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Estimation of Indoor Radon and Its Progeny in Dwellings of Akoko Region, Ondo State, Southwestern Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author AMA designed the study, carried out the research, manage the literature searches and wrote the first draft of the manuscript. Author IRA vetted and provided finishing touch to this manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Radon gas is by far the most important source of ionizing radiation among those that are of natural origin. In this study, radon was measured in some homes built of different types of building materials in Akoko region of Ondo state, Nigeria. The test was conducted using Accustar alpha track long term passive test devices containing CR-39 solid state nuclear track detector foil. The detectors were exposed for a period of six months. After removal the detectors were subsequently etched electrochemically and counted with computer aided image analysis system. The results show that radon concentration varies between 15.00 Bqm^{-3} to 141.00 Bqm^{-3} with a mean of 35.54 Bqm^{-3} and geometric mean of 29.95 Bqm^{-3}. Annual exposure varied between 0.10 WLM to 0.17 WLM with a mean of 0.13 WLM, annual effective dose varied between 0.38 $mSvy^{-1}$ to 0.69 $mSvy^{-1}$ with a mean of 0.50 $mSvy^{-1}$ and lifetime fatality risk varied between $0.50x10^{-4}$ to $0.85x10^{-4}$ with a mean of $0.64x10^{-4}$ in bedroom, living room, store and lobby. This study shows that the local soil origin greatly contributes to radon concentrations recorded in these areas.

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1. INTRODUCTION

Exposure to radon and its progeny make the single largest contributor to an individual radiation dose [1]. Radon-222 is a radioactive decay product of Uranium-238 which is present in the earth crust in varying concentrations. Radon comes from the ground with exposure affected by factors such as local geography, building construction and lifestyle. The transfer of radon from soil to a building depends on several parameters like the composition of the soil, the concentration of radon in the soil, the pressure differential between inside and outside, the area of building in contact with the ground and the transfer of radon within the ground. The transfer of radon within the building also depends on the ventilation system in the building, the meteorological and seasonal parameters, the lifestyles and working habits of the building occupants [2].

Radon being a gas mixes readily with the air, easily inhaled and exhaled. As radon-222 accumulates in the air there is a gradual build up of its short lived progeny-bismuth, lead and polonium. The largest dose from radon result when radon is in equilibrium with its short-lived progeny, the gas contributes only slightly to the total dose. Most of the damage is done by the attached and unattached decay products especially the alpha–emitting polonium isotopes. They lodge in the respiratory tract and some end up delivering high doses of radiation to the bronchi where most lung cancers originate. The radiation dose delivered to the respiratory system and the resulting potential health detriment are a complex function of the radon decay product aerosol characteristics and the physiological parameters of the exposed individual [3].

This research is a form of community development and health based. It has been recommended that every home be tested for radon and its progeny level [1]. This is the first research to monitor indoor radon-222 in homes using alpha track detectors in Akoko region of Ondo State, Nigeria. Besides, awareness and knowledge about radon exposure is very limited in these areas. The aim of the present study is to measure ^{222}Rn in homes and estimate the dose and risk received by the people. This study will present a baseline data that could be used for future reference in Nigeria.

1.1 Study Area

Radon monitoring was carried out in different homes in Akoko Region of Ondo State, Southwestern, Nigeria. Akoko region is situated between longitude 5°30′ and 6°30′ of Greenwich Meridian and latitude 7°20′ and 7°45′ north of the equator. The region is made up of undulating lowlands along the western highland. The climate of the area is characterized by a fairly high uniform temperature, moderate to heavy seasonal rainfall in the month of March to September with a mean annual rainfall about 1200 mm and mean temperature about 21°C. The relative humidity is high in the early morning and decreases in the afternoon. Geologically the area is situated in the basement complex of Southwestern, Nigeria, generally referred to as migmatite gneiss quartzite complex [4]. The rock types found there includes grey gneiss, granite gneiss, quartzite and other subordinates like charnockites and a few pegmatitic bodies. The map of the study area is shown in Fig. 1.

2. MATERIALS AND METHODS

The detectors used, are previously calibrated long term passive alpha track test kits AT 100 of dimensions 2.3 cm by 5.3 cm manufactured by Accustar laboratory, United State of America. The detectors are diffusion based track detectors that filter out dust and radon progeny through an integral filter into the housing, resulting in increased sturdiness. The track detector foil inside the housing is from dosimetry grade CR-39.

A total of 60 detectors were exposed by simple random sampling selection of houses in thirteen communities in the area. Rooms tested include bedroom, living room, lobby and store. The houses were built with cement bricks or mud bricks. The total data was collected from November 2014 to July 2015. The detectors were hanged at least three feet away from exterior doors or windows, at least two feet off the floor and two meters from ground level. Each detector was exposed for a minimum period of six months. The Global Positioning System (GPS) was used to record the location of every home measured. Questionnaires were distributed to home owners to gather certain information about their houses. Such information includes ventilation habit, brick used, floor composition, roofing sheets, age of building and detector

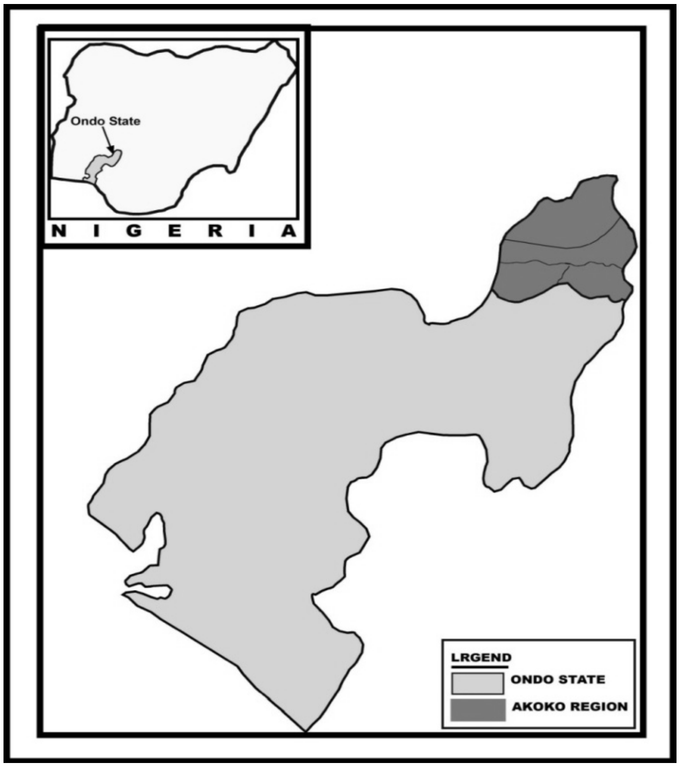

Fig. 1. Map of the study area

Fig. 1 shows the map of the study area. At the top left corner is located the map of Nigeria showing Ondo State. The dark portion on the map of Ondo State shows the study region-Akoko region which is divided into four local government areas

location. On removal, the detectors were immediately placed inside a sealed nylon so that no new track will be recorded on it prior to etching. The detectors were etched electrochemically in the Accustar laboratory, U.S., and subsequently counted with computer aided image analysis system. However some detectors could not be retrieved back from the house owners due to death and poor scientific orientation.

3. RESULTS AND DISCUSSION

3.1 Radon Concentrations

Table 1 shows the mean concentrations of radon obtain in each location. Radon concentrations varied between 15 Bqm^{-3} to 141 Bqm^{-3} with a mean of 35.53 Bqm^{-3}, and geometric mean of 29.95 Bqm^{-3}. The radon concentration was higher in Epinmi Akoko followed by Isua and Ifira Akoko in the same local government area. Although information was obtained about each home measured through the distributed questionnaires, these information does not show any relation with lower or higher radon concentrations in the region. Buildings with the same history, structure and construction materials gives lower radon concentrations in some locations and higher radon concentrations in some other locations. The results show that ventilation, building materials and age of buildings does not significantly contributes to radon concentrations in this region. Radon concentrations greater than 50 Bqm^{-3} and up to 141 Bqm^{-3} were recorded in nine different homes concentrated in the same Local Government Area. Another six homes located in a different Local Government Area recorded lesser radon concentrations of 15 Bqm^{-3}. These are indications that the local geography and the composition of the soil – the chemistry, geology, soil moisture and permeability greatly contribute to the radon concentrations recorded in the research area. The radon concentrations are comparable with those reported in Ado Ekiti, a neighboring town state [5] as stated in Table 3. Fig. 2 presents the radon level contour mapping which shows the radon concentrations at every location visited.

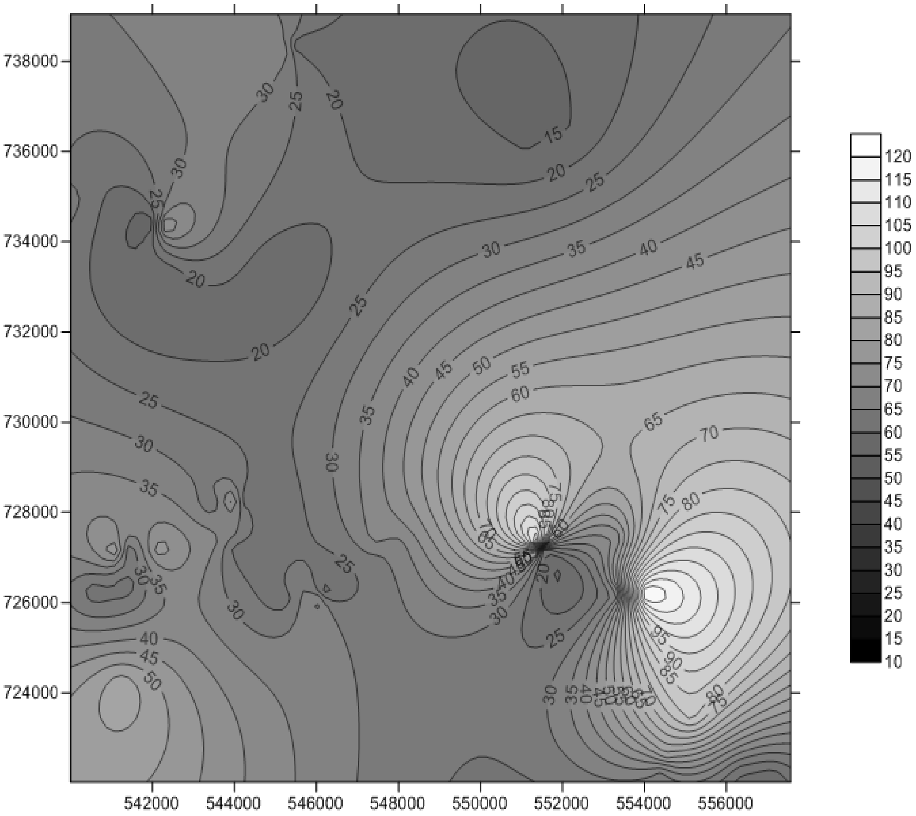

Fig. 2. Radon level contour map of the study area

Fig. 2 present the radon levels contour mapping of the study area. The vertical axis represents the longitude while the horizontal axis represents the latitude. The highest radon concentrations of 141 and 121 Bq/m^3 can be found on longitude 7°27'23.8", latitude 5°51'46.4" and longitude 7°26'19.5", latitude 5°54'00.4" respectively

3.2 Annual Effective Dose

It is essential to convert the radon concentration to dose because of its harmful effects on the human body. The mean radon concentration for each location in the region was used to calculate the annual effective dose equivalent in homes. For calculation, the occupancy time of 7000 hy^{-1}, equilibrium factor of 0.4 and dose conversion factor of 9x10^{-6} mSvh^{-1}/Bqm^{-3} was used to convert radon concentration to population effective dose using equation (1) [6,7,8].

$$He = C \times F \times T \times D \qquad (1)$$

Where He is the annual effective dose (mSvy^{-1}), C is the mean radon concentration (Bqm^{-3}), F is the equilibrium factor, T is the indoor occupancy time (hy^{-1}) and D (mSvh^{-1}/Bqm^{-3}) is the dose conversion factor.

Table 1 shows the annual effective dose (mSvy^{-1}). The annual effective dose varied between 0.38 mSvy^{-1} to 1.89 mSvy^{-1} with a mean of 0.86 mSvy^{-1}. Three communities: Isua, Ifira and Epinmi Akoko showed doses higher than 1 mSvy^{-1} but the mean dose in the research area is lower than the 1 mSv recommended for the members of the public. The annual dose matches well with those reported outdoor and in offices in Nigeria [9,5] as presented in Table 3.

3.3 Excess Lifetime Cancer Risk

Lifetime risk is the cumulated risk by an individual up to a given age. Exposure to radon and its progeny in working level month (WLM) is the cumulative exposure from breathing an atmosphere at a concentration of 1 WL for a working month of 170 hours.

The Potential Alpha Energy Concentration (PAEC) (mWL) is a linear combination of all the energies of the emitted alpha particles associated with the decay of all the radon progeny present in the volume of air under consideration [2]. In order to estimate the lifetime risk associated to exposure of radon indoor for the occupants of these areas, the PAEC was calculated using equation (2).

$$PAEC\ (WL) = (C_{Rn} \times f)/3.7 \quad (2)$$

Where C_{Rn} is the mean radon concentration and F is the equilibrium factor.

In a home with a (PAEC) of 1 mWL, the annual exposure in WLM = 0.0412 WLM. That is,

$$Annual\ exposure\ (WLM) = PAEC\ \times 0.0412 \quad (3)$$

A radon concentration of 1Bqm^{-3} corresponds to an annual effective dose of 1.716x10^{-2} mSvy^{-1} [10]. The annual effective dose was calculated using equation (4)

$$Annual\ Effective\ Dose\ = C_{Rn} \times 1.716 \times 10^{-2} (4)$$

The lifetime risk associated with exposure to indoor radon was then calculated taking into consideration the estimates of lifetime excess absolute risk of lung cancer associated with radon and radon progeny concentrations, also denoted as fatality probability of 5x10^{-4}/WLM = 14x10^{-5}(mjhm^{-3})$^{-1}$ [11].

$$Excess\ Lifetime\ Cancer\ Risk = 5 \times 10^{-4} \times Annual\ Exposure \quad (5)$$

Table 2 shows the minimum and maximum radon concentration (Bqm^{-3}), the mean radon concentrations (Bqm^{-3}), annual exposure (WLM), annual effective dose (mSv) and lifetime fatality risk for bedroom, living room, store and lobby. The living room has the highest lifetime fatality risk followed by the bedroom as shown in Fig. 3. This is attributed to the composition of the local soil in the same local government area where high concentrations of radon were recorded in the rooms tested.

The mean annual exposure, annual effective dose and lifetime fatality risk are 0.13 WLM, 0.50 mSvy^{-1} and 0.64x10^{-4} respectively. These values are comparable with those reported [10]. The mean radon concentration (Bqm^{-3}), annual exposure, annual effective dose and lifetime fatality risk was (29.33 Bqm^{-3}, 0.13 WLM, 0.50 mSvy^{-1}, and 0.65x10^{-4}) for bedroom; (40.25 Bqm^{-3}, 0.17 WLM, 0.69 mSvy^{-1}, and 0.85x10^{-4}) for living room; (24.0 Bqm^{-3}, 0.11 WLM, 0.41 mSvy^{-1} and 0.55x10^{-4}) for store and (22.0 Bqm^{-3}, 0.10 WLM, 0.38 mSvy^{-1} and 0.50x10^{-4}) for lobby respectively. Radon concentrations, annual effective dose and excess lifetime cancer risk in the region were compared with values from other researches in Table 3.

Table 1. Radon concentrations and annual effective dose in the region

Location (Akoko)	Mean (Bqm^{-3})	Annual effective dose (mSvy^{-1})
Ikaram	15.00	0.38
Iyani	15.00	0.38
Ipesi	19.25	0.49
Oke agbe	22.20	0.56
Ogbagi	22.20	0.56
Irun	26.00	0.66
Iwaro oka	27.50	0.69
Akungba	33.00	0.83
Oke oka	33.30	0.84
Supare	37.00	0.93
Ifira	54.30	1.37
Isua	67.75	1.70
Epinmi	75.00	1.89

Table 2. Variation of mean radon concentration, annual exposure, annual effective dose and lifetime fatality risk in the rooms tested

Room Location	Min radon (Bqm^{-3})	Max radon (Bqm^{-3})	Mean radon (Bqm^{-3})	Annual exposure (WLM)	Annual effective dose (mSvy^{-1})	Lifetime fatality risk x10^{-4}
Bedroom	15	48	29.33	0.13	0.50	0.65
Living room	15	141	40.25	0.17	0.69	0.85
Store	18	30	24.00	0.11	0.41	0.55
Lobby	18	26	22.00	0.10	0.38	0.50
Mean				=0.13	=0.50	=0.64x10^{-4}

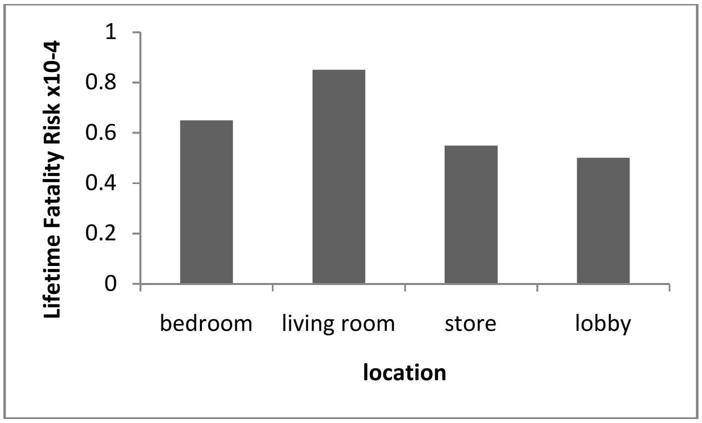

Fig. 3. Variations of lifetime fatality risk in rooms tested

Fig. 3. shows the variations of the lifetime fatality risk in room location. The highest was recorded in the living room followed by the bedroom

Table 3. Comparison of this study with others

Country	Detector location	Radon concentrations (Bqm^{-3})		Annual effective dose ($mSvy^{-1}$)		Excess lifetime cancer risk		Ref.
		Min	Max	Min	Max	Min	Max	
New Delhi	Bedroom	43.5±12.0	294.1±27.8	1.5±0.4	9.9±1.0	------	-------	[12]
Iraq	Living room	94.883	358.552	2.391	0.017	9.205	34.7795	[13]
Haryana India	Indoor	47.45	134.40	0.82	2.31	0.63×10^{-4}	1.80×10^{-4}	[10]
Nigeria	Office	20.0	37.1	0.11	0.18	0.86	1.37	[14]
Nigeria	Office	157	495	0.99	3.12	------	-------	[9]
Nigeria	Outdoor	2.22	95.50	0.69	3.81	-----	-------	[5]
Nigeria	Indoor	15	141	0.38	0.69	0.50×10^{-4}	0.85×10^{-4}	[this study]

4. CONCLUSIONS

This study was carried out to measure radon concentrations in indoor environment. 60 homes in thirteen communities in the study region were selected for measurements. Detectors were mounted for six months with information collected in questionnaires for each home. Radon concentrations were less influenced by the building materials used; high values were found in homes in the same localities which suggested that the local geography and soil characteristics may be responsible for the value obtained in these areas. The highest radon concentration of 141 Bqm^{-3} found in the area is less than the 200 Bqm^{-3} recommended by ICRP 1993. The overall average of 35.54 Bqm^{-3} and geometric mean of 29.95 Bqm^{-3} in this work is comparable with the worldwide values of 40 Bqm^{-3} averages and 30 Bqm^{-3} geometric mean [6]. The overall annual effective dose average of 0.86 $mSvy^{-1}$ in Table 1 and 0.50 $mSvy^{-1}$ in Table 2 is higher than the worldwide annual effective dose of 0.48 $mSvy^{-1}$ [6]. The lifetime fatality risk varied between 0.50×10^{-4} to 0.85×10^{-4} in bedroom, living room, store and lobby with a mean of 0.64×10^{-4}.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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