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Assessment of radon concentration in groundwater within Ogbomoso, SW Nigeria

Assessment of radon concentration in groundwater within Ogbomoso, SW Nigeria

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Abstract. The study is aimed at investigating the level of radon and to determine the health effect connected to radon in drinking water. A total of thirty (30) water samples were randomly investigated in Ogbomoso using an active electronic device RAD 7, produced by Durridge Company USA. The radon concentrations within the study area vary from 0.60 to 2.64 Bq L^{-1}, with the mean value of 1.86 Bq L^{-1}. The committed annual effective doses due to ingestion vary from 6.25×10^{-3} to 1.93×10^{-2} mSv y^{-1}, with mean values of 0.02 mSv y^{-1}. The radon concentrations in water samples of Ogbomoso are lower than the threshold as set by both United States Environmental and Protection Agency, and European Commission of 11 and 100 Bq L^{-1} respectively.

Keywords: Radon, Hazards, Effective doses, Ingestion, Precambrian Basement rocks

1. Introduction

Radon has been identified by World Health Organization (WHO) as a carcinogenic agent in human beings [1]. It is a major cause of lung cancer [2]. Epidemiology studies have revealed that there is a connection between mine workers and outbreak of lung cancer [3]. The total estimation of health threat pose by radon is about 16% per 100 Bq m^{-3} [4]. The damage caused only to lungs is estimated to be ranged from 3% to 14% [5]. Radon is a radioactive element hosted by rock water and diffuses into the atmosphere due to its solubility properties [6, 7]. Radon is a radioactive element, an alpha particle emitter and a noble gas which has no odour, colour or taste, and it is of concern because of the danger poses by it [8, 9]. The radon isotopes are many but only three has been identified. However out of these three isotopes, Radon-222 is of major concern due to its half-life, which helps to determine its presence quickly in water, indoor and outdoor air. There are two ways in which humans are exposed to radiation from radon, these are: inhalation and ingestion. Inhalation of radon occurs when air that contains radon is inhaled, while by ingestion is when water that contains radon is consumed. Though the associated risk of ingested radon through water is low compare to the hazard from inhalation of radon from air yet the hazard pose by this cannot be neglected [10]. The alpha particles released as a result of natural radioactive decay of radon interact with tissues which lead to deformation of DNA [1]. Some of the previous works on radon concentration in water especially in SW Nigeria can be found in [11 – 14].

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2. Geology of the study area

Ogbomoso is bounded by latitude 8° 2´– 8° 11´ N and longitude 4° 7´– 4° 22´ E [15]. The study area resides on the African crystalline rocks, which are chiefly composed of meta-sedimentary, igneous and meta-igneous rocks [16, 17]. These rocks are of PreCambrian in age. Overlying the bedrock units of Africa are varying geological formations, which range from volcanic and sedimentary sequences to unconsolidated Cenozoic sediments [18]. In Nigeria, the major pronouncing geological settings which are divided in equal proportion are: the sedimentary Basins [19-26] and crystalline Basement Complex [27-42] as revealed in Figure 1. The rocks of Ogbomoso is an integral part of the Proterozoic Schist belt [43], which is developed towards the western half of Nigeria. The lithological units in Ogbomoso include Granite-Gneiss, Banded Gneiss and Quartzite (Figure 2). Augen and agmatitic gneisses are also present in the study area. The quartzite occurs as elongated ridges, which trends in NW-SE orientation. The quartzites are observed as Schistose, which dominates the southern region, while granite gneisses covered the northeastern region of the town. Other lithological units are noticed in other regions of Ogbomoso land [44].

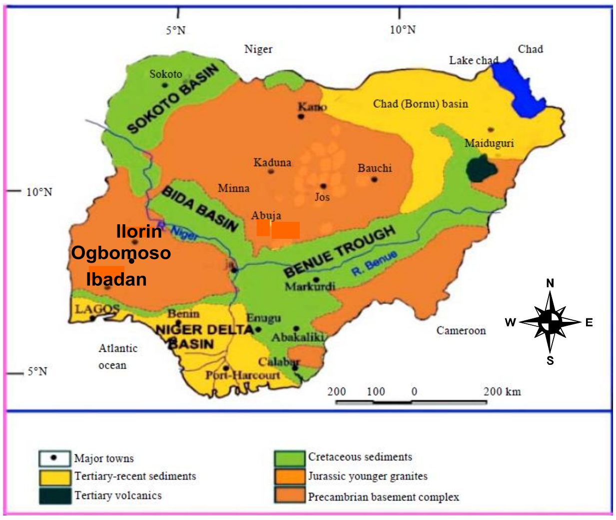

Figure 1: Generalized geology of Nigeria revealing the study area (Adapted from [45])

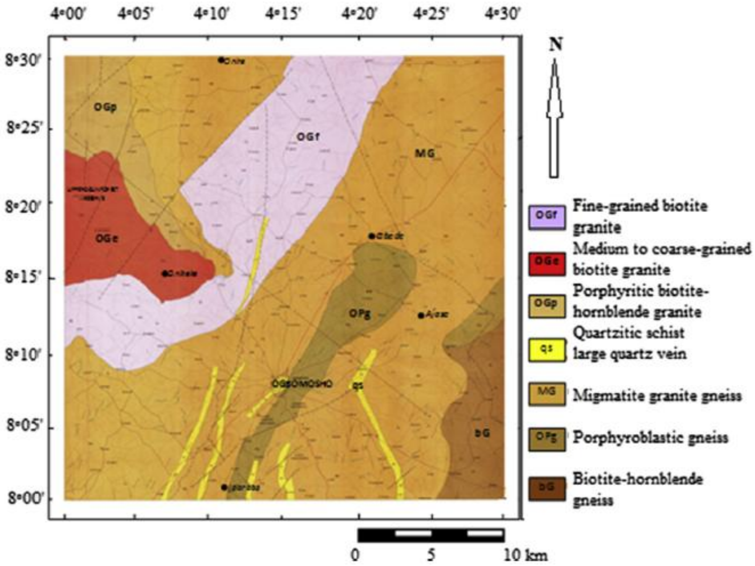

Figure 2: Geological map of Ogbomoso (Adapted from [46])

3. Materials and Methods

Ten (10) water samples were randomly selected to represent the residential groundwater in the city. The samples were collected into the jar from the main source. In each location, three (3) samples were collected for replicability and precision, which culminates to thirty (30) samples in all. The water samples were collected with care and covered in order for radon not to escape from the jar, due to its gaseous state. The water samples were later transported to the laboratory to determine the concentration of radon in each sample. The technique employed in this study was a close loop method, whereby the air volume and water were constant and not depended on the flow rate [47]. The air constantly flow through the water and extract radon until a stable equilibrium is established. A total compliance with the guidelines in the manual of the device, on how radon in water can be determined was keenly followed. To establish the reliability of the sampling and measurement method, each of the water samples was analyzed in more than one cycle, while the mean value for the radon concentration in water was determined. The water analysis employed was in line with the methods used by [11-13]. A well calibrated portable electronic radon monitoring device produced by an American based company Durridge was employed for this study. The device was made to determine radon level in water and other sources of radon [10]. The accuracy and sensitivity of the device cannot be compared with other devices, which in turn make it superior over other existing device [48]. The device has capacity to determine concentration of radon in water within the 30 minutes of the measurement which is far lower than the half-life of radon, hence the choice of this device.

The annual effective dose by ingestion was assessed based on the intake of water by the populace of the study area [49]. The annual effective dose was calculated based on Eq. (1).

$$E = K \times C \times KM \times t \tag{1}$$

where,
E = the committed effective dose from ingestion;
K = the ingesting dose conversion factor of radon (10^{-8} Sv Bq for adult) [50];
C = the concentration of radon;
KM= the average water consumption per day (2 litre /day); and
t = the duration of consumption (365 days) [51].

For the dose estimation, a conservative consumption of 2 litres per day for standard adult drinking the same water and directly from the source point was assumed [50].

4. Results and Discussion

A total of thirty (30) samples were analyzed for radon concentration in different locations within Ogbomoso. The results of radon concentration in water samples are presented in the Table 1. The Radon-222 present in the water samples varied from 0.60 ± 0.37 to 2.64 ± 0.80 Bq L^{-1}, with the mean value of 1.69 ± 0.70 Bq L^{-1}. The peak recorded value was found in Stadium area with mean of 2.64 ± 0.80 Bq L^{-1}, while the minimum value was found in Kuye area with mean of 0.60 ± 0.37 Bq L^{-1}. Therefore the radon in Ogbomoso city is comparatively low, since the Maximum Recommended Level (MCL) of United States Environmental and Protection Agency (USEPA) is 11 Bq L^{-1}. In addition, by comparing the results obtained in this study with the standard value of 100 Bq L^{-1} as recommended by European Commission (EC), it was observed that all the analyzed samples from these locations were below the recommended limit. The variation in radon level could be attributed to the differences in the lithological units and depths at which the aquifers are located. Another factor that may contribute to the variation of radon level in water is time of storage as reported by [52].

The annual effective doses due to intake of radon were also estimated and the values varied from 4.38 × 10^{-3} to 1.89 × 10^{-2} mSv y^{-1}. The effective dose from radon due to intake of water in this study is presented in Table 1 as well. It was discovered that all the effective doses are less than the recommended limit of 0.1 mSv y^{-1} [53]. This implies that the doses obtained in the study area are negligible.

Table 1 Result of radon concentration in drinking water in Ogbomoso.

Location	Radon concentration Bq L^{-1}	Annual effective dose Ingestion (mSv y^{-1})
Kuye	0.60 ± 0.37	4.38 × 10^{-3}
Lawyer Hammed	0.86 ± 0.39	6.27 × 10^{-3}
Yoaco	1.82 ± 0.50	1.33 × 10^{-2}
Aba	2.59 ± 0.69	1.89 × 10^{-2}
General	2.54 ± 0.83	1.85 × 10^{-2}
Stadium	2.64 ± 0.80	1.93 × 10^{-2}
Seminary	2.60 ± 0.82	1.89 × 10^{-2}
Oke Ado	0.74 ± 0.31	5.40 × 10^{-3}
Adenike	1.74 ± 0.48	1.27 × 10^{-2}
Under G	0.75 ± 0.38	5.48 × 10^{-3}

5. Conclusion

In this paper, the results of radon concentration in drinking water in Ogbomoso are presented. The radon measurements were performed using an electronic active device. Comparing the result with the MCL, it can be concluded that the results obtained in this study is lower than the threshold limit as recommended by USEPA and EC. Therefore, the water within the city is safe for consumption. However, periodic check of domestic water in the city is recommended in order to ensure safe consumption.

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