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Assessment and Comparative Study of Radon Level in Water Samples Collected within Ogbomoso Metropolis, Oyo State, Nigeria

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Abstract

In the recent time, due to the unavailability of public pipe borne water which the government provides for use, the alternative uncased and cased water became the popular means of water supply, both in rural and urban areas, not minding the likely health effect that may arise due to high level of concentration of radon and its progeny in drinking water from the aforementioned sources. Hence, this study focuses on the radon concentration in underground water samples collected across Ogbomoso land. A total of 300 water samples were collected, comprising of 160 water samples from uncased and 140 samples from cased well. The samples were analysed using a well calibrated active electronic radon detector RAD7 (DURRIDGE Company Inc., USA). The results obtained revealed that the radon concentration of the uncased well is in the range of 3.30 $kBqm^{-3}$ to 33.95 $kBqm^{-3}$, while the radon concentration for the cased well fell in the range 30.39 $kBqm^{-3}$ to 65.98 $kBqm^{-3}$. The results obtained from the two categories of water samples analyzed showed that the cased well sources had the highest concentration of radon compared with the limit set by local and international bodies. Hence, appropriate measures should be taken to mitigate the level of concentration of radon in the water within the study area before consumption. Concerted effort should also be made by the health workers to enlighten the residence on the potential harmful effect of radon to human health.

Keywords: Comparative Study; Radon Level; Water; Ogbomoso Metropolis; Nigeria.

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1. Introduction

Water is an essential commodity of life and its importance to human cannot be over-emphasized. The existence of organic matter would have been impossible if not for water, as water is the most abundant element in protoplasm, the essential material of which plants and animals are composed [1]. Water serves as solvent that promotes chemical activities, transportation medium for nutrients, hormones, enzymes, minerals, nitrogenous waste and respiration gases as well as several other important functions [2, 3]. It was reported that, the Earth's surface is covered with about 70% of water, which is estimated at a volume of approximately 1.4 billion km^3, out of which groundwater occupy about 30%. Water is said to be potable provided it is safe to use for domestic purposes without causing damage to human health [4]. In essence, the water must be free of harmful concentrations of chemicals, pathogenic microorganisms and radionuclides. However, the distribution of radionuclides in water arise from trace amounts of terrestrial radionuclides comprising of the decay series of ^{238}U,^{232}Th and the singly occurring ^{40}K, most of which are dissolved solids from rocks, soils and mineral deposits [5]. The presence of radionuclides in water can cause human internal exposure which result from the decay of radionuclides taken into the body through ingestion and inhalation [6]. These radionuclides are then distributed within the sensitive organs of human body according to the metabolism of the element involved [7]. Of most radiological concern to human health is radon, most especially ^{222}Rn and its short decay products, as it contributes about 55% to the annual radiation dose received by the general public [5]. Radon is a colorless, odorless, tasteless and naturally-occurring radioactive gas, with a half-life of 3.8 days. It originates from the natural decay series of ^{238}U, found in terrestrial materials buried within the Earth's crust [8, 9]. While the health risks associated with high radon exposures in underground mines have been known for a long time, relatively little attention was paid to environmental radon exposures until the 1970s [5], since then several studies on radon continues unabated. Radon travels through soil and enters buildings through cracks and holes in the foundation of the building. Radon gas can also diffuse from rock into water from underground sources whose contribution depends on the concentration of radon in the water sources used for domestic purposes such as drinking, cooking, showering, washing and laundry. The concentrations of radon in water may range over several orders of magnitude, generally being highest in underground water, and lowest in surface water. Thus, radon is not a concern in surface water that comes from lakes, rivers, and reservoirs, because the radon gas is released into the air before it arrives at the water supply. However, radon is of major concern if the water comes from underground sources, such as wells and boreholes that pump water from an aquifer [4, 5, 8]. Radon in water supply poses an inhalation and ingestion risk. Hence, radon is a known human carcinogen, as it has been reported that radon is the second leading cause of lung cancer deaths after smoking [4, 8]. Owing to the increase in population size and the inadequate or unavailability of government potable water to cater for the increase, the populace had embarked on obtaining water whether potable or not, from whatsoever means available. In Nigeria, half of the land area of 923 768 km^2 is underlain by crystalline rocks or basement complex and the remaining half by sedimentary rocks, which most studies have reported to contribute highly to radon level. In view of this, the study takes a look into different available water sources in Ogbomoso and its environs so as to determine and quantify the concentration of radon in water utilized for domestic activities, estimate the annual radon ingestion and inhalation dose from the water and recommend any safety measure where necessary.

2. Materials and Methods

2.1 Study Area

The study area is Ogbomoso, located between latitude 8°06´70″ and 8°06´98.7 north and between longitude 4°14´28.2″E and 4°14´56.9″ east. It is one of the largest city in Oyo State, Nigeria with geology of the area consists of Precambrian rocks that are typical of the basement complex in Nigeria [10]. The major rock associated with Ogbomoso area form part of the Proterozoic schist belts of Nigeria (Figure 1), which are predominantly, developed in the western half of the country, details of which are reported by the authors in [10, 11].

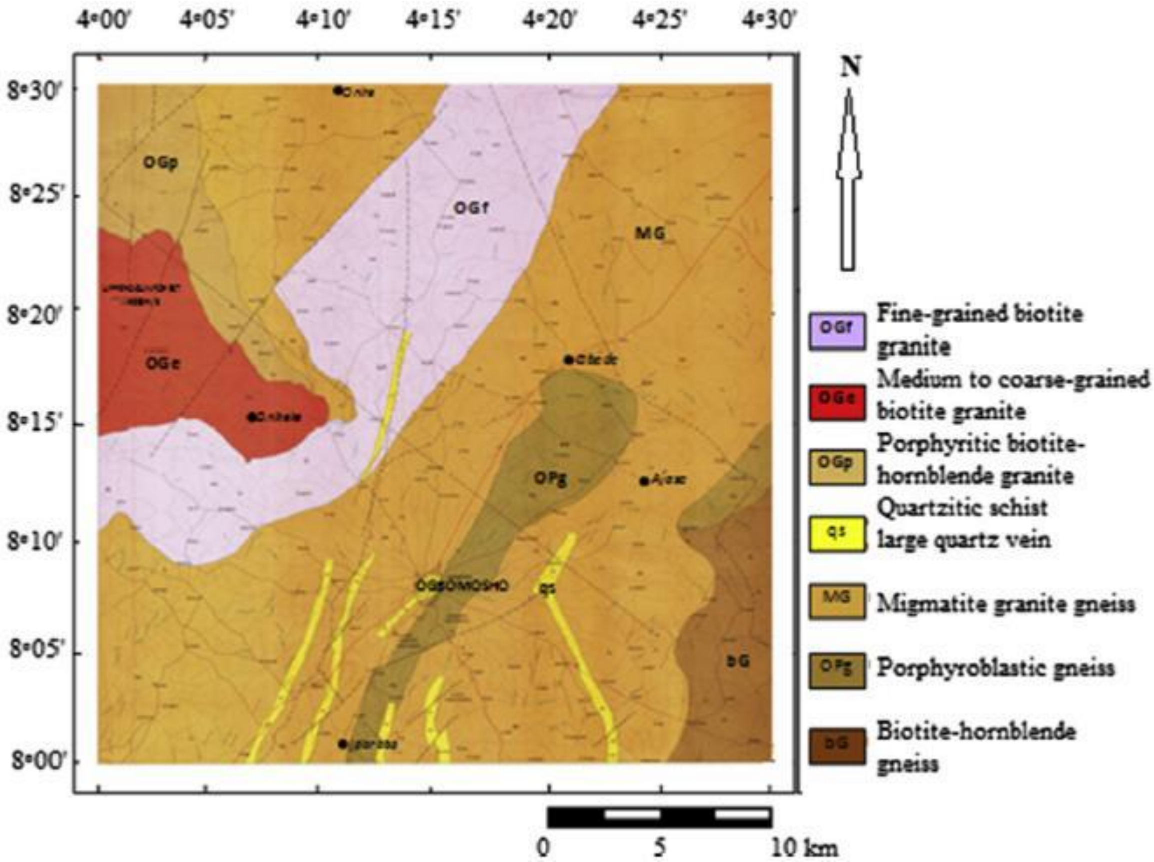

Figure 1: Geological map of Ogbomoso (Adapted from [10])

2.2 Sample Collection

Three hundred (300) water samples were collected across Ogbomoso land comprising, one hundred and sixty (160) from uncased well and one hundred and forty (140) from cased well for analysis. Samples were collected at early hours of the day from different water sources comprising of uncased well and cased well (boreholes). Effort was made to reduce the water turbulence so as to avoid loss of radon due its short have life. Each sample was collected into a clean and dried 1.5 L bottle previously washed with dilute nitric acid and further rinsed with distilled water before the samples were tightly sealed and labelled accordingly.

2.3 Sample Analysis

The prepared samples assayed were analysed in-situ using a well calibrated active electronic solid state alpha detector RAD7 connected to a RAD H_2O accessory kit (DURRIDGE Company Inc., USA). The method was adopted because of the short half-life of ^{222}Rn. The detector uses alpha spectrometry technique to sniff and grab out radon gas concentration. The detector is capable of accurately measuring radon gas concentration in water sample within 30 min making it an appropriate means of detecting radon gas having its half life of 3.8d also eliminates the need for noxious chemicals. The detector was employed by connecting it with a bubbling kit which enables it to degas radon from a water sample into the air in a closed loop. Within the closed loop is desiccant to dry the air before entering the detector for the measurement of radon concentration. Each water sample was assayed three times and average concentration of ^{222}Rn in the water was determined.

2.4 Estimation of Annual Effective Dose

Radiation dose to the public from radon and its progeny via water consumption of usage is a serious threat than other water pollutants, as radon in drinking water can deliver a radiation dose to the stomach through ingestion and inhalation. Thus, the annual effective dose for ingestion (AED_{ing}) and inhalation (AED_{inh}) were estimated using Equations (1) and (2) respectively [5].

$$AED_{ing}\,(mSvy^{-1}) = RC_W \times W_C \times EDC_{ig} \times 10^{-3}m^3L^{-1} \quad (1)$$

$$AED_{inh}\,(mSvy^{-1}) = RC_W \times R_{AW} \times EF_{in} \times OF_{in} \times DCF \quad (2)$$

Where, RC_W is the determined radon concentration in water ($kBqm^{-3}$), W_C is the weighted estimate of water consumption for infants, children and adults (60 ly^{-1}), EDC_{ing} is the effective dose coefficient for ingestion (3.5 $nSvBq^{-1}$), R_{AW} is the ratio of radon in air to water (10^{-4}), EF_{in} is the indoor equilibrium factor (0.4), OF_{in} is the indoor occupancy factor (7000 hy^{-1}) and DCF is the dose conversion factor (9 $nSv(Bqhm^{-3})^{-1}$) for radon and its progeny [5].

3. Results and Discussion

The radon concentration and annual effective dose obtained for the assayed water samples are as presented in Table 1 for the uncased and cased well water sources respectively. The results shown that the radon concentration of the uncased well is within the range 3.30 $kBqm^{-3}$ to 33.95 $kBqm^{-3}$, while the radon concentration for the cased well fall in the range 30.39 $kBqm^{-3}$ to 65.98 $kBqm^{-3}$. The report of this study indicated that all the samples analysed had radon concentration greater than the maximum permissible limit of 0.1 Bq/L set by the local regulatory body [12] and 11.1 Bq/L (300 pCi/L) proposed by [8]. The depth of the underground sources may contribute to this high concentration, as the saturated zone of the Earth crust had been reported to contain high amount of radon [13, 14, 15]. The report of this study confirmed the previous researcher submission about the geological structure and morphology of Ogbomoso. The annual effective dose due to ingestion estimated from the radon concentration obtained show that, the dose varies from 0.001 $mSvy^{-1}$ to 0.014 $mSvy^{-1}$ for all the water sources assayed. The results obtained show that thirty-three (33) locations had an annual effective dose higher than the permissible limit of 0.002 $mSvy^{-1}$ for radon gas ingested in underground water sources [5], as radon ingested in drinking water will give a radiation dose to the lining of the stomach that may lead to stomach cancer [4].

Table 1: Radon Concentration ($kBqm^{-3}$) and Annual Effective Dose ($mSvy^{-1}$) in the water

S/N	Locations	Numbers collected	RC	AED_{ing}	AED_{inh}
1	Odo-oba (UW)	8	3.30	0.001	0.008
2	Ikose (UW)	7	8.20	0.002	0.021
3	Kinnira (UW)	7	6.30	0.001	0.016
4	Aaduin (UW)	8	7.42	0.002	0.019
5	Isale-Ora (UW)	8	5.76	0.001	0.015
6	Olorunda (UW)	6	4.21	0.001	0.011
7	Obandi (UW)	8	5.67	0.001	0.014
8	Aarada (UW)	8	6.29	0.001	0.016
9	Baale Yaku (UW)	8	4.53	0.001	0.011
10	Olomi (UW)	8	5.87	0.001	0.015
11	Arowomole (UW)	8	13.30	0.003	0.034
12	Idi-Oro (UW)	8	12.50	0.003	0.032
13	Caretaker (UW)	8	12.10	0.003	0.030
14	Sunsun (UW)	8	15.21	0.003	0.038
15	High School (UW)	8	12.90	0.003	0.033
16	Apake (UW)	8	13.21	0.003	0.033
17	Idi-Abebe (UW)	7	11.89	0.002	0.030
18	Atenda (UW)	7	13.45	0.003	0.034
19	Oko (UW)	7	23.48	0.005	0.059
20	Iresapa (UW)	5	24.21	0.005	0.061
21	Iresaadu (UW)	5	33.95	0.007	0.086
22	Navy Area (UW)	5	33.21	0.007	0.084
23	Sabo (BH)	8	50.43	0.011	0.127
24	Masifa (BH)	8	45.32	0.010	0.114
25	Saja (BH)	8	35.91	0.008	0.090
26	Oja-gbo (BH)	8	55.03	0.012	0.139
27	Ayegun (BH)	8	44.99	0.009	0.113
28	Taraa (BH)	8	30.39	0.006	0.077
29	Okelerin (BH)	8	41.35	0.009	0.104
30	Iluju (BH)	7	39.56	0.008	0.100
31	Saamo (BH)	5	45.87	0.010	0.116
32	Ikoyi (BH)	8	50.32	0.011	0.127
33	Aipo (BH)	6	51.19	0.011	0.129

34	Tewure (BH)	5	44.21	0.009	0.111
35	Iwagba (BH)	8	41.20	0.009	0.104
36	General (BH)	8	47.52	0.010	0.120
37	Adenike (BH)	8	52.30	0.011	0.132
38	Aroje (BH)	8	63.20	0.013	0.159
39	New Waso (BH)	5	40.14	0.008	0.101
40	Iresa market (BH)	4	65.98	0.014	0.166
41	LAUTECH (BH)	12	60.21	0.013	0.152

UW – Uncased well, BH – Borehole

In addition, the annual effective dose due to inhalation estimated from the radon concentration obtained show that, the dose range from 0.008 $mSvy^{-1}$ to 0.021 $mSvy^{-1}$ for all the water sources assayed. The results obtained show that thirty-one (31) locations had an annual effective dose higher than the permissible limit of 0.025 $mSvy^{-1}$ for exposure to radon gas via inhalation route [5], and breathing in radon in indoor air can cause lung cancer [8]. These values are however less than 1.1 $mSvy^{-1}$, which is the total annual effective dose from inhalation of ^{222}Rn and its decay products present in air from all sources. As an evaluation of international research data [5] has concluded that, on average, 90% of the dose attributable to radon in drinking-water comes from inhalation rather than ingestion. Therefore, controlling the inhalation pathway rather than the ingestion pathway is the most effective way to control doses from radon in drinking-water.

4. Conclusion

With the result obtained from this study, it can be deduced that drastic measures be taken by appropriate authorities towards the reduction of radon concentration in water within the study area. Concerted effort should also be made by the health workers to enlighten the residence on the potential harmful effect of radon to human health. This will help in protecting humans from the risks associated with the inhalation and ingestion of radon gas.

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