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Preliminary Studies on Indoor Radon Measurements in Some Adobe Houses in the Kassena Nankana Area of the Upper East Region of Ghana

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Abstract: The present study has measured radon gas concentration in some Adobe houses in the Kassena Nankana Area of the Upper East Region of Ghana by using passive radon indoor dosimeter containing Solid-State Nuclear Track Detector (SSNTD) commercially known as LR - 115 (type II, pelliculable). Inhalation of radon and its daughter products is the major contributor to the total exposure of the population to natural radiation. Fifty (50) indoor radon dosimeters were placed in the various Adobe houses in the study area. The indoor radon dosimeters were retrieved after 78 to 82 days. The detectors were then chemically etched. The digital laser optic system was used in counting the detectors. Indoor radon concentration in the study area range from 35.28 to 244.22 Bq/m^3.

Key words: Concentration, detector, etching, lr- 115, radiation, radon, track

INTRODUCTION

There has been a lot of concern about the effects of radon exposure to people all over the world and Ghana is no exception. Due to lack of information about the concentrations and harmful effects of radon, many people have continued to work in, and live in places unaware of the dangers posed to their lives. There is a lack of information about radon concentrations in Adobe houses in northern Ghana. There is no national database of radon concentration in houses, but also there are very few houses that have had measurement of radon concentrations done in Ghana.

Adobe are natural building material made from sand, clay, and water, with some kind of fibrous or organic material (sticks, straw, dung), which is shaped into bricks using frames and dried in the sun. It is similar to cob and mud brick. Adobe structures are extremely durable and account for the oldest extant buildings on the planet. In hot climates, compared to wooden buildings, adobe buildings offer significant advantages due to their greater thermal mass, but they are known to be particularly susceptible to seismic damage in an event such as an earthquake (Wikipedia, 2008).

Radon poses a major concern with regard to radiation pollution and human health hazard (Chen, 2005). The radon gas can diffuse easily out of the soil surface into air or houses; it can be trapped in poorly ventilated houses and so its concentration can build up to higher levels. Although the soil is considered to be the main source of indoor radon concentration, raw building materials (especially quartz, cement, etc.) can make a significant contribution to the level of natural radioactivity in closed spaces such as stores and badly-ventilated dwellings. Moreover, the production rate of radon in dwellings depends on the concentration of radium in the subsoil, building materials, and porosity as well as the density of the wall material. The emission of radon from building materials is found to be a function of ventilation as well as of the radium content in building materials. The nongaseous ^{222}Rn decay products are partially suspended in air as a mixture of attached and unattached fractions and partially deposited on walls and furniture (Chen, 2005). In recent years, exposure to radon gas has become a global concern due to its health hazards inside dwellings (ICRP, 1987; Nazaroff *et al*., 1987). Radon as a cause of leukemia has also been discussed (Richardson *et al*., 1991; Darko *et al*., 2009).

Here in Ghana however, some attempts have been made between the late 80's and early 90's to study radon exposure in adobe houses. Unfortunately these studies did not catch the attention of the lay Ghanaian the way it was expected for that matter awareness of radon in the country is low. Some Studies in traditional houses in Dome (Accra) have shown that some houses exceeded the remedial action limit of 150 Bq/m^3, with three of them exceeding the action level of 400 Bq/m^3 set by the U.S E.P.A. The mean for that period was 171±34 Bq/m^3. They also estimated that there were changes in the three monthly mean values which reflect on the weather changes in the region, with the period from March to late July being the rainy period, hence colder nights

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and a significant increase in the radon levels (Oppon *et al*., 1990).

The objective of this study is to provide some data on the indoor radon concentrations in Adobe houses in the northern parts of Ghana

MATERIALS AND METHODS

The study was performed at the Physics Department of the National Nuclear Research Institute, Ghana Atomic Energy Commission from September - December, 2008.

Description of study area: The Kassena Nankana Area of the UER of Ghana lies between latitudes 10º30′ and 11º00′ N of the equator, between longitudes 1º00′ and 1º30′ west of the zero meridian and covers an area of 1,675 km^2 along the Ghana-Burkina Faso border. It measures roughly 50 km long and 55 km wide and has an altitude of 200-400 m above sea level. The land is relatively flat and passing through it from Burkina Faso is the White Volta River, which feeds Lake Volta (the world's largest artificial lake) in the Volta region, south of Ghana. Located in the Guinea Savannah belt, the district's ecology is typically Sahelian (hot and dry), with the vegetation consisting mostly of semi-arid grassland interspersed with short trees. There are two main climatic seasons, the wet and dry seasons. The wet season extends from April to October, with the heaviest rainfall mainly occurring between June and October (Nyarko *et al*., 1999).

The geology in the study area mainly consists of Birimian rocks of the Pre-Cambrian age and granitoids (granodiorites, granite and gneiss). The Birimian rocks are associated with the granites, while the granites intruded into the Birimian meta-sediments during a period of orogeny. The Birimian meta-sediments are made up of phyllite, schist and quartzite and can be found in small patches among the granitoids. The granite complex has developed secondary permeability and porosity as a result of fracturing and weathering of the material. The upper layer is presently covered with alluvial material. The Ghanaian Soil Research Institute (SRI) distinguishes three soil types in the alluvial material in the UER (Berg, 2008).

The Kassena Nankana Area is predominantly rural in outlook, the population of the area from the 2000 Population and Housing Census is estimated to be 149,680. The figure represents 1.0% increase over the 1984 figure of 149,491. This inter censual growth rate of 1% is below the national growth rate of 2.7% Most of the entire District's population live in rural settlements (Ghana District Assemblies, 2008). Kassena Nankana Central District Assembly and Kassena Nankana East District Assembly with Navrongo and Paga as the district capitals respectively are the two districts in the study area.

Fig. 1: A typical Adobe house found in the study area

Fig. 2: A picture showing how the detector was deployed in one of the rooms

The study area can also boast of two constituencies namely Navrongo Central and Chiana-Paga. One of the types of Adobe houses in the study area is shown in Fig. 1.

Indoor radon gas measurement: A wide variety of well-established techniques are available for the measurement of radon, and their progeny levels either by active or passive methods (Danalakshmi *et al*., 2008).

Sampling included Adobe constructed houses which are built with locally manufactured materials, these Adobe constructed houses have poor ventilation due to it's small windows, which are used and sometimes not at all. This sampling was homogeneous in that the detectors were randomly placed in the homes at corners of the rooms away from the openings. This was to give an indication of the exposure level of the entire area. In all about fifty houses will be considered.

The Bare detector method or envelope type radon monitor was used. It consists of a bare LR115 detector film placed in an envelope with one half exposed and the other half protected to be used as the background. The

Table 1: ^{222}Rn concentrations and their averages for indoor measurements in some parts of the Kassena Nankana Area

Biu	conc. (Bq/m^3)	Upper Gaane	conc. (Bq/m^3)	Vonania	conc. (Bq/m^3)	Bundunia	conc. (Bq/m^3)	Gognia	conc. (Bq/m^3)
SGX 02	147.79	SAG 73	244.22	SAB 66	194.40	SGU 55	84.08	SGU 4	121.59
SHH 23	93.66	SAG 70	141.12	SAE 11	115.98	SGN 50	62.83	SGN 73	164.61
SGL 68	134.48	SAH 45	48.75	SAB 18	44.65	SAB 84	67.79	SGN 77	76.32
SHH 27	226.39	SAG 62	151.87	SAB 82	137.00	SGN 71	170.98	SGU 5	148.56
SHG 21	157.49	SAG 79	226.93						
Average	151.96		162.58		123.01		96.42		127.77
Chiana	Conc. (Bq/m^3)	Kayoro	Conc. (Bq/m^3)	Kaakung Paga	Conc. (Bq/m^3)	Mamprusi Community	Conc. (Bq/m^3)	Nania	Conc. (Bq/m^3)
WBC 38	46.77	01	152.78	NGE 48	81.26	NGC 35	101.10	NGE 29	35.28
WBC 18	120.07	02	144.84	NGE 61	94.38	NGA 41	85.07	NGD 52	137.47
WBC 61	110.40	03	201.14	NGE 23	159.91	NGA 11	111.61	NGD 32	115.38
WBC 8	176.03	04	166.57	NGE 18	173.36	NGA 62	69.20	NGD 38	163.82
WBC 43	191.80	05	223.69					NGE 39	147.7
Average	129.01		177.80		122.00		91.74		119.93

detector was of dimension 6.0 cm x 4.2 cm.The detectors were then deployed by placing them in the corners of the various rooms and held in position by tag pins as is shown in Fig. 2 in one of the houses monitored.

Sampling was done at random depending on who permits us to carry out the study in his or her house. In all fifty (50) rooms were monitored. These detectors were kept in the rooms for periods between seventy eight (78) - eight four (84) days before being removed. The detectors were then taken to the Nuclear Track Detection Laboratory of the NNRI (GAEC) for analysis.

The detectors were then chemically etched in 2.5 M NaOH solutions for 90 min at 60ºC and then washed very well and dried. The Digital Laser Imaging System of the Laser and Fibre Optics Centre (LFOC), Department of Physics, University of Cape Coast was used in counting the alpha tracks.

Evaluation of track density: The following parameters are needed in order to obtain the radon concentration for both soil and the indoor measurements:

Track density (ρ)
Calibration factor (ϵ)
Time of exposure in hours T (h)

Track density was evaluated by the formula:

$$\text{Track density } (\rho) = \text{Average number of tracks obtained} / \text{Area of count} \quad (1)$$

Radon Concentration in Bq/m^3 and K Bq/m^3 for indoor and soil measurements respectively were evaluated using the formula:

$$\text{Concentration (K Bq/m}^3) = \rho - \rho_B / \epsilon\, T\,(h) \quad (2)$$

where,
ρ = The track density
ρ_B = The Background track density

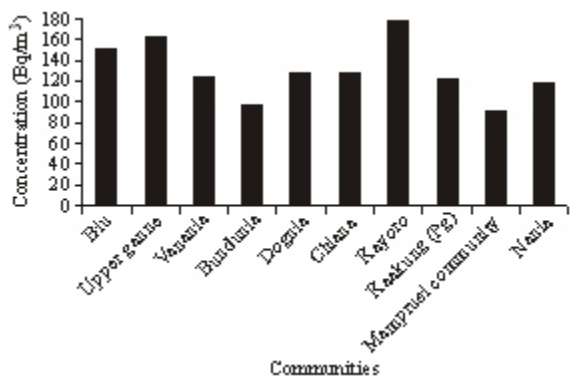

Fig. 3: Mean indoor radon concentration for the Ten (10) communities in the study area

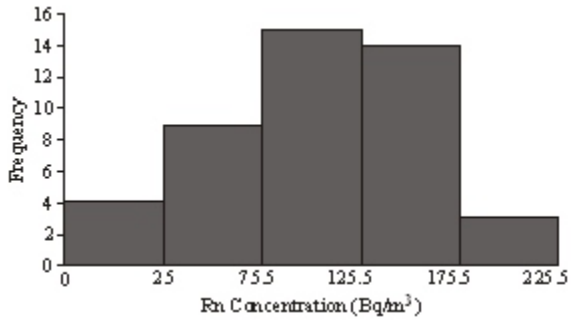

Fig. 4: A histogram showing the frequency and Rn concentration for the indoor measurements

ϵ = The calibration factor
T(h) = The exposure time in hours.

RESULTS AND DISCUSSION

Table 1 shows the Radon concentrations and their averages for indoor measurements in forty five (45) rooms in the study area. Figure 3 and 4 shows the mean indoor radon concentrations of the ten communities in the study

area and the frequency distribution of the indoor radon concentration in the study area respectively.

The measurements were done in fifty (50) Adobe houses but data is presented for only forty five (45) measurements. Five (5) of the detectors were lost.

The results should be taken as an initial data, and to find out the range of radon concentrations in the different types of Adobe houses in the study area. The results indicate where we can expect high levels of radon concentrations. The radon concentrations in the study range between 35.3 and 244.2 Bq/m^3. Concentrations above the Action Level of 150 Bq/m^3 set out by the US EPA were found in 38% of the Adobe houses in the study area. The mean concentration of the ten (10) communities is shown in Fig. 3 with their concentrations ranging from 91.74-177.80 Bq/m^3.

Here it is striking to note that a community like Upper Gaane had one of its houses registering (house number SAG 73) the highest concentration of 244.2 Bq/m^3 with the Kayoro community having the highest mean concentration of 177.8 Bq/m^3. The frequency distribution of indoor radon levels is shown in Fig 4. This distribution of indoor radon concentrations is normal and it is a departure from the log- normal distribution found in most works of this nature (Owusu., 1989; Hadad *et al.*, 2007; Lianqing *et al.*, 1987). The distribution pattern of this work can be attributed to the same nature of housing types monitored in the study area.

These are some probable explanations for the higher levels of ^{222}Rn in 38% of the Adobe houses under consideration:

- The type of construction materials used for the building and the way it was built gives rise to ventilation challenges. Most of the windows of the Adobe houses in the study area are not opened at all which leads to a relatively low level of fresh air in the buildings
- All the houses in the study area monitored had no platform (sub-floor) on which the super structure is placed. For this reason, a direct coupling is created between the building and the soil which leads to direct radon emissions into the buildings
- Life styles of inhabitants/occupants

The results of this work compared with work done by Oppon *et al.* (1990) in similar housing type shows some resemblance (i.e., In his work an average percentage of twenty eight (28%) of the houses monitored exceeded the action level of 150 Bq/m^3 for the three surveys' done within a nine (9) month period. It is also intriguing to note that for the same said work, the results showed that about 44% of the houses monitored during the first period, 27% during the second and 13% during the third period respectively had radon concentrations exceeding the 150 Bq/m^3 action levels. From the statistical error on track counting the statistical uncertainty of the track density was about ten percent (10 %)

CONCLUSION

The main objectives of the study are to provide data on the indoor radon concentrations in Adobe houses in the northern of parts Ghana and to determine the correlation between the indoor radon concentration and that of the soil. The determination of the indoor radon concentration in some selected households and the determination of the soil radon concentration around some of the selected households are ways to achieve the said objectives.

The overall average indoor radon concentration of the ten communities monitored using the SSNTD technique was 130.03 Bq/m^3. This value is below the radon reference level which ranges from 200 - 600 Bq/m^3 as recommended by ICRP, IAEA (50), and is lower than the USA intervention radon level of 150 Bq/m^3.

All these not withstanding 38% of adobe houses in the study are had high indoor radon concentration values. Construction materials, poor ventilation, age of building and life styles of inhabitants/occupants are the main possible reasons for those high concentration obtained. The frequent occurrence of high levels of radon in this and the limited surveys show how widespread radon is.

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