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Determination of radon concentration in ground water in Dutsin-Ma Katsina State, Nigeria

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Abstract

Level of Radon contamination in selected Dutsin-Ma ground water sources was studied. Twelve (12) samples from three ground water sources were analyzed the study was conducted in areas where ground water was the only available water source to the populace for domestic applications. Liquid scintillation counter was employed in taking the measurements. Counter was first characterized for background count, calibration factor as well as detection limit. At the end of the analysis, the average concentration obtained was 2.86 and 2.12Bq/l for wells and borehole waters respectively. These values are below the standard (11.1Bq/l) set by United State Environmental Protection Agency (USEPA) and adopted by Standard Organization of Nigeria.

Keywords: Liquid scintillation counter, ground water, radon in growth.

Introduction

Water is found almost everywhere on earth and it's vital to life, as it constitutes 71% of earth surface and a major component of living organisms. It's significant to man in many applications – power generation, transportation, agriculture, etc. Therefore, its availability and quality (level of contamination) are crucial[1]. In developing nations including Nigeria are faced with the challenge of accessing safe drinking water sadly, and they depend largely on unsafe surface and ground water for their needs.

Radon has been reported to be naturally occurring as a uranium decay product (specifically ^{238}U), it's a noble gas that remains a gas even under normal temperature condition, it's a compact gas (having high density), been odorless, tasteless and having no color and due to its radioactive nature, happened to be hazardous to human health. It takes 3.8 days for its most stable isotope to decay. However, the study of radon by researchers is less due to its higher radioactive nature[2].

Ground water going past via a rock with a considerable amount of radon in it can easily pull toward radon and move it from one location to another; this is due the ease of radon dissolving in water. As such, the rapidity of motion of groundwater determined the presence of Radon in drinking water. Before water gets to the borehole source or spring, the radon get decayed when the rate of motion of the water is relatively slow[3].

Indoor air contributes about 95% exposure to radon, sources of drinking water contributes 1%. Radon discharged from running water doings contributes almost 1% from inhalation of radon gas, running water doings includes, bathing of humans, cleaning of utensils and environment and from shower. Drinking water impured with radon gas made up just 0.1% exposure. Studies showed that, most of the dose of radiation from these exposure resides in the stomach even though, the consequences of ingested radon are not well cleared[4].

Boreholes, spring and most especially wells are main sources of drinking water for many homes in developing nations. Volatile radon is released to ground water as it passes through uranium rich rock, making its contamination high in ground water. As a result higher radon contaminations are found in ground water than surface water[5].

Due to cancerous effect of high level and long exposure, United States Environmental Protection Agency considers polonium, radon radiation progeny, and serious heath hazard[6].

Among the main challenges faced by developing is inadequate portable water. Over the past 25 years, studies on the radon levels in ground water sources available to the populace have carried out[7].

Complementary relationship between some particular types of rocks with radon concentration at high levels in ground water has been established specifically. Mica granites and associated pegmatites are the two well-known[8].

When water with significant amount of radon happened to be in wells meant for domestic purposes, the threat to human health is doubled, stomach cancers would be the results of intake of these waters, though inbreathing of the gas which is at ease of release from tap as the water flows is of major concern[9].

Radon poses serious health threat in human as it's implicated in lung cancer from cigarette smoking. The number one principal cause of cancer among people who doesn't smoke is radon as discovered by the Environmental Protection Agency (EPA) with almost 21,000 deaths related to lung cancer each year. Dutsin-Ma is full of rocks, granite as well as vulcanoic soils which are probable sources of radon. Ground water has been the major water source of Dutsin-Ma populace due to the inaccessibility of clean water from pipe in the area, boreholes and hand dug wells are the main sources[10].

Measuring the concentration of radon in the whole Dutsin-Ma locality will take a longer time and it will consume a lot of resources. As such some selected areas that solely rely on ground water (particularly borehole and hand dug well) are focused on in this research.

Materials and methods

Materials: The under listed are the materials used in this study, and they are so applied according to American Society for Testing and Materials description[11]. i. Sample bottles (plastic). ii. 20ml, 10ml, and 2ml disposable hypodermic syringes, all with 38mm (1in) hypodermic needles. iii. Surgical gloves. iv. Distilled water. v. Teflon or viton seal vial caps. vi. Scintillation cocktail. vii. Indelible ink, viii. Masking tape. ix. Liquid Scintillation Counter (Packard Tri-Carb LSA 1000TR).

Study area: The studied area is Dutsin-Ma town where water scarcity is very pronounced and the populace heavily depends on groundwater (borehole and well) sources for many activities e.g. domestic and agricultural purposes. The area is bounded by latitude $12^0$17.00N' to $12^0$17.84'N and longitude $007^0$26'E [12]. Dutsin-Ma share boundaries with various local governments of same states; to the north with two local government areas, Charanchi and Kurfi, to the east with Kankia, to the west with Dan-musa and Safana, and to the southeast with Matazu. 552.323km^2 has been reported to be the land size of Dutsin-Ma local government area and In the year 2006 according to the National Population Commission, the population of Dutsin-Ma was reported to be 169,829 with farming, cattle rearing and trading been the major occupation of the populace.

This research is based on the analysis of ^{222}Rn (its concentration) in some water samples from selected areas in Dutsin-Ma town. These selected sources of water are ground water and surface water sources in Bayan Area, Hayin Gada and Dogon karfe.

Sample collection: Using clean plastic samples bottles, water samples from water (borehole and well) was collected from Bayan Area, Hayin Gada and Dogon Karfe area in Dutsin-ma town.

Samples of water from hand dug well were collected using bailers, however, before taking the samples, the steadfast water was first bailed out from the well severally and allowing the well to fill up again all in order to ensure a candid water sample is taken, while water from boreholes were pumped out for a period of 3 minutes before taken samples.

In order to achieve a high level accuracy and to avoid interference, the water samples were analyzed immediately within 2-3 days of the collection.

Sampling: 10ml was carefully drawn from the source of the water into a syringe, however proper care was taken to avoid interference with air (aeration). Also, loss of radon-222 by grassing out was avoided during sample collation by maintaining proper care.

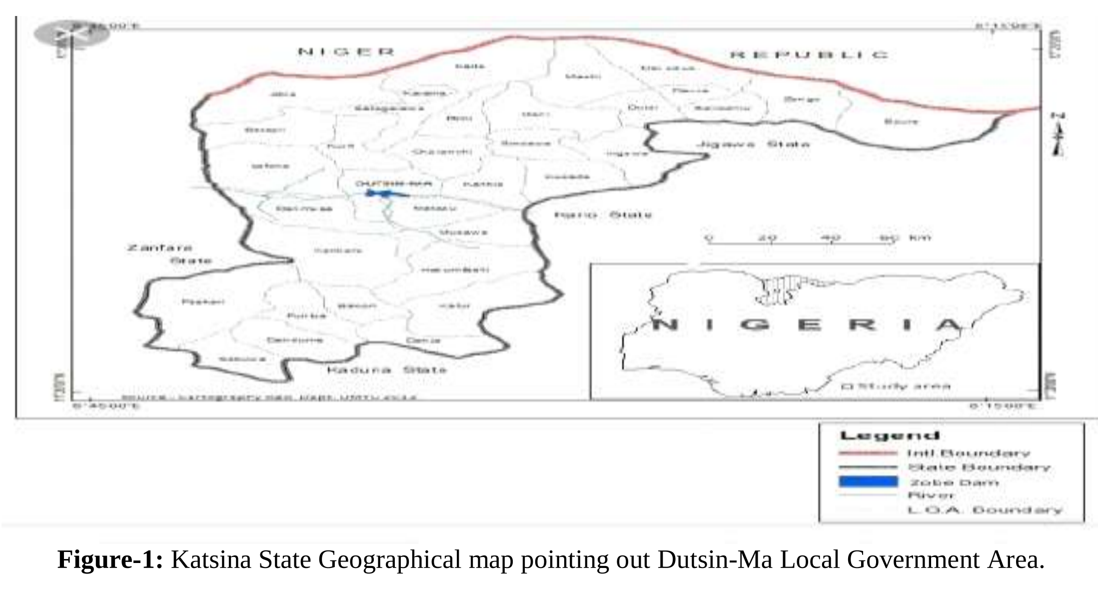

Figure-1: Katsina State Geographical map pointing out Dutsin-Ma Local Government Area.

Sample Preparation: 10ml of each sample were put into scintillation vial with 10ml install-gel scintillation cocktail. In order to extract ^{222}Rn in water phase into the organic scintillator, the tightly sealed vials were shaken for two minutes.

Sample analysis and Counting: After the preparation, the samples were taken for analysis using Liquid Scintillation counter (Packard Tri-Cab LSA 1000TR) situated at Centre for Energy Research and Training (CERT) in Ahmadu Bello University, Zaria, Kaduna State-Nigeria.

Counting procedures been carefully followed immediately after returning samples to laboratory. Using moderately wet cloth, the outer surface of each vial were carefully wiped by first deeping the cloth in ethanol and it was kept for at least 180 minutes (3 hours) in order to let the in growth of short period decay daughters of Radon-222. After 3 hours, ^{222}Rn and its daughters became in equilibrium. If there exist degree of disequilibria between ^{222}Rn and its short lived daughters within the same organic cycle, then, it would be taken into consideration by the counting manner just as illustrated and would be in line with samples' measurements.

Using calibrated window for alpha counting, each of the vials were counted for a pre-set period as they were carefully placed in the Liquid Scintillation Counter. After a period of 3 hours, when conveying the vials from the point of storage to the counter, they were not shaken as this could disrupt the equilibrium condition in the organic scintillant between ^{222}Rn and its daughters. Commencement of counting with date and time was recorded. ^{222}Rn concentration present in the sample determined an apt period of counting, however, for low-level measurements, a period of 5000 seconds per each vial is usually sufficient. Counting each of the vials with organic scintillant solution of 10ml and distilled or deionized water of 10ml determined the counting system background. Using the same period of counting and spectra-range just as that of the samples, the background was determined.

Results and discussion

Determination of ^{222}Rn concentration in the water samples: ^{222}Rn concentration in the water samples was determined using equation (1);

$$Cs = \frac{(R - R_o)exp^{(\lambda \Delta t)}}{\mathrm{V} \times \mathrm{E}}$$

Where: R=Gross counting rate for the sample pulses per second, R_o= Counting rate for the blank counting vials in pulses per second, λ=Decay constant for ^{222}Rn days^{-1} (0.182days^{-1}), V= Volume of the sample, Δt= Time interval in days between the collection of the sample and commencement of the counting, E=Counting efficiency in pulses per second.

Water samples from the two sources (underground well and hand pump borehole) were collected, taken to and analyzed. The depths of the wells and the boreholes were about 3-8m and 100-800m below the surface respectively. The analysis of the twelve (12) water samples from the borehole and hand dug wells was carried out using liquid scintillation counter. The pH and radon concentrations of the samples are presented in Table-1.

Table-1: ^{222}Rn Concentration from the Study Areas.

Sample ID	Sample pH	Rn Conc Bq/L
DK W1	7.80	1.21
DK W2	7.62	1.88
DK B1	6.93	0.79
DK B2	7.00	1.73
BA W1	7.13	2.23
BA W2	6.56	8.54
BA B1	6.86	4.90
BA B2	7.21	1.03
HG B1	7.33	3.22
HG B2	6.73	1.06
HG W1	6.46	2.19
HG W2	6.96	1.11

Key: BA = Bayan area, DK = Dogon Karfe and HG = Hayin Gada.

The ^{222}Rn concentration determined for both the (hand-dug wells and boreholes) from some selected areas in Dutsin-Ma (Hayin Gada, Bayan Area and Dokon Karfe) were presented in Table-1 and also shown in Figure-2 and 3 for well and borehole water respectively.

Discussion: In this study, twelve (12) samples from two different water sources (6 underground wells and 6 from boreholes) were taken from the selected areas for analysis. Figures-2 and 3 shows the result of the entire chart regarding the radon concentration in well and borehole water sources respectively.

The three sampling areas include Hayin Gada, denoted with (HG), Bayan Area denoted with (BA) and Dogon Karfe denoted with (DK). The mean concentration of the radon concentration in borehole and well water sources was found to be 2.12Bq/L and 2.86Bq/l respectively. 11.1Bq/L and 10Bq/L are the highest concentration limits / standards set by United State Environmental Protection Agency in the year 1991 and World Health Organization, 1993; UNSCEAR, 1993 respectively. The mean concentration of radon-222 obtained from the two water sources of the study/area are both below the highest concentration limits/standards[13].

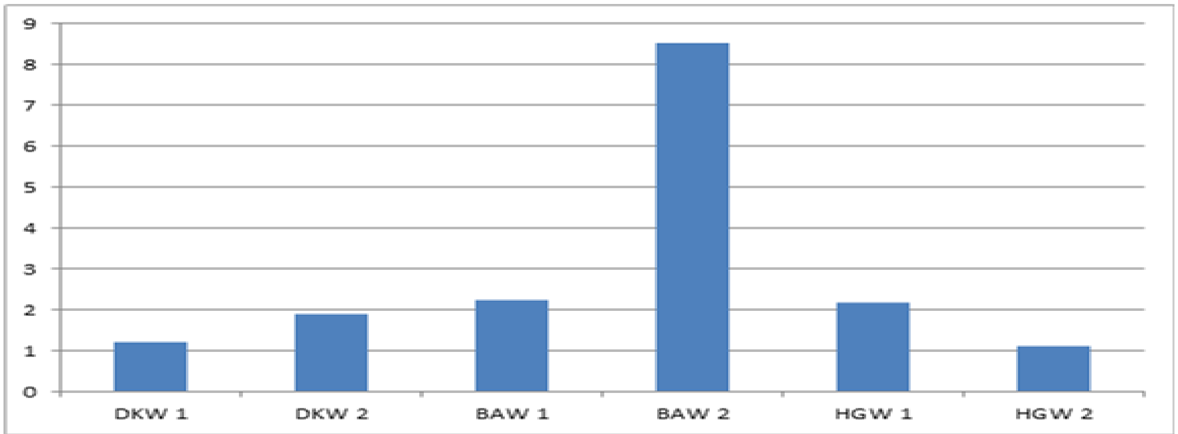

Figure-2: Plot of underground well water ^{222}Rn concentration.

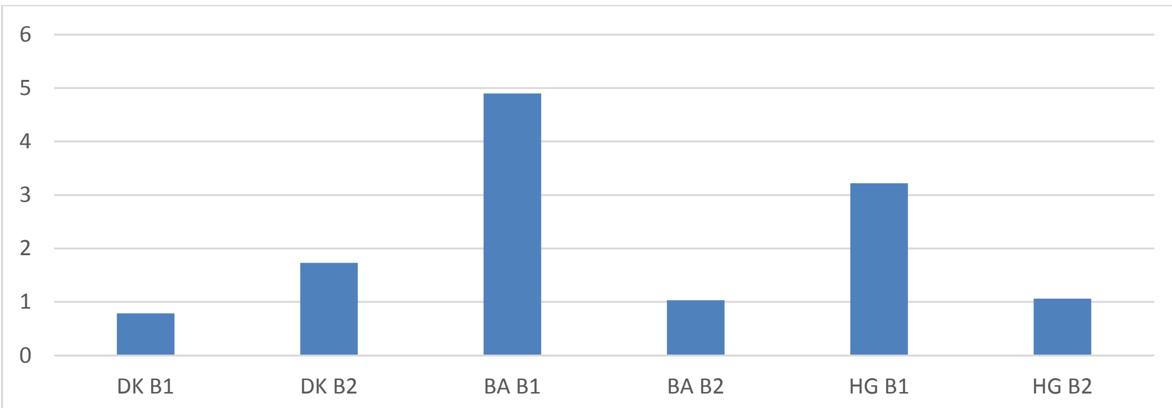

Figure-3: Plot of borehole water ^{222}Rn concentration.

Well water: Well type has some influence on radon concentration in ground water. Research shows that low amount of radon is found in surface water than deep bedrock water. Wells with high discharge capacity (public water) has low radon concentration compared to low discharge capacity supplies (private waters) because public wells draw from gravel aquifers to meet the high water demand, consequently diluting radon amount. Therefore, radon level in private supply is always multiples of radon concentration in public water well[14].

It has also been found that low discharge of the private wells and increasing the exposure of water to radium have effect on radon level elevation[15]. Also reported is the negative correlation between well yield and radon level in water, with low radon level being associated with high yield wells – suggesting the impact of residence time on radon content[14].

In this present studies the low concentration of radon suggest that it is as a result of decrease in exposure of water to radium. Other reasons that are attributed to this low radon concentration also range from lesser human activities such as mining, exploration and quarrying and less weathering around these areas.

Borehole Water: In this present study the mean radon concentration of the borehole was found to be 2.12Bq/L and this value is lower than the mean radon concentration of well water, and still, this value is below the value recommended by WHO. Below shows the chart for radon concentration in borehole.

Radon concentrations in water is highly dependent on three factors – natural activities, industrial processes and human activities located close to the water source. Generally, low radon concentration has been reported for shallow wells and water sources from areas with less human and industrial activities. The mean radon concentration in both wells and boreholes were lower than the world mean concentration of 10Bq/L by WHO[16] and UNSCEAR[17] and the maximum permissible value of 11.1 Bq/L by USEPA[18]. This is attributable to lower range of distribution of radon daughter products in the environment, soils and the natural water[19].

Radioactive particles from radon decay can be trapped in lung during breathing. These particles are further disintegrated to give off some destructive energy which can damage the lung over time, and eventually leads to lung cancer. Due to the differences in peoples' physiology and metabolism, the effect of radon on humans differs.

Using water with high level of radon concentration for a long time can induce cancer. There is drawn just like other undesirable substances in the environment uncertainty about the magnitude of radon health risks. Nonetheless, a lot is known regarding radon risks compared with risks associated exposure to radon.

The above notwithstanding, scientists believe that radon is next to cigarette smoking as cancer causing agent[14]. Due to the inherent differences in body's immune system, radon doesn't affect everyone the same way.

Symptoms of chronic Radon-222 effects can take a very long time (years) to reveal themselves depending upon the amount of Radon-222 inhaled and or taken. The findings of a short while study done by the U.S. Environmental Protection Agency (EPA) estimates that a person has a 1 percent (1 in 100) risk of developing cancer from lifelong household use and consumption of water containing 740Bq/L of dissolved radon, or breathing air containing 0.148Bq/L of radon. This is considered a high risk when compared to the cancer risks from other contaminants in drinking water, which are in the range of 1 in 10,000 to 1 in 1 million[20].

The prevalent way for obtaining ground water of low Radon-222 concentration is by accessing safe shallow groundwater, rainwater harvesting, treating water using aeration equipment and or granular activated carbon, taking a well-packed and treated bottle container water will lower the possible adverse effects from radon.

A number of factors are responsible for variation in radon content in water, among these is aquifer mineralogy which baseline radon content in ground water. Knowledge about the amount of radon from well water may be improved by studying radon level in a borehole water.

Decrease in water-table level may influence variation in radon content in borehole water where the borehole intersects many bedrock fractures by eliminating some fracture supplying the well[21]. Complication in mixing may arise in a borehole with multiple fractures having different flow rates and radon contents, though, only few fractures may provide all the flows in well with crystalline rock aquifers[22]. Difference or similarity in radon concentration in well water can be well understood using radon concentration profile, which measures the concentration directly by taking the gamma-ray log of the well[14]. However, radon may not emit gamma-ray itself, its daughters with short lives (^{214}Pb and ^{214}Bi) do. It has been found that gamma-log from ground water flow is dominated by radon daughters[23]. It's also found that total gamma activity increases near high radon concentration ground-water inflow and decreases along the flow inside the borehole[21,22]. Study has shown that radon content water can be measured directly at discrete intervals by employing straddle packer assembly which shows the vertical variation in the water column[24].

Conclusion

The radon concentration in ground water (borehole and well) water samples from some specified areas of Dutsin-ma town were determined using the Liquid Scintillation Counter.

The investigation revealed, that the mean concentration of radon in well water was greater than that of borehole water, both were below the mean concentration of 10Bq/L by WHO[16] and UNSCEAR[17]. And the maximum accepted value of 11.1Bq/L set by USEPA and the Standard Organization of Nigeria (SON). As proactive measure to safeguard human health, radiological test (gross alpha activity determination) is recommended even for water samples with low radon activity level to ensure safe water supply for human consumption.

From the result, it can be predicted that due to the low-level of radon concentration in boreholes and well water, the people in Dutsin-Ma (Hayin Gada, Bayan area and Dogon Karfe area) are not expose to radon danger such a lung cancer, leukemia and other chronic disease.

In conclusion, since radon poses a serious health risk (lung cancer) and represents public health burden both in human and economic terms, preventive measures have to be taken particularly for the fact that there are simple and relatively low-cost solution to radon concentration problem.

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