



Assessment of Radon Concentration in Groundwater in Some Selected Areas in Lapai, Niger State

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ABSTRACT

This paper is on the assessment of the activity concentrations of Radon in water samples collected from Lapai town and compare the results with world Standards to have an idea of the risk level with respect to cancer. Liquid scintillation counter was used to determine the radon concentration in different water samples (borehole and well). A total of seven (7) samples which include five boreholes and two well water was analysed. The experimental data were compared. And the results obtained from the calculation of the activity concentrations of Radon-222 in water samples collected at different locations in Lapai town revealed that 86.18% of the recorded values of radon concentrations in the present study as well as the mean values obtained for the two (2) water types were above the world average Maximum Contamination Level (MCL) of 10 Bq/L.

Keywords: Liquid Scintillation Counter (LSC), maximum contaminant level, Radon Effective dose

INTRODUCTION

Water is the major constituent of the Earth's streams, lakes and oceans and the fluid of most living organisms, (USEPA, 1991). It covers about 71% of the Earth surface. It is vital for all known forms of life especially man. Man uses water for various reasons such as transportation, power generation, Agriculture and other domestic activities hence its availability and quality as regard radiological, microbiological, chemical and any other form of contamination are delicate and vital issues (Garbaet *al.*, 2008). Unfortunately, access to potable drinking water in most developing countries such as Nigeria is a major challenge hence most people rely heavily on untreated surface and ground water sources for consumption.

For instance, most inhabitant of Lapai local Government Area of Niger State rely solely on untreated groundwater sources (well and borehole) as well as surface water source for their daily water usage. This is because there are only few available pipe-borne water sources and in most places where such sources are available, they are not operational or adequate. It is therefore

important to investigate the radiological content of ground water sources in Lapai town so as to determine its fitness for consumption and hence compare the results with international best practices.

Radon(Rn) is a naturally occurring radioactive inert gas with a half-life of 3.82 days which is a member of the Uranium decay series (Somlai, 2007). It contributes the largest proportion of the total radiation from natural sources. Studies have shown that Radon and its progeny contribute about 50% of the total effective dose equivalent from natural sources. Radon is soluble in water. The concentration of radon in water is due to the decay of Radium-226 associated with the rock and soil. The Radon gas penetrates through soil and rocks and dissolves in water (Xinwei, 2006). Normally, drinking water from ground water sources has higher concentration of radon than surface water (Abajeet *al.*, 2015).

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The exposure of a population to high concentration of radon and its daughters for a long period has significant health effects ranging from respiratory functional changes to cancer of the lungs (BEIR, 1999). Also a very high level of radon in drinking water can lead to stomach and gastrointestinal tract cancer (Kendelet al., 2002).

In Nigeria, most areas lack established data on the activity concentration of Radon. Lapai town, Lapai Local Government Area, Niger State is one of such areas from the survey of literature and Author’s knowledge, despite the fact that most of its inhabitant rely heavily on untreated surface and groundwater sources for drinking, agriculture and their domestic activities. Since its geology revealed that it is enriched in granite, it is possible that the concentrations of radon in both surface and groundwater sources in Lapai town are higher than normal.

METHODOLOGY

Sample collection and Sampling Site

A total of 7 samples were collected for analysis from the selected underground (Boreholes and open wells) water sources at different locations in Lapai town, Lapai Local Government Area, Niger State.

Samples were collected using a plastic vials. Before collecting samples from Borehole source, the water was first purged out and the samples were first collected with the aid of bailers and then transferred into plastic vials. On the other hand, the water samples from boreholes were collected by pumping and allowing the water to flow out for about three (3) minute before samples were collected in order to ensure that fresh samples were obtained. Each sample collected was properly labelled using a measuring tape and the time of sample collection was noted and recorded, respectively. During sample collection, global positioning system was used to mark the geographical locations on the earth surface for easy identification.

The samples were analyzed as soon as possible (maximum of three days) after collection to achieved maximum accuracy because the composition of the samples may change if kept longer before analysis.

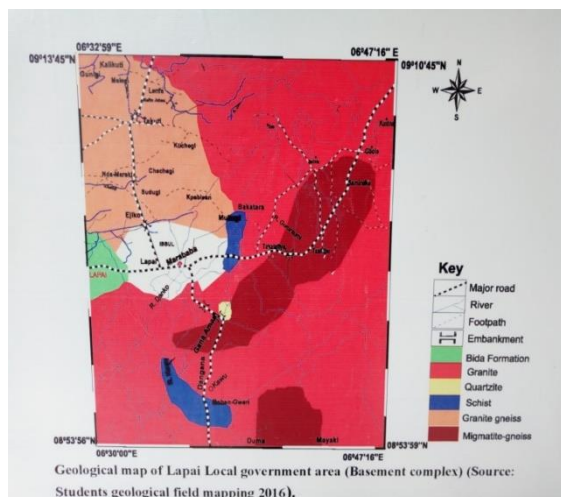


Figure a: Geological map of Lapai Local Government area (Basement complex) (source: student geological field mapping)

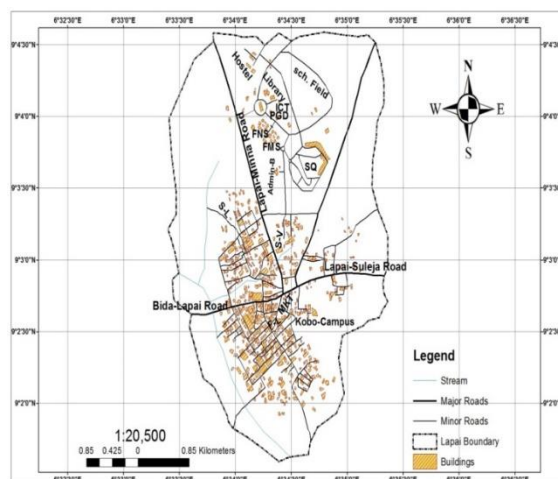


Figure b: Geographical Map showing points where samples were collected in Lapai and the water type collected

Sample Preparation

10 ml of each sample was added into a vial containing 10 ml of toluene based cocktail (scintillator) using a hypodermic syringe. The vials were tightly capped and shaken vigorously for three (3) minutes to extract radon-222 in water phase into the organic scintillator. In a similar manner a blank sample for the background was prepared using distilled water that has been kept in a glass bottle for at least 21 days. The prepared samples were allow to stand undisturbed for at least three (3) hours in order for ²²²Radon-222 and its alpha decay products attain equilibrium before counting.

Sample Analysis

The prepared samples and the blank were each analyzed using the Liquid Scintillation Counter (Tri-Card LSA 1000) at the Center for Energy Research and Training (CERT), Ahmadu Bello University Zaria, Kaduna, Nigeria. Radiation emitted from the samples transferred energy to the organic scintillator which in turn emits light photons. This way each emission result is a pulse of light in form of digit. The activity concentration of Radon-222 will be graphically analysed using excel spreadsheet and the activity concentration of Radon-222 was calculated from the samples and background results obtained using the formula below:

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

where Rn = Concentration of Radon-222 in Becquerel per litre.

SC= Sample Count Rate (Countmin⁻¹), BC = Background Count Rate (count min⁻¹).

t =Time elapsed between sampling to counting (minutes), λ = Decay constant (1.26 × 10⁻⁴min⁻¹).

60 = Conversion factor from minutes to seconds

CF = Calibration factor

D = Fraction of Radon-222 in the cocktail in a 22 total capacity vial for 10 of sample, 10 of cocktail and 2 of air.

Annual water consumption by an adult of 2 litres per day that is 730 / (UNSCEAR,

1993).According to United Nation Scientific Committee on the Effect of Atomic Radi doses due to ingestion of radon in water for similar consumption rates could be factor of 2 and 7 higher for children and infants respectively.

RESULTS

A total of seven (7) samples comprising of 7 groundwater (wells and boreholes) water samples were collected from Lapai town and analysed using Liquid Scintillation Counter (LSD). The results of the analysis are shown in Table 1.

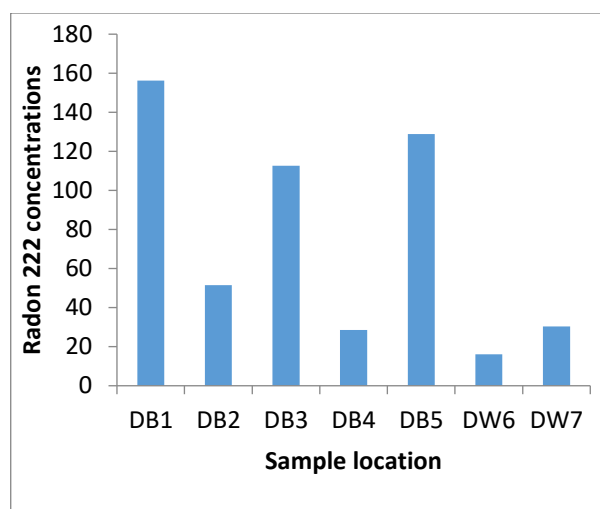


Figure 1: Bar chart of radon-222 concentrations for Borehole and Well water samples at different location in Lapai town.

Table 1: Results for Radon Concentrations in wells and borehole and their corresponding Annual Effective Doses (AED) in forgroundwater Samples at Lapai town

| S/N | Sample Location | Sample ID | Latitude | Longitude | Elevation (m) | Rn (Bq/L) | AED (mSv/y) | |
|-----|------------------|-----------|----------|-----------|---------------|-----------|-------------|----------|
| | | | | | | | Adult | Children |
| 1 | Student Villa | DB1 | 23356 | 1001747 | 154.09 | 156.3 | 1.14 | 0.228 |
| 2 | Magajinprischool | DB2 | 232955.4 | 1001181.4 | 151.21 | 51.53 | 0.376 | 0.753 |
| 3 | KpadaRaod | DB3 | 233032.8 | 1000978.7 | 131.83 | 112.6 | 0.822 | 1.643 |
| 4 | EffuKenchi | DB4 | 232905.9 | 1000800 | 134.24 | 28.58 | 0.208 | 0.417 |
| 5 | State lowcost | DB5 | 23257 | 1001457 | 154.09 | 128.9 | 0.941 | 1.882s |
| 6 | EffuKenchi | DW6 | 232915.9 | 1000919.4 | 150.03 | 16.05 | 0.117 | 0.234 |
| 7 | Student Villa | DW7 | 233615.9 | 1001682 | 156.08 | 30.34 | 0.222 | 0.443 |

DISCUSSION

The mean values of Radon-222 concentrations were found to be 75.58 and 46.39 Bq/L for boreholes and wells in (Table 1). Also using equation 3.2 to calculate the annual effective doses, we find the mean values of the corresponding Annual Effective Doses due to ingestion of Radon-222 in Borehole water to be, 4.024, 1.12 and for adults and children respectively. While that due to the intake of Radon-222 from open wells and found to be (0.228 and 0.338,) for adults and children respectively. These results have shown that both the mean values of Radon-222 concentrations and the Annual Effective Doses due to ingestion of borehole and well water samples exceeded the world average recommended values of 10 and 0.1 set by the World Health Organization, (WHO, 1993) and (WHO, 2004) for Radon concentration and annual effective dose due to intake of radionuclide in water respectively.

Borehole Water

The result of the analysis of radon concentrations for the five (5) borehole water samples collected at different locations in Lapai town, Lapai Local Government Area, Niger State are presented in table 4.1 revealed that the concentrations of Radon-222 varies from 28.58 to 156.3 Bq/L with a mean value of 86.18 Bq/L. The maximum concentration was obtained from Kpada road with radon concentration of 112.6 Bq/L while the minimum concentration was found at Effu-Kenchi. All the radon concentration value obtained from these samples were found to be above maximum contaminant levels of 11.1 Bq/L set by USEPA and the world average value of 10 Bq/L set by World Health Organization (WHO, 1993). The mean concentration of Radon-222 was found to be lower than the recommended guideline level of 100 Bq/L set by WHO, (2008). However, 25% of the analysed borehole water samples which include samples from student Villa and state low-coast were found to be above 100.

Well Water

The concentrations of Radon-222 in well water samples collected from two different wells located in Lapai town (student villa opposite IBBU Lapai, and Effu-Kenchi), are presented in table 4.1 These were found to vary from (16.05 to 30.34 Bq/L) with a mean value of 23.19 Bq/L. It was found that student Villa recorded the maximum radon concentration of 30.34

Bq/L which below the recommended reference level of 100 Bq/L set by (WHO, 2008) for which action on the reduction of radon concentration in water is justify. On the other hand, Effu-Kenchi recorded the minimum radon concentration of 16.05 Bq/L see table 1. However, Radon concentrations of samples obtained from Low-coast and Effu-Kenchi were found to below the Maximum contaminant levels of 10 Bq/L and 11.1 Bq/L set by United States Environmental Protection Agency (USEPA, 1991) Therefore these water sources are considered fit for consumption as far as radon concentration in water is concerned.

Mean Radon Concentration

Samples from borehole have the highest mean concentration of Radon-222 followed by well water samples with the least mean concentration of radon. All the mean values from the two (2) water samples exceeded the maximum contaminant levels set by USEPA (1991) and the world average value of 10 Bq/L set by WHO (1993). However, the lower mean value of Radon-222 concentration for well water as compared to mean radon concentrations of Borehole water could be linked to the fact that well water is exposed to the air and since radon is a gas it tends to escape into the air. While the higher mean values recorded for boreholes could be attributed to the fact that radon readily dissolves in water under high pressure which lead to the radon accumulation in groundwater as reported by Cho *et al.*, (2004).

Annual Effective Doses (AED)

The corresponding Annual Effective Doses due to intake of Radon-222 from borehole water sample collected in Lapai town, Lapai Local Government Area, Niger state were estimated for the same water consumption rate using equation 3.2 and found to vary between 0.941 to 1.140 Sv and 1.882 to 0.228 Sv as shown in table 1 with corresponding mean values of 0.697 and 0.984 for adults and children. While the estimated annual effective doses due to ingestion of Radon-222 from Well water samples were found to range between 0.117 to 0.222 Sv and, 0.234 to 0.443 Sv with corresponding mean values of 0.169 and 0.33 Sv for Adults and Children. Student Villa (DW) and Effu-Kenchi (DW) which recorded the highest and lowest concentrations of Radon-222 for well water, gave the maximum and minimum annual effective doses (AED) respectively for all the two categories of people. 72.47% of the

Estimated Annual Effective doses were found to be above the recommended reference level of 0.1 Sv/year for intake of radionuclide in water set by WHO (WHO, 2004) as presented in figure 4.

Mean Annual Effective dose

The Mean Annual Effective Doses due to ingestion of Radon-222 from the two (2) water types were calculated for the two (2) categories of people (Adult and Children) and found to be 0.697 and 0.984SV in borehole water for adults and children respectively. While mean annual effective doses due ingestion of Radon-222 in well water samples were found to be 0.169 and 0.33 Sv for adults and children. All the mean annual effective doses were found to be above World Health Organization recommended reference level of 0.1Sv for ingestion of radionuclide in water (WHO, 2004). These results revealed that children, for the same water consumption rate receive significantly higher doses hence have higher risk of cancer compared to adults as illustrated in figure 1 with higher values of mean annual effective doses.

Conclusion

Results obtained from the calculation of the activity concentrations of Radon-222 in water samples collected at different locations of Lapai town, Lapai Local Government Area, Niger State revealed that 86.18% of the recorded values of radon concentrations in the present study as well as the mean values obtained for the two (2) water types were above the world average Maximum Contamination Level (MCL) of 10 Bq/L set by World Health Organization and the MCL of 11.1 Bq/L set by United States Environmental Protection Agency (USEPA, 1991). 20% of the recorded values of radon concentration which include well and borehole water samples from Student Villa (DB1), and borehole water sample exceeded the recommended action level of 100 Bq/L set by the World Health Organization (WHO, 2008). Therefore these water sources could pose a threat to the health of the inhabitant of Lapai town, particularly Effu-Kenchi and Student Villa if continually ingested without proper treatment. The likelihood of this threat to the health of these inhabitants (which could be

stomach or lung cancer) is more on children than adults as evident from the Estimated Annual Effective doses of the corresponding radon concentrations in water since most water source are above the reference level of 0.1 S/year set by World Health Organization (WHO, 2004) for intake of radionuclide in water.

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