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Preliminary Studies on ^{222}Rn Concentration in Ground Water from Zaria, Nigeria

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Abstract: *Preliminary studies on ground water samples from selected wells and boreholes in the city and surrounding areas of Zaria were carried out to determine the concentration of ^{222}Rn. The analysis was carried out during the dry season when the weather was fairly stable and the community depended solely on ground water sources for domestic use. Measurements were carried out using a liquid scintillation counter at the Center for Energy Research and Training, Ahmadu Bello University, Zaria-Nigeria. The average concentration obtained was 7.18 ± 1.11 Bq/ for wells and 7.41 ± 2.04 Bq/l for borehole waters. The results are within the maximum concentration limit of 11.1 Bq/l and world average value of 10 Bq/l for drinking water.*

Keywords: ^{222}Rn concentrations, ground water, LSC, wells, boreholes

1. INTRODUCTION

Water is one of the most abundant substances on earth and is a principal constituent of all living things. It is used in various aspects of daily lives that include power generation, agriculture and domestic activities.[1] It is therefore important for water to be free from chemical, microbiological and radiological contamination.[2]

Radon is a naturally-occurring element that contributes to radiological contamination of drinking water and poses a health risk. Since the late 1980s, it has been identified as a health concern. Radon radioactive gas is formed when uranium or radium decays. It escapes from the earth's crust through cracks and crevices in the bedrock and either dissolves in ground water or seeps through foundation cracks into the environment/human habitations.[2,3]

Radon is a colourless, odourless radioactive gas that is a daughter element in the decay chain of uranium 238 (U-238).[4] The alpha radiation emitted by radon and its progeny, polonium, is considered a significant health hazard by the United States Environmental Protection Agency[5] because elevated levels and/or extended durations of exposure can lead to lung cancer. The presence of radon in the earth's crust continuously diffuses through the bedrock, leading to the formation of ^{222}Rn in ground water. Radon has the highest solubility in water of the noble gas, with a mole fraction value of 0.00125 at 37°C and a half life of 3.8 days, which is 15 times higher than that of helium or neon.[6] Because of this property, radon can accumulate in high concentrations in ground water and possess a greater health risk for people who ingest or inhale it.

Radon in water is primarily a problem for water supplies that extract water from drill holes in rocks, which have somewhat higher uranium concentrations than the average bedrock. Some types of rocks that have uranium concentrations greater than 5 ppm of uranium often include granites, syenites, pegmatite, acid volcanic rocks and gneisses. Wells in areas with these rocks may contain ground water with radon concentrations of 50–500 Bq/l or considerably higher.[7]

Inadequate potable water is one of the major problems facing most developing nations. Pipe borne water is largely nonoperational where provided; therefore, most of the populace rely heavily on untreated ground water sources as their primary sources of drinking water, and the authorities concerned have not taken serious measures to provide adequate and safe drinking water for the area. Hence, it is important to investigate the radiological content of water from such sources.

Across Nigeria, particularly in the city of Zaria, data on radon concentrations in drinking water sources are lacking, even though most of the inhabitants of the country, especially those in the rural areas, depend solely on ground water and surface water sources for drinking, household activities and agricultural purposes. This water might contain higher-than-normal concentrations of radon. This study aimed to determine the radon concentration in the ground water sources that serve as sources of domestic water for the city and surrounding areas of Zaria. The study was carried out during the dry season between October and March during which the weather was fairly stable. The residents depend solely on ground water sources from wells and boreholes for domestic purposes because of the acute water scarcity during the dry period.

Measurements were carried out using a liquid scintillation counter. In liquid scintillation analysers, energy from emitted radiation is absorbed by a fluorescent material (scintillator or fluorophore) and re-emitted as light photons.[3,8]

The light photons are detected by one or more photomultiplier tubes and converted to electrical energy for analysis. The radioactive material is brought into close contact with the scintillator, usually by dissolving both the radioactive material and the scintillator in a suitable solvent; this type of instrument is particularly suitable for the qualitative measurement of radiation with limited penetrating power, such as alpha particles, beta particles and soft x-rays. The instrument also has a very short resolving time, so high rates of disintegration can be measured.[9]

1.1 Description of the Study Area

The city of Zaria was selected because of the scarcity of water and its total dependence on ground water sources for drinking, domestic use and agricultural purposes. The area is bounded by latitudes 11°02'S, 11°08'N and longitudes 7°31'W, 7°44'E.

The study area falls within the semiarid region of Nigeria.[10] It is underlain by gneisses, magmatite and meta-sediments of the Precambrian age, which have been intruded by a series of granitic rocks of late Precambrian to lower Paleozoic age (a portion of the study area fall within a region underlain by older Granite that belongs to a single batholith called the Zaria Granite batholith; the remaining portion is underlain by Gneissic rocks)[17]. Details on Zaria batholith with schist and gneissic rocks are provided in Webb.[14] Details on the geology of this region are further described in The Geology of the precambian to lower palezoic rocks at Northern Nigeria.[17]

2. EXPERIMENTAL

2.1 Sample Collection and Pretreatment

Samples were collected in cleaned plastic sample bottles. The containers used for the sample collection were cleaned to avoid contamination or adsorption of the analyte (radon) presence in the samples.

The water samples from underground wells were collected with the aid of bailers, but the stagnant water in the wells was first purged by emptying out and allowing the wells to refill. Several well volume purges were performed to ensure that fresh samples were obtained. Boreholes were operated for at least three minutes before sample collection.

The samples were analysed as soon as possible (maximum of three days) after collection to achieve maximum accuracy, because the composition of the sample may change if samples are left for long before performing the analysis.

2.2 Sample Preparation and Analysis

10 ml each of the samples was added into a scintillation vial containing 10 ml of the insta-gel scintillation cocktail. The vials were sealed tightly and shaken for more than two minutes to extract ^{222}Rn in water phase into the organic scintillator.

2.3 Sample Analysis

The prepared samples were analysed using a liquid scintillation counter (Tri-Carb-LSA1000) located at the Center for Energy Research and Training (CERT), Ahmadu Bello University, Zaria–Nigeria. The samples were analysed after they were allowed to stand for three hours after preparation in order to establish radioactive equilibrium between ^{222}Rn and its daughter progeny.

The liquid scintillation counter was calibrated prior to the analysis using IAEA ^{226}Ra standard solution. For the calibration, the ^{222}Rn standard samples were counted for 60 minutes. Background count measurements were also made for the same time period (60 min). The ^{222}Rn activity concentration was calculated using the following equation:[4]

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

where,

Rn = radon level in Bq/l;
SC = sample count rate (count min^{-1});
BC = background count rate (Count min^{-1});
K = calibration value;
T = elapsed time from sampling to testing given in minutes.[4]

The annual effective doses due to the intake of radon were calculated from the mean activity concentration using the following equation:[7]

$$E_{Rn} = DF_{Rn}.\ I_w.\ A_{222Rn} \qquad (2)$$

where DF_{Rn} is the effective dose per unit intake of radon in water for adults, taken as 10^{-8} Sv/Bq from UNSCEAR 1993 report,[13] and I_w is the water consumption rate (l/a), taken to be 2 l per day from WHO report.[14]

3. RESULTS AND DISCUSSIONS

Two categories of water samples both of which are ground water (hand-dug wells and boreholes) from the city and surrounding areas of Zaria were collected and analysed. The hand-dug wells have depths of about 3–8 m while the boreholes have depths of 100–700 m. A total of 15 samples were collected and analysed; 5 from wells and 10 from boreholes (Table 1).

As the results show, most of the values are below 10 Bq/l (Table 1, Figure 1), representing about 80% of the total samples analysed. Thus, only about 20% of the samples are above 11 Bq/l and 10 Bq/l, the standards set for Radon in water and drinking water, respectively. Moreover, the mean values of 7.18 ± 1.11 Bq/l for wells and 7.41 ± 2.04 Bq/l for boreholes are lower than the Maximum Concentration Limit (MCL) of 11.1 Bq/l set by the USEPA (1991) and the world average value of 10 Bq/l set by World Health Organisation.[3,8,]

Even though the mean concentrations do not exceed the set standard, the distribution according to the type of water source shows that borehole water sources are generally more enriched in ^{222}Rn concentration than well water sources (Figure 1).

Table 1: ^{222}Rn concentrations and annual effective doses in samples of water from Zaria metropolis

Sample ID	Latitude(°)	Longitude(°)	^{222}Rn Conc.	Annual effective dose (μSv/Year)
ZW1	11.07	7.76	2.42 ± 0.56	0.48
ZW2	11.03	7.42	8.13 ± 1.85	1.63
ZW3	11.06	7.69	6.43 ± 0.54	1.29
ZW4	11.03	7.42	2.32 ± 0.52	0.46
ZW5	11.03	7.42	16.60 ± 2.07	3.32
ZB1	11.06	7.72	8.02 ± 1.83	1.60
ZB2	11.03	7.43	4.07 ± 0.02	0.81
ZB3	11.02	7.43	21.31 ± 2.62	4.26
ZB4	11.03	7.42	3.05 ± 0.75	0.61
ZB5	11.07	7.72	8.89 ± 0.98	1.78
ZB6	11.07	7.69	15.63 ± 1.95	3.13
ZB7	11.06	7.71	6.39 ± 0.53	1.28
ZB8	11.02	7.42	3.11 ± 0.76	0.62
ZB9	11.03	7.42	0.77±0.08	0.15
ZB10	11.04	7.43	2.90±0.70	0.58

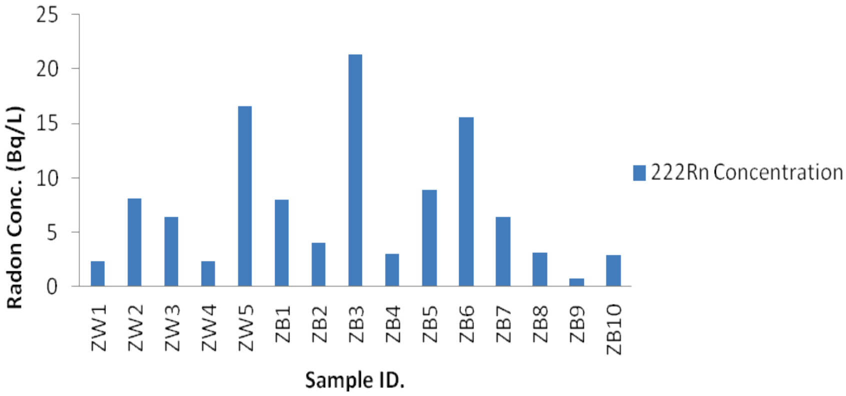

Figure 1: ^{222}Rn concentration from wells and boreholes samples of Zaria Metropolis.

Radon concentrations in water depend largely on the source of radon emanation, which may be the result of natural processes, industrial or agricultural activities and human activities in the area where the wells are located. Different findings have been reported by many researchers on radon concentrations in water sources worldwide.[13,14]

Higher concentrations of radon were recorded in borehole samples compared with wells samples from the sampled area of Zaria, likely because boreholes are deeper and closer to surface sub soil, which is underlain by the older granite. Moreover, the areas near boreholes have high level of human and agricultural activities as well as natural processes.

The generally low levels of ^{222}Rn concentration in much of the samples could be attributed to the shallowness of most of the wells and boreholes, which would allow much of the ^{222}Rn to escape. The desorbed/escaped ^{222}Rn must have therefore added to the existing airborne radon in the area. Exposure to radon from inhalation may also pose a public health concern.[15,16]

The annual effective dose due to ingestion of ^{222}Rn in the water varied from 0.46 to 3.32 µSv, with an average of 1.44 µSv for well water. For boreholes, the value varied from 0.15 to 4.26 µSv, with an average of 1.48 µSv. The overall average is 1.46 µSv, as shown in Table 1.

It is also noted from the results that among the 15 samples analysed, the borehole samples recorded higher ^{222}Rn concentrations and higher annual effective doses compared with the well water samples. In each of the samples collected, though the activity concentration varied, the geological content was almost the same. This similarity in geological content could result from the ground water formation, discharge rate and the radon emanation rate from the parent nuclide uranium or radium. The effective doses are also within the World Health Organisation (WHO) recommended reference level of 0.1 mSv per year for intake of radionuclides in water.[7]

4. CONCLUSION

Water samples from various sources in the city and surrounding area of Zaria were analysed for their Rn concentration. The results obtained in this study indicate that the ^{222}Rn concentration was in the range of 2.42–16.60 Bq/l and 3.11–21.31 Bq/l for wells and borehole water samples, respectively. Mean concentrations were measured as 7.18 ± 1.11 Bq/l for wells and 7.41 ± 2.04 Bq/l for boreholes. While the average values are within the maximum concentration limit of 11.1 Bq/l set by USEPA and world average value of 10 Bq/l set by WHO, several incident values from well and borehole sites exceeded these values.

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