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Assessment of Radon Concentration in Underground Well Water from Selected Parts of Kaduna Metropolis

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ABSTRACT
Underground well water samples from selected areas in Kaduna metropolis were collected and analysed in order to ascertain the concentration of ^{222}Rn. The analysis took place during the dry season when the weather was fairly stable and the community depended solely on ground water as their major water source for domestic use with a well calibrated a liquid scintillation counter situated at the Center for Energy Research and Training (CERT), Ahmadu Bello University, Zaria-Nigeria utilized for the measurements. The analysis results revealed and average concentration of 10.69 ± 0.39 Bq/L which is within the maximum concentration limit of 11.1 Bq/L and world average value of 10 Bq/L for drinking water.

Keywords: ^{222}Rn, Groundwater, Kaduna, Liquid scintillation counter, Maximum contaminant level

INTRODUCTION
Water is the most abundant substance on earth, and it is the principal constituent of all living things. Man uses water for many purposes in areas such as power generation, agriculture and above all for domestic purposes. Water for human consumption should be free from chemical, microbiological and radiological contamination (Garba *et al.*, 2008). Water and its management will continue to be a major issue with definite profound impact in our lives and that of our planet (Herschy, 1999). It is the most important natural resources without which life would be non-existent (Adebo and Adetoyinbo, 2009). Availability of safe and reliable sources is an essential prerequisite for sustainable development. Deserts are not habitable because of lack of water (Asonye, *et al.*, 2007).

Radon is one of the major sources of environmental health threats in the nation. As stated by the Environmental Protection Agency (EPA), radon is the number one cause of lung cancer among non-smokers and is also responsible for about 21,000 lung cancer death every year, where about 2,900 of these deaths occur among people who have never smoked. In Kaduna state, certain types of rocks such as granite and volcanic soils are more likely to contain radon. Hence, the majority of the people in Kaduna barely have access to clean pipe borne water and normally use other alternative sources such as ground water through hand dug wells or boreholes.

Radon can also be found in drinking water and can reach human organs when ingested along with water (Garba *et al.*, 2008). Certain types of materials such as granite and volcanic soils, as well as aluminous shales, are more likely to contain radon. Conversely, low concentrations of this gas are expected in sedimentary rocks.

Therefore, the objective of this work is to determine the concentration of radon in water sources from Kaduna metropolis, which will serve as a baseline data against which future determination can be compared.

MATERIALS AND METHODS
Study Area
Water scarcity is prevalent in the study area (Unguwar rimi and Kabala costain of Kaduna metropolis) due to inadequate supply of pipe borne water, hence switching to underground water sources becomes necessary most times for consumption, cooking, domestic use and agricultural purposes.

Geology of the Study Area
The study area falls in a state located at the Northern part of Nigeria's High Plains. The vegetation cover is Sudan Savannah type, characterized by scattered short trees, shrubs and grasses. Soil type is mostly loamy to sandy type with substantial amount of clay also found.

The entire Kaduna state is underlain by a basement complex of igneous and metamorphic rocks of mainly Jurassic to Pre-Cambrian ages. The basement complex rocks are essentially granites, gneisses, migmatites, schists and quartzites. The geology of Kaduna North is predominantly metamorphic rocks of the Nigerian basement complex consisting of biotite gneisses and older granites. The topographical relief is relatively flat, having an elevation of between 600-650 meters in large areas of the local government. It is over 650 meters above sea level (a.m.s.l) in some places, and below 500 meters in places that slope downward towards the river.

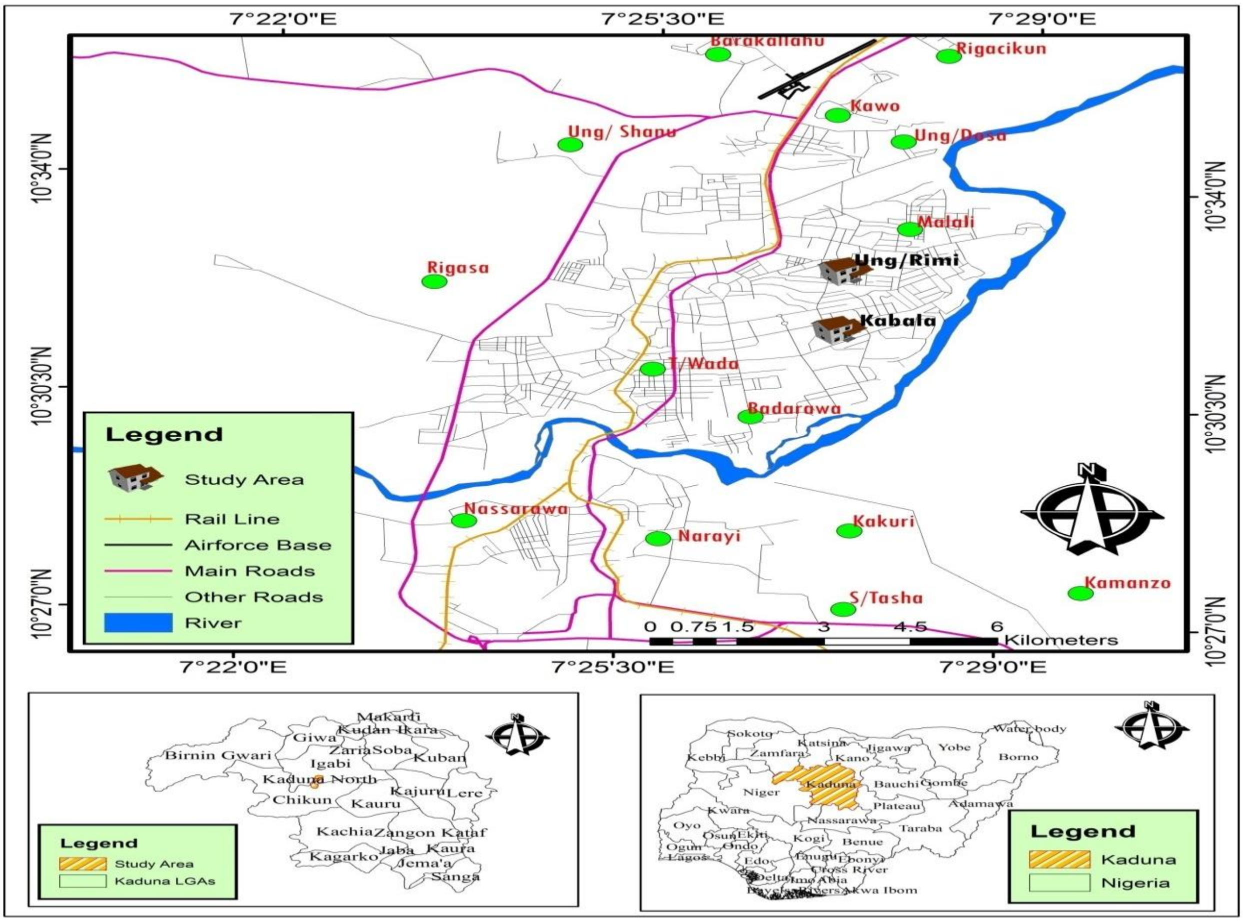

Figure 1: Map of Kaduna metropolis showing study areas.
Source: G.I.S. Lab Department, Geography and Environmental Managements Ahmadu Bello University, Zaria.

Sample Collection

Water samples were collected from Kaduna metropolis, (Unguwar rimi and Kabala to be precise), in clean plastic bottles labelled R1-R5. The containers used for the sample collection were cleaned to avoid contamination or adsorption of the analyte (radon) present in the samples. The samples were obtained from the underground well by the aid of a pulley which was then later collected into the 120 mL capacity sample bottle. The samples were then analyzed in less than 24 hours so as to achieve maximum accuracy.

Sampling Preparation

About 10 mL of each sample was added into a scintillation vial containing 10 mL of install-gel scintillation cocktail. The vials were tightly sealed and then shaken thoroughly for three minutes to extract ^{222}Rn in the water phase into the organic scintillator.

Sampling Analysis and Counting

The prepared samples were analyzed using liquid scintillation counter (Tri-Carb-LSA1000) located at the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria Nigeria. The counting was carried out immediately the prepared samples were brought to the laboratory. After shaking the counting vials, the outer part of each vial was wiped with a cloth dampened with ethanol and allowed to stand for 3hours to be left for in growth of the short lived decay products of ^{222}Rn. The ^{222}Rn and its short-lived daughters were in equilibrium after the third hour. The counting vial was placed in the liquid scintillation counter (LSC) and each vial was counted for a pre-set period of time using a calibrated window for alpha counting. It was ensured that the vials were not shaken to avoid disturbing the state of equilibrium between ^{222}Rn and its short-lived daughters in the organic scintillant. The time and date of counting were all noted. A suitable counting period will depend upon the activity concentration of ^{222}Rn in the sample, but 5000 secs per vial is usually sufficient for low level measurement. The background of the counting system was determined by counting a vial with 10ml of the organic scintillant solution and 10mlof distilled water. The background was measured over the same spectral range as the samples and for the same counting period.

The ^{222}Rn concentration in a sample of water was determined using equation 1.

$$\mathrm{Rn(Bq/L)} = \frac{100-(SC-BC)\exp(\lambda t)}{60(CF)\times(D)} \quad 1$$

Where;

Rn = Radon concentration in Bq/L, SC= Sample count rate (count/min), BC= Background count rate (count/min), T or t = Elapsed time from sampling to testing given in minutes, CF = Calibration factor and D = Decay time

Calibration Procedure of LSA for Measurement of ^{222}Rn in Water

A secondary calibration material was prepared by dissolving 1mlof the ^{226}Ra in distilled water. The solution was stored for one month for equilibrium to be attained. 10ml of the solution was later mixed with 10 mL of install-gel scintillation cocktail and counted with a window setting of 25-900 in region C of the LSA for 60 mins. With the use of equation 2, the calibration factor was found.

$$\text{Calibration factor} = \frac{SC-BC}{C-V} \quad 2$$

Where;

SC= Standard ^{226}Ra concentration (count/min), BC= Background count rate (count/min)

C= Standard ^{226}Ra concentration (pCi/L) and V= volume of standard ^{226}Ra used (L)

Decay Correction Factor:

Corrections were made in the decay of ^{222}Rn to augment some loses (decay) in the process of transporting the sample from the collection point to the middle time of sample measurement in liquid scintillation counter (Kambar and Okunade, 2015). This was represented by the decay correction factor (D) given by equation 3.

$$D = exp(-\lambda T) = exp\left(-\frac{0.693T}{t_{1/2}}\right) \quad 3$$

Where,

D = decay correction factor, T = decay time between sample collection and the middle time of sample measurement (minutes) and $t_{1/2}$= Half life, $\lambda =$ wavelength.

Activity Concentration

Background count measurements were also made for the same time period (60 min). The ^{222}Rn activity concentration was calculated using equation 4.

$$Rn(\mathrm{Bq/L}) = \frac{100 \text{ x } (\mathrm{SC-BC}) \exp(\lambda t)}{60(\mathrm{CF})\text{X D}} \quad 4$$

Where:

Rn = radon level in Bq/L, SC = sample count rate (count min^{-1}), BC = background count rate (count min^{-1}), t = elapsed time from sampling to testing given in minutes and CF = Calibration factor

RESULTS AND DISCUSSION

The ^{222}Rn concentration determined for the underground water samples are presented in Table 1. ^{222}Rn concentration in water depends so much on the source of radon emanation which may likely be as a result of natural processes or activities and other human activities in the area where the wells are located. Different works have been reported by many researchers on ^{222}Rn concentration in wells and boreholes. In a work by Zhou *et al.*, (2001) where Radon (Rn) bubbler was used and a scintillation cell method described by Yang et al. (1998) to study radon in underground water samples collected from Fujian Province in which they found that the radon concentration has exceeded the maximum contaminant level (MCL) of 11.1 Bq/L for drinking water set by USEPA (1991).

Table 1. ^{222}Rn concentration from the study areas

S/No.	Sample ID	Latitude (^{0})	Longitude (^{0})	^{222}Rn Conc.(Bq/L)	Mean deviation
1	R1	10.5240	7.4656	12.15	0.27
2	R2	10.5228	7.4664	11.05	0.68
3	R3	10.5232	7.4655	9.14	0.23
4	R4	10.5008	7.4436	12.12	0.57
5	R5	10.4995	7.4410	9.01	0.22

Figure 2 shows the concentration of ^{222}Rn from the sample areas (Unguwar Rimi and Kabala costain). The mean concentration of the ^{222}Rn concentration in all the water samples was found to be 10.69 Bq/L which is below the Maximum Concentration Limit (MCL) of 11.1Bq/L as set by USEPA (1999) and a little higher than the assumed world average value of 10Bq/L (WHO, 1993; UNSCEAR, 2002) and adopted by the Standard Organization of Nigeria (SON, 2003).

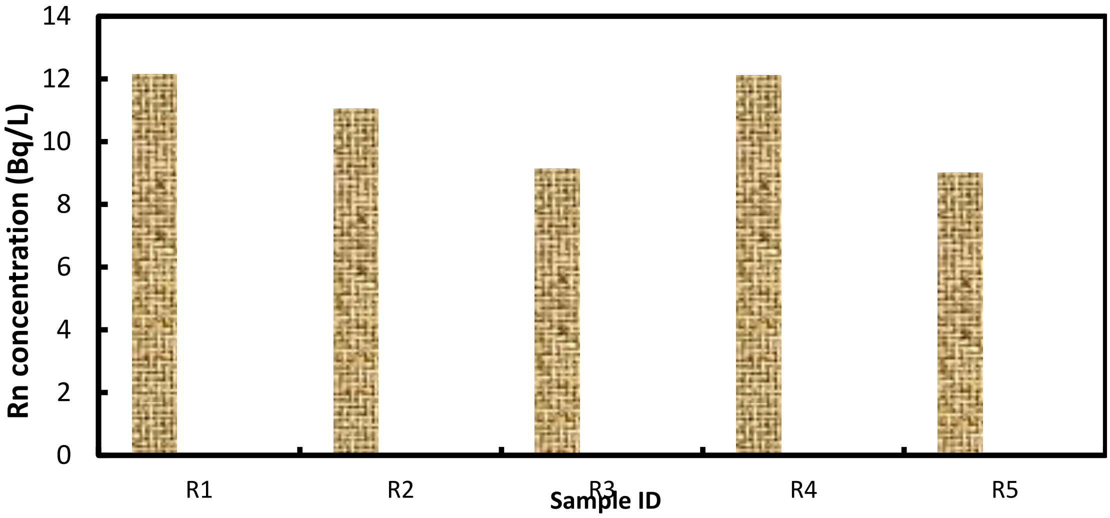

Figure 2. A plot of concentration of ^{222}Rn concentration obtained from underground hand dug wells.

From Figure 2 and Table 1, it can be stated that high ^{222}Rn concentration in groundwater is highly dependent on the type of geologic rock aquifers (Cho *et al.,* 2004). Result from this study showed that the mean concentration of all the water samples is below the MCL of 11.1 Bq/L and slightly higher than the world average value of 10 Bq/L for drinking water (Mustapha *et al.*, 2002) and this may be attributed to the fact that radon readily dissolves in water under pressure which leads to the radon accumulation in groundwater (Cho *et al.*, 2004). High concentration of ^{222}Rn has been of great concern about its health effects. Therefore, either drinking groundwater or bathing can give rise to exposure of humans to its radiation and may result in cancer and even death in extreme saturation (USEPA, 1999). As reported by Cothern (1990), it showed that approximately 1-7% of lung cancer fatalities in the USA are due to indoor radon levels arising from groundwater. This may be due to the wide distribution of its daughter products in the environment, soils and the natural water (Garba *et al.,* 2008; Mustapha et al., 2002). Hence, it can be said that the high level of ^{222}Rn concentration may be as a result of ^{222}Rn release from the surrounding geological formation (Lawal 2008).

Table 2. ^{222}Rn concentration of ground water samples from Kaduna with other parts of the world (Oni *et al.,* 2016).

Location	Radon concentration (Bq/L)
India	2.63
Turkey	9.28
Romania	15.4
Jordan (many locations)	2.8-116
Lebanon (many locations)	11.3
Tassili, South-east Algeria	0.67-21.25
Eastern Doon Valley, outer Himalayas	20-95
Northern Venezuela	0.1-5.76
Finland	630
United States of America	5.2
Selected part of Kaduna, Nigeria (Present Study)	10.69

Comparing the result of this study with the other parts of the world (Table 2), it can be noticed that the average ^{222}Rn concentration determined in some parts of Kaduna metropolis is lower than the Radon concentrations from places like Romania, parts of Jordan, outer Himalayas and Finland, but higher compared to concentrations from India, Turkey, some parts of Jordan, Algeria, Northern Venezuela and USA (Oni *et al.*, 2016).

Current options for providing safe drinking water in Nigeria include: obtaining low ^{222}Rn ground water by accessing safe shallow groundwater, rain water harvesting; treating water using aeration equipment and or granular activated carbon, using bottled water will reduce the risk from carbon. A concern for exposure to radiation from ^{222}Rn sources has necessitated studies to reduce/mitigate the dangers. International organizations have established recommended limits for ^{222}Rn concentration in water but Nigeria has not yet introduced any legal regulation concerning permissible radon concentration in water. Therefore, there is need for radon concentration in water to be investigated thoroughly so that guidelines for regulations on the radon concentrations in Nigeria may be established.

CONCLUSION

The present study showed that the ^{222}Rn concentration in the underground water samples from Unguwar rimi and Kabala costain of Kaduna metropolis have concentration value slightly above the mean concentration of 10 Bq/L as stated by the World Health Organization (WHO) and a little lower than the maximum possible value of 11.1 Bq/L. From the obtained data in this research, the respective values of ^{222}Rn from each source do not actually pose a serious threat to the health of an individual in that environment. But for samples R1, R2 and R4 which have values slightly higher than the approved mean concentration of 10 Bq/L and the maximum permissible value of 11.1 Bq/L respectively. This indicated that, the people using the water may be prone to suffer from diseases like lung cancer, leukemia and other chronic diseases.

REFERENCES

Adebo, B.A and Adetoyinbo, A.A (2009). Assessment of ground water quality in unconsolidated sedimentary coastal aquifer in Lagos state, Nigeria. *Scientif. Res. Essay,* 4 (4), 314-319.

Asonye, C.C., Okolie, N.P., Okenwa, E.E and Iwuanyanwu, U.G (2007). Some physic-chemicalncharacteristics and heavy metal profile of Nigerian rivers, streams and waterways. *African J. Biotechnol.,* 6(5), 617-624.

Cothern C.R (1990). Estimating the health risks of radon in drinking water. *J. American Water Works Assoc.,* 79, 70–74

Cho, J.S., Ahn, J.K., Kim, H-ch., Lee D.W (2004). Radon concentration in groundwater in Busan measured with a liquid scintillation counter method. *Env. Rad.,* 75, 105-112.

Garba N.N., Rabiu N., Yusuf A.M., Ismail A (2008). Radon; its consequences and measurement in our living environs, *J. Res. Phy. Sci.,* 4(4), 23-25.

Herschy, R.W (1999). Hydrometry principles and practices (2nd edition) John Wiley and Sons, Chicchester. ISBN: 0471973505 9780471973508

Kambar, A. M., Okunade, I. O. (2015). Radon measurement in commercial borehole water from some selected areas in Kaduna metropolis using Liquid Scintillation Counter. *Intl. J. Maths. Phy. Sci. Res.,* 3(2), 71-81.

Lawal, M.G (2008). Natural Radioactivity of Groundwater in N.W Precambrian Rocks of sheet, 102, Zaria. Unpublished Ph.D Thesis, A.B.U, Zaria.

Mustapha, A.O., Patel, J.P., Rathore, I.V.S (2002). Preliminary report on Radon Concentration in drinking water and indoor air in Kenya. *J. Geochem. Health,* 24, 1573-2938.

Oni, E.A., Oni, O.M, Oladapo, I.D., Adediwura, F.E (20016). Measurement of Radon concentration in drinking water of Ado-Ekiti, Nigeria. *J. Acad. Indust. Res.,* 4, 1-3

World Health Organization, WHO. (1993). Guidelines for drinking water quality, vol.1, 2nd ed. Geneva: WHO.

USEPA. (1999). Health risk reduction and cost analysis for radon in drinking water. Federal register 64(38), 9559, Washington.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 2002). Sources and effects of ionizing radiation, UNSCEAR to the general assembly with scientific annexes, United Nations, New York.

Standard Organization of Nigeria (SON) (2003). Inorganic constituents for drinking water quality.

Yang X, Weng D, Qian T, Chen X, Chen W, Chen J, Yang W, Zhang J, Lai S, Gu X, Fang G, Xu L, Zhao S (1988). Radionuclide levels in foods and drinking water and their internal doses in Fujian. *Chinese J. Radiol. Med. Protec.,* 8, 84-94.

Zhou W, Iida T, Yang X (2001). Occurrence of ^{222}Rn, ^{226}Ra, ^{228}Ra and U in ground water in Fujian Province, China. *J. Env. Rad.,* 52, 111-120.