoor**						
SOIL1	**57.18**	**70.13**	**280.50**	**403.74**	**117.59**	**0.46**	**0.32**	**245.44**	**0.8796**
SOIL2	**58.84**	**72.16**	**288.64**	**438.22**	**111.35**	**0.32**	**0.30**	**252.56**	**0.9388**
SOIL3	**65.70**	**80.57**	**322.29**	**484.60**	**126.30**	**0.39**	**0.34**	**282.01**	**1.0410**
SOIL4	**48.47**	**59.44**	**237.75**	**356.54**	**93.67**	**0.29**	**0.25**	**208.03**	**0.7674**
SOIL5	**54.25**	**66.53**	**266.11**	**405.19**	**101.91**	**0.29**	**0.28**	**232.85**	**0.8652**
SOIL6	**76.43**	**93.73**	**374.93**	**564.08**	**146.70**	**0.45**	**0.40**	**328.06**	**1.2108**
SOIL7	**32.89**	**40.34**	**161.35**	**238.43**	**65.37**	**0.22**	**0.18**	**141.18**	**0.5180**
SOIL8	**64.57**	**79.19**	**316.75**	**483.82**	**120.52**	**0.33**	**0.33**	**277.16**	**1.0310**
SOIL9	**69.96**	**85.80**	**343.18**	**516.14**	**134.36**	**0.41**	**0.36**	**300.28**	**1.1082**
SOIL10	**66.25**	**81.25**	**325.01**	**488.90**	**127.28**	**0.39**	**0.34**	**284.38**	**1.0501**
MEAN	**59.45**	**72.91**	**291.65**	**437.97**	**114.50**	**0.35**	**0.31**	**255.20**	**0.9410**

Table 5. Radiation hazard parameters for the water samples.

Sample code	**D (nGy/h)**	**AED (mSv/year) (Adults)**	**AGED (µSv/y)**	**Ra_{eq} (Bq/kg)**	**H_{in}**	**H_{ext}**	**ELCR (x 10^{-6})**	**I_γ (mSv/y)**
WATER1	**3.46**	**0.4334**	**24.13**	**7.31**	**0.030**	**0.020**	**1516.91**	**0.05314**
WATER2	**6.73**	**0.8515**	**47.89**	**13.79**	**0.051**	**0.037**	**2980.23**	**0.10481**
WATER3	**9.10**	**1.4084**	**62.48**	**19.89**	**0.078**	**0.054**	**4929.23**	**0.14091**
WATER4	**7.21**	**0.8948**	**51.57**	**14.62**	**0.053**	**0.039**	**3131.74**	**0.11247**
WATER5	**10.80**	**1.5573**	**75.53**	**22.88**	**0.086**	**0.062**	**5450.63**	**0.1681**
WATER6	**7.92**	**1.2042**	**54.91**	**17.07**	**0.065**	**0.046**	**4214.82**	**0.12319**
WATER7	**8.97**	**1.2898**	**63.24**	**18.81**	**0.068**	**0.051**	**4514.27**	**0.14033**
WATER8	**8.19**	**1.0779**	**58.27**	**16.83**	**0.061**	**0.045**	**3772.81**	**0.12793**
WATER9	**10.99**	**1.6096**	**76.96**	**23.32**	**0.086**	**0.063**	**5633.58**	**0.17147**
WATER10	**9.91**	**1.3615**	**69.70**	**20.73**	**0.077**	**0.056**	**4765.24**	**0.15414**
MEAN	**8.33**	**1.1688**	**58.47**	**17.53**	**0.065**	**0.047**	**4090.95**	**0.12965**

radiological hazards. The estimated hazard indices H_{in} and H_{ext} for the soil is 0.35 and 0.31 respectively. While that of water is 0.065 and 0.047 respectively (see tables 3 and 4). These values of H_{in} and H_{ext} in soil and water are less than unity which follows that hazardous effects of these radionuclides and their short-lived progenies are negligible.

The mean ELCR for the soil and water samples is 255.20 x 10^{-6} (= 0.25520 x 10^{-3}) and 4090.95 x 10^{-6} (= 4.09095 x 10^{-3}) (See tables 3 and 4). The estimated value of ELCR for soil is less than the average value of 0.2 x 10^{-3} while that of water is higher. The high values of the ELCR index for water samples is due to high AED caused by high specific activity of ^{40}K radionuclide in the samples. This high value implies that the probability of developing cancer over a lifetime considering seventy years as the average life span of humans is high. The mean values for the AGED in the soil and water is 437.97 µSv/y (= 0.43797 mSv/y) and 58.44 µSv/y (0.05844mSv/y) respectively. While the estimated mean I_γ for the soil and water samples is 0.9410 mSv/y and 0.1297 mSv/y respectively. These values are within the safe limit of less than the universal standard.

4. CONCLUSION

A study on the assessment and analysis of the radionclide present in soil and water samples within Tanke area of Ilorin have been carried out. From the measured values of the activity concentration of the natural radionuclides (^{40}K, ^{238}U and ^{232}Th) for both the soil and water samples, the average values of the absorbed dose rate, Ra_{eq}, H_{ex} and H_{ext}, AGED and AED (outdoor and indoor) were calculated. The results show levels that are generally low for most radiation hazard indices calculated except for few indices whose values are above the UNSCEAR recommended thresholds. Therefore, there may be no serious immediate radiological effects to the populace in the area except for the disturbing fact that beside 10years and 15years which are within the safe limits, the average values for the AED for the other age groups are higher than the acceptable limits of 1mSv/y for the general public which disagrees with findings of Nwankwo, 2013. Although it should be noted that daily intake of water per person of 2 l/d for adults was used as against the 1 liter per day for adults used by Nwankwo, 2013 in his determination of natural radioactivity of groundwater in the study area. This study can be used as a baseline for future investigations and the data obtained in this study may be useful for natural radioactivity mapping. The results may also be used as reference data for monitoring possible radioactivity pollution in future.

REFERENCES

Adeyemi, O., Oloyede, O., and Oladiji, A. (2007). Physicochemical and microbial characteristics of Leachate contaminated ground water, Asian Journal Biochemistry 2(5), 343-348.

Ajadi, B.S. (1996). Pattern of Water Supply in Ilorin City, Unpublished B.Sc Thesis Department of Geography, Unilorin.

Ajayi, O.S. and Ajayi, I.R. (1999), A Survey of Environmental Gamma Radiation Levels of Some areas of Ekiti and Ondo States, Southwestern Nigeria. Nigerian Journal. of Physics 11(15), 17 –21.

Al-Hamameh I. F. and Awadallah M. I. (2009). Soil Radioactivity levels and Radiation Hazard Assessment in the Highlands of Northern Jordan. Radiation Measurements. 44, 102-110.

Avwiri, G. O. (2005). Determination of Radionuclide Levels in Soil and Water around Cement Companies in Port Harcourt. Journal of Applied Sciences and Environmental Management 9(3), 27-29

Avwiri G. O and Ononugbo C. P (2012). Natural Radioactivity levels in surface soil of Ogba/Egbema/Ndoni Oil and Gas fields. Energy Science and Technology 4(2), 92-101.

Avwiri G. O., Osimobi J.C. and Agbalagba E. O. (2012). Evaluation of Radiation Hazard Indices and Excess Lifetime Cancer Risk Due to Natural Radioactivity in soil profile of Udi and Ezeagu Local Government Areas of Enugu State, Nigeria. Comprehensive Journal of Environmental and Earth Science 1(1), 1 – 10.

Avwiri G.O, Ononugbo C.P, Nwokeoji I.E. (2014): radiation hazard indices and excess lifetime cancer risk in soil, sediment and water around mini-okoro/oginigba creek, port harcourt, rivers state, nigeria. Comprehensive Journal of Environment and Earth Sciences 3(1), 38-50 Dec. 2014 ISSN-2315-7488 Copyright © 2014 Knowledgebase Publishers. http://www.knowledgebasepublishers.org/ENV%20SCI.html

International Atomic Energy Agency/Water Resources program (IAEA/WRP) (2010). Water sampling procedure for isotope hydrology. Video clip by IAEA Vienna. www-naweb.iaea.org/napc/ih/index.html. [accessed 16th December, 2011]

Farai I. P. and Ademola J. A. (2005). Radium Equivalent Activity Concentrations in Concrete Building Blocks in Eight Cities in Southwestern Nigeria, Journal of Environmental Radioactivity 79(2), 119-125. doi:10.1016/J.Jenvrad.2004.05.016

Farai I. P. and Ejeh J. E (2006). Radioactivity Concentrations in Common Brands of Cement in Nigeria, Radioprotection 41(4), 455-462. doi:10.1051/Radiopro:2006020

Farai I. P. and Isinkaye M. O. (2009). Radiological Safety Assessment of Surface Water Dam Sediments Used as Building Materials in Southwestern Nigeria, *Journal of* Radiological Protection 29(1), 85-93. doi:10.1088/0952-4746/29/1/006

ICRP (2012). ICRP Compendium of dose coefficients based on ICRP publication 60. Annals of the ICRP 41(1)

Issa, S.A.M., Uosif, M.A.M. and Elsaman R. (2013). Gamma radioactivity measurements in Nile River sediment samples Turkish Journal of Engineering and Environmental Science 37, 109 – 122. doi:10.3906/muh-1207-21

Karanth, K. R. (1987). Groundwater assessment, development and management. Tata-McGraw-Hill, New Delhi: 720

Meindinyo R. K and Agbalagba E. O (2012). Radioactivity concentration and heavy metal assessment of soil and water, in and around Imirigin oil field, Bayelsa state, Nigeria. Journal of Environmental Chemistry and Ecotoxicology 4(2), 29-34

Nwankwo. L. I. (2013). Determination of Natural Radioactivity in Groundwater in Tanke-Ilorin, Nigeria. West African Journal of Applied Ecology 21(1).

Oni O. M., Farai I. P. and Awodugba A. O. (2011). Natural Radionuclide concentration and Radiological Impact Assessment of Rivers Sediments of the coastal Area of Nigeria. Journal of Environmental Protection 2, 418 - 423.

Ononugbo CP, Avwiri GO, Egieya JM (2013). Evaluation Of Natural Radionuclide Content in Surface and Ground Water and Excess Lifetime Cancer Risk Due To Gamma Radioactivity. Academic Research International 4(6), 636-647.

Oyegun R.O (1985). The Use and Waste of Water in a Third World City. Geo Jornal, Reidel Publishing Company 10(2), 205 – 210.

Rahaman M. A. (1973). Review of the basement Geology of South Western Nigeria. In Geology of Nigeria. (C. A. Kobe, ed), pp. 39–56. Rockview Publishers, Jos.

Ramasamy, V., Suresh, G., Meenakshisundaram, V. and Ponnusamy, V. (2011). Horizontal and Vertical Characterization of Radionuclides and Minerals in River Sediments", Applied Radiation and Isotopes, 69, 184-195.

Sule, B. F. and Olu, O. E. A. (1994). Impact of Ilorin Water Supply Expansion on Asa River Catchment, Journal of Water Supply and Research - AQUA 43(5) 246-251.

Taskin, H., Karavus, M., Ay, P., Topuzoglu, A., Hindiroglu, S. and Karahan, G. (2009). Radionuclide Concentrations in Soil and Lifetime Cancer Risk Due to the Gamma Radioactivity in Kirklareli, Turkey", Journal of Environmental Radioactivity 100, 49-53.

UNSCEAR (1993). United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation. UNSCEAR 1993, Report to the General Assembly, with Scientific Annexes A and B: Sources. New York: United Nations.

UNSCEAR (2000). United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Sources and effects of ionizing radiation. UNSCEAR 2000, Report to the General Assembly, with Scientific Annexes. Volume I: Sources. New York: United Nations.

UNSCEAR (2008). United Nations Scientific Committee on Effect of Atomic Radiation. Sources and Effect of Ionising Radiation . Report vol.1 to the General Assembly with scientific Annexes: United Nations Sales Publications,United Nations, New York.

WHO (2008). World Health Organisation. Guidelines for Drinking Water Quality in Cooperating first Addendum vol.1, Recommendations, third Edition. Radiological Aspect Geneva: World Health Organiztion. WHO Geneva.

WHO (2011). World Health Organisation. Guidelines for Drinking Water Quality. Fourth edition incorporating the 1st and 2nd Agenda Vol.1 Recommendations; WHO Geneva.