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A preliminary comparative study of indoor radon measurement in Sakumono and Kassena Nankana area of Ghana

F. K. Quashie[1], Eric Akortia[2], A.B. Asumadu-Sakyi[1], C.A. Adjei[1] and I. Nsiah – Akoto[1]

[1]Ghana Atomic Energy Commission, Nuclear Application Centre, P.O.Box LG 80, Legon

[2]Ghana Atomic Energy Commission, National Radioactive Waste Management Centre, P.O.Box LG 80, Legon.

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ABSTRACT

A comparative indoor radon measurement by nuclear track detectors was undertaken in both Sakumono and Kassena Nankana area in sandcrete and Adobe houses respectively. In all, about seventy seven (77) detectors (type LR 115) were deployed for a period of three (3) months. The study was undertaken for the purpose of health risk assessments. The average indoor radon concentration in dwellings of Sakumono and its environs varied from 5.29 – 18.6 Bq/m^3 but that of the Kassena Nankana Area varied from 35.3 and 244.2 Bq/m^3. About 38% of the Adobe dwellings found in the Kassena Nankana Area had indoor radon concentration values that were above the action level of 150 Bqm^3 recommended by the US EPA. The annual effective dose for the whole study varied from 0.15 to 3.05 mSv/y.

Introduction

Radon is a radioactive gas that emanates from rocks and soils and tends to concentrate in enclosed spaces like underground mines or houses. Soil gas infiltration is recognized as the most important source of residential radon. Other sources, including building materials and water extracted from wells, are of less importance in most circumstances. Radon is a major contributor to the ionizing radiation dose received by the general population (WHO handbook on indoor radon, 2009).

If radon is inhaled, solid short lived radon progeny may deposit on the bronchial epithelium exposing sensitive cells to alpha (α) irradiation. Radiobiological evidence suggests that cells exposed to even a single α particle become appreciably damaged. Therefore, at low doses the risk of cancer is proportional to the number of cells exposed, and the dose-response relation is likely to be linear (Committee on Biological Effects of Ionising Radiation, 1999). For most people the bronchial dose of radiation is determined principally by the concentration of radon in the home. Studies of radon related lung cancer have quantified the risk in terms of radon concentration rather than radiation dose because concentrations can be measured directly. For the same reason policies to control radon are usually formulated in terms of radon concentration (Gray et al 2009)

The risk of lung cancer due to exposure to radon and its decay products is of concern to State and Federal health officials. There is increased awareness that indoor radon concentrations may pose a significant health threat, and that there are areas in the country where some indoor levels are such that even short-term exposures can cause a significant increase in risk. It is extremely important that homes and other buildings be tested to determine if elevated radon levels are present indoors. However, in the process, the collection of unreliable or misleading data must be avoided (US EPA 1992).

This work is a comparative study of indoor radon measurement in Adobe houses in the Kassena Nankana Area of the Upper East Region of Ghana and that of dwellings in the Sakumono Estates and its environs in the Greater Accra Region of 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 & Quashie et al 2011). A typical Adobe house in the study area is shown in Fig. 1.

Modern estate houses in Ghana are constructed from sandcrete blocks and are of different designs, with an average of two large windows per room as shown in Fig 2. Some of these windows come with louver blades and wooden doors, whilst others have modern sliding windows also known as glazing and door fittings to aid ventilation.

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

Fig 2: Modern estate houses in Sakumono

Tele: +233244469120

E-mail addresses: ololofrank@yahoo.com

In Ghana, some attempts were made between the late 80's and early 90's to study indoor radon exposure (Oppon *et al*., 1990) around Dome village near Ghana Atomic Energy Commission (GAEC). These studies showed that some houses around the Dome village and the residential area of the staff of GAEC exceeded the remedial action limit of 150 Bq/m^3, with three of the houses exceeding the immediate action level of 400 Bq/m^3 as per the US E.P.A (Oppon *et al*., 1990).

This work is intended to:

- Compare the radon gas concentration in some dwellings in Abode houses in the Kassena Nankana area of the Upper East Region and that of dwellings in Sakumono, in order to assess the risk of exposure to indoor radon.
- Provide some data on the indoor radon concentrations in these types of dwellings in Ghana.
- Raise public awareness on the health effects of radon and its progeny.

Study Areas: Two areas were selected for this study. The first area is Sakumono and its environs where sandcrete houses were considered and the second area is the Kassena Nankana area where Adobe houses were the focus of the study.

Sakumono is an area located in the Greater Accra region of Ghana and very close to the coast of Gulf of Guinea on the Greenwich meridian (Fig. 3). It is also an area where modern estate development in Ghana began but the estate houses located in this community have not been monitored for possible indoor radon gas accumulation. It is against this backdrop that this monitoring exercise has been initiated in order to determine the level of exposure to radon gas (Akortia et al 2010).

The Kassena Nankana Area of the Upper East Region (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 as is shown in Fig 4. 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 & Quashie et al 2011).

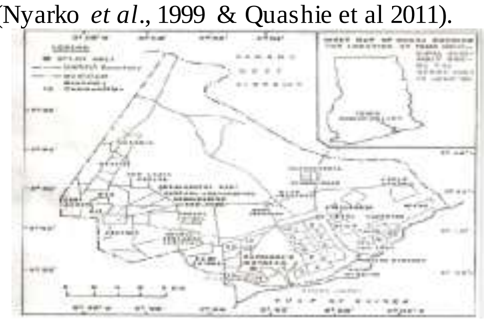

Fig 3: Map of the study area Sakumono and its environs

Materials and Methods

The study was performed at the SSNDT laboratory of the Nuclear Application Centre (NAC) of the National Nuclear Research Institute (NNRI), Ghana Atomic Energy Commission. From December 2007 – February, 2008 and September - December, 2008 was when the study was done respectively in Sakumono and its environs in the Greater Accra Region of Ghana and in the Adobe houses in the Kassena Nankana area.

Fig 4: Map of the study area Kassena Nankana

Indoor radon gas measurement: Radon concentration is generally measured using either passive solid state nuclear track detectors (SSNTD's) technique or using active technique (working-level meter) (Awawdeh et al 2001; Al-Kofahi et al 1992) . The structure of passive dosimeters has been developed and described else where by several works (Cartwright et al 1986; Al-Kofahi et al 1992; Hassan et al 1996). The dosimeter used in this study was the bare cellulose nitrate LR-115 type II. The detector materials (dosimeter) were cut out of a full size film with dimensions of 11.8 cm x 8.8 cm. The dimension of the cut out detector is 5.8 cm x 4.4 cm for Sakumono and that of Kassena Nankana was 6.0 cm x 4.2 cm. They were made into two sections, namely, the exposed area and the background, which was shielded by a portion of the miniature envelope detector holder that was designed.

The set of detectors were deployed in the selected homes in the study area. In the deployment exercise, each labelled envelope was coded with the house numbers and recorded for easy identification. The time and date of deployment was recorded. The Radon monitors were then left in the homes for a period of about one and half to two months, about which time it was expected that a good number of alpha particle tracks would have been registered in order to ensure good counting statistics.

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. The detectors were then deployed by placing them in certain positions away from the windows in the various rooms and held in position as is shown in Fig. 5 in one of the houses monitored. The detectors were then taken to the Solid State Nuclear Track Detection (SSNDT) Laboratory of the NNRI (GAEC) for analysis after it was remove from the field.

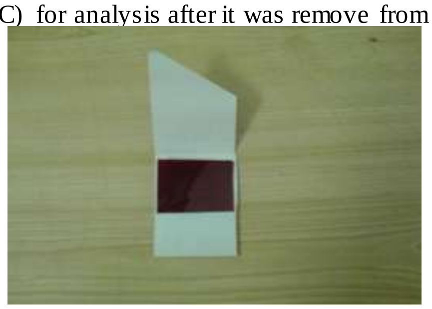

Fig. 4: LR-115 Detector with its holder

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, 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 (D)
Calibration factor (ε)
Time of exposure in hours T (h)
Track density was evaluated by the formula:

Track density (D) = Average number of tracks obtained /Area of count (1)

Radon Concentration in Bq/m^3 and kBq/m^3 for indoor and soil measurements respectively w ere evaluated using the formula:

Concentration (kBq/m^3) = D – DB / εT (h) (2)

where,
D = Track density
DB = The Background track density

Results and Discussion

The results obtained in the indoor radon gas measurements, using alpha track detectors LR – 115 are presented. However it must be noted that results for only thirty two (32) and forty five (45) detectors will be shown for both Sakumono and the Kassena Nankana Area respectively out of the fifty (50) each that was deployed. These short falls were attributed to the fact that some detectors were damaged during etching and also unintentional removal by home owners.

Figure 6 shows the indoor radon gas concentrations in houses at Sakumono and its environs. The radon concentration ranges from (5.29 – 18.6) Bq/m^3. All the concentrations obtained were below the Action Level of 150 Bq/m3 set out by the US EPA. The housing types were those with an average of two large windows per room. Some of these windows come with louver blades and wooden doors, whilst others have modern sliding windows also known as glazing and door fittings to aid ventilation. Various categories exist such as:

• Flats, which are mostly storeys with or without basements
• Semi-detached and detached houses uniquely designed by estate developers
• Bungalows

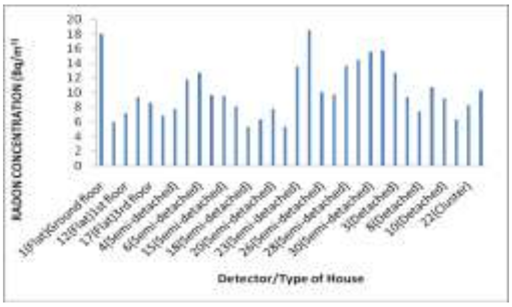

Figure 6: Indoor radon gas concentrations in houses at Sakumono and its environs

Comparing with other works, it could be inferred that there was no much deviation from what has been obtained in previous works (Nazaroff and Nero, 1988).

Figure 7 shows the indoor radon gas concentrations in Adobe houses in the Kassena Nankana Area. The radon concentrations in the study range between 35.3 Bq/m3 and 244.2 Bq/m3. Concentrations above the Action Level of 150 Bq/m3 set out by the US EPA were found in 38% of the Adobe houses in the study area. A log- normal frequency distribution was obtained in this work which is a big departure from most works of this nature. (Quashie et al 2011)

Figure 8 shows a graph of indoor radon concentration of Sakumono and its environs and that of Adobe houses in the Kassena Nankana area. The results show clearly that the indoor radon concentration in Adobe houses is higher than that of Sakumono and its environs in the range 6.8 – 13.1 times. This is evident in work done by (Oppon et al 1990) the Physics department of Ghana Atomic Energy Commission in traditional houses (Mud Houses) in Dome.

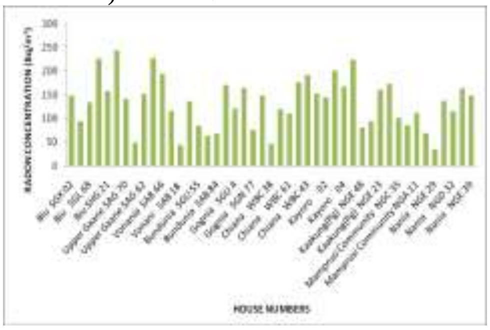

Fig 7: Indoor radon gas concentrations in Adobe houses in the Kassena Nankana Area

This brings to the fore the importance of construction materials for the modern buildings in either elevating or reducing indoor radon gas concentration. Thus, buildings constructed with concrete together with proper sealing against radon ingress routes often tend to have lower concentrations (Qiu et al., 2005& Akortia et al 2010).

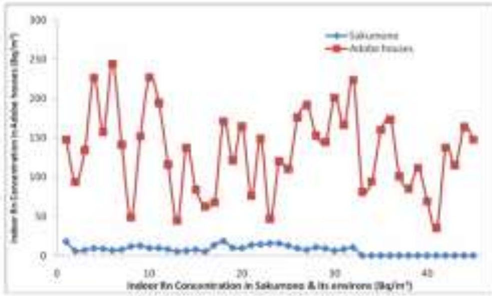

Fig 8: A graph of indoor radon concentration of Sakumono and its environs and that of Adobe houses in the Kassena Nankana area

The mean radon gas concentration for the study in Sakumono and its environs was estimated to be 9.33 Bq/m3. Also, the standard deviation of the mean determined for the block of flats was 4.44 Bq/m3, whereas those for the semi detached and cluster houses were 3.58, 2.28 and 1.45 Bq/m3, respectively, whiles that of the Adobe houses ranges from 91.74 - 177.80 Bq/m.

Explanations for the high concentrations in Adobe houses than that of Sakumono and its environs were as follows:

• 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 whiles that of Sakumono and its environs are well ventilated.
• 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 on the other hand the estate houses had floorings covered with cement, terrazzo tiles or porcelain/ceramic tiles with carpets)
• Life styles of inhabitants/occupants in the study areas is also a factor

The annual dose rate was also taken during the study and the results are shown in Table 1. In calculating the effective dose, the USA-Environmental Protection Agency Assumption (EPAA) dose conversion factor of 20 Bq/m3 of radon which is equivalent to an effective dose of 1 mSv/y was adopted as shown in some works (Abu-Samreh 2005; Baxter 1993; Conaba et al 2000).

An occupancy factor of six (6) hours was used in the calculation as the average time spent in rooms by the occupants for the measurements in Adobe houses whiles that of Sakumono and its environs were given as 12 hours and about 8 hours for the modern estate building and the cluster houses respectively. The average annual effective doses received by people in the study area are found to vary from 0.44 mSv/y to 3.05 mSv/y and 0.15mSv/y to 0.26 mSv/y for Adobe houses and that of Sakumono and its environs respectively.

Conclusion

The study has shown that the indoor radon concentration and annual effective dose rate measured in Sakumono and its environs were within the acceptable range/limit set out by both the US EPA and the International Commission on Radiological Protection (ICRP).This is an indication that buildings in Sakumono and its environs are good for habitation when it comes to radon but that can not be said about Adobe houses in the Kassena Nankana area.

38% of Adobe houses in the study area were above the Action Level of 150 Bq/m3 set out by the US EPA. Remedial action is therefore needed in those houses in order not to pose a radiation risk to its occupants. The average effective dose for the Adobe houses is 1.66 mSv/y and the value is a little higher than the average global dose of 1.3 mSv/y (Gonzalez 1993).

The following are recommended:

1. Enlarging of windows and openings in the Adobe houses will improve ventilation of the houses in the Kassena Nankana area resulting in increased air exchange rates with the outside, thereby lowering the radon concentrations in the various rooms.
2. Currently Ghana cannot boast of any Radon map for the whole nation and all efforts must be channelled into making one. This radon map will help identify radon risk zones and its other health effects.
3. The regulatory guide for the control of hazards due to radon in homes and working places in Ghana should be passed into law.
4. Land - use planners should incorporate radon measurements in their works.

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Table 1: Inhalation dose due to radon and its progeny in the dwellings of the study

Kassena Nankana Area	Effectivedoses(mS/y)	Sakumono and its environs'	Effectivedoses(mSv/y
Biu SGX 02	1.11	1(Flat)Groundfloor	0.24
Biu SHH 23	0.70	2(Flat)2nd floor	0.26
Biu SGL 68	1.01	12(Flat)1st floor	0.26
Biu SHH 27	1.70	14(Flat)1st floor	0.24
Biu SHG 21	1.18	17(Flat)3rd floor	0.27
Upper Gaane SAG 73	1.83	24(Flat)1st floor	0.26
Upper Gaane SAG 70	1.06	4(Semi-detached)	0.24
Upper Gaane SAH 45	0.37	5(Semi-detached)	0.26
Upper Gaane SAG 62	1.14	6(Semi-detached)	0.26
Upper Gaane SAG 79	1.70	13(Semidetached)	0.26
Vonania SAB 66	1.46	15(Semidetached)	0.24
Vonania SAE 11	0.87	16(Semidetached)	0.26
Vonania SAB 18	0.33	18(Semidetached)	0.26
Vonania SAB 82	1.03	19(Semidetached)	0.24
Bundunia SGU 55	0.63	20(Semidetached)	0.24
Bundunia SGN 50	0.47	21(Semidetached)	0.24
Bundunia SAB 84	0.51	23(Semidetached)	0.24
Bundunia SGN 71	1.28	25(Semidetached)	0.26
Gognia SGU 4	0.91	26(Semidetached)	0.26
Gognia SGN 73	1.23	27(Semidetached)	0.24
Gognia SGN 77	0.57	28(Semidetached)	0.24
Gognia SGU 64	1.11	29(Semidetached)	0.26
Chiana WBC 38	0.35	30(Semidetached)	0.26
Chiana WBC 18	0.90	31(Semidetached)	0.24
Chiana WBC 61	0.83	3(Detached)	0.24
Chiana WBC 8	1.32	7(Detached)	0.25
Chiana WBC 43	1.44	8(Detached)	0.24
Kayoro 01	1.15	9(Detached)	0.25
Kayoro 02	1.09	10(Detached)	0.25
Kayoro 03	1.51	11(Detached)	0.24
Kayoro 04	1.25	22(Cluster)	0.16
Kayoro 05	1.68	32(Cluster)	0.14
Kaakung(Pg) NGE 48	0.61		
Kaakung(Pg) NGE 61	0.71		
Kaakung(Pg) NGE 23	1.20		
Kaakung(Pg) NGE 18	1.30		
Mamprusi Community NGC 35	0.76		
Mamprusi Community NGA 41	0.64		
Mamprusi Community NGA 11	0.84		
Mamprusi Community NGA 62	0.52		
Nania NGE 29	0.26		
Nania NGD 52	1.03		
Nania NGD 32	0.87		
Nania NGD 38	1.23		
Nania NGE 39	1.11		