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Indoor Radon Gas Monitoring in Brakwa Central Region, Ghana

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Abstract: Radon is the most important source of natural radiation and responsible for approximately half of the received dose of the totality of natural radioactivity. Most of the dose comes from the inhalation of the progeny ^{222}Rn and this happens especially in enclosed environments. Indoor radon levels in 30 dwellings of rural areas in Brakwa located in the Asikuma-Odoben-Brakwa District of the central region of Ghana were measured using bare solid state nuclear track detectors. These dwellings were monitored for 6 successive months. The random sampling method was employed in this study. The results from this work showed an average concentration of radon gas at 57.45 Bq/m^3. This concentration is below the accepted action levels of radon gas concentration. The various possible ways of mitigation of indoor radon gas concentration level in the Brakwa area of the Central Region of Ghana are discussed in the study.

Key words: Inhalation, radioactivity, radon

INTRODUCTION

The various risks associated with human health posed by ionizing radiation are well documented. Radon gas is by far the most important source of ionizing radiation among those that are of natural origin. It is a naturally occurring radioactive gas that originates from the decay of uranium 238. Radon is the heaviest of the noble or inert gas group and is therefore characterized by chemical inertness. It is the largest natural source of human exposure to ionizing radiation in most countries. In the general population most exposure occurs indoors, especially in small buildings such as houses (UNSCEAR, 2000), although there are some groups for whom occupational exposure presents a greater risk.

When radon gas is inhaled, densely ionizing alpha particles emitted by deposited short-lived decay products of radon (^{218}Po and ^{214}Po) can interact with biological tissue in the lungs leading to DNA damage (WHO, 2009). In the early 1980s, several surveys of radon concentrations in homes and other buildings were carried out, and the results of these surveys, together with risk estimates based on the studies of mine workers, provided indirect evidence that radon may be an important cause of lung cancer in the general population. Recently, efforts to directly investigate the association between indoor radon and lung cancer have provided convincing evidence of increased lung cancer risk causally associated with radon, even at levels commonly found in buildings. Due to the findings, the International Agency for Research on Cancer in 1988 (IARC, 1988) classified radon as a human carcinogen. A large number of investigators in Europe, North America, and China have brought their data together, and analyzed it centrally (Lubin *et al*., 2004; Krewski *et al*., 2005, 2006; Darby *et al*., 2005, 2006). These three pooled-analyses present very similar pictures of the risks of lung cancer from residential exposure to radon. Together, they provide overwhelming evidence that radon is causing a substantial number of lung cancers in the general population and they provide a direct estimate of the magnitude of the risk.

Due to the increasing effects of radon on human health, a study was conducted in 2007 to investigate indoor radon gas concentration in the Brakwa area of the Central Region of Ghana to document the levels of radon gases indoors over a period of time. The data acquired will also be used in advising the populace on the effects of radon above the critical levels.

THEORY

Radon concentration is normally given in the unit of Bq/m^3. Radon dose is another quantity which gives energy deposition from radon and its progeny per unit mass of the absorber, such as human body or human lung. Radon concentration level is given by the expression:

Radon concentration level

$$= \text{Net track density} / [\text{Time in h} \times \text{Calibration factor}]$$
$$= [\rho_{(tk)} - \rho_B] / [T \times \varepsilon]$$

where $\rho_{(tk)}$ = Radon concentration (track/m^2)
ρ_B = Background radon concentration (track/m^2)
$\rho_{(tk)} - \rho_B$ = Net density
ϵ = Calibration factor
T = Time in h
The radon concentration level is given in Bq/m^3.

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Fig.1: Typical placement of "Bare" film detector at the project site

MATERIALS AND METHODS

The sampling site: The sampling site, Brakwa, Central Region, Ghana, lies between 05º43′20″ N and 00º55′72″ W. It is about 191 m above sea level in a moist semi-deciduous forest zone. The highest mean monthly temperature of 30ºC occurs between March and May while the lowest of 25ºC, occurs in August. Mean annual rainfall of the vegetation zone is between 1270 and 1778 mm. The main occupation of the inhabitants is farming. Cocoa and oil palm are the principal cash crops while cocoyam, cassava, maize, plantain, tomatoes and pepper constitute the main staple food crops.

Radon gas measurement: Recognition of charged particles passing through dielectric solids produce damage tracks that may be revealed as a result of preferential chemical etching. Applications of this technique generally known as solid State Nuclear Track Detection (SSNTD). The effectiveness of the SSNTD technique allowed radon gas concentration survey in Brakwa. It is important to mention that the technique allows measurement of very low and very high radon gas concentrations, with a detection limit that is a function of the background track density of the LR-115 films (Damkjaer, 1986).

Preparation of SSNT detector: Solid State Nuclear Track (SSNT) detector films made by Kodak Pathé of France were cut into dimension of 6 cm by 4 cm and placed in envelopes with half of the films exposed (bare) and the other half covered by the envelope (Fig. 1). Sixty copies of likewise detectors were prepared for the work. The sample preparation and all lab work were done at the Physics department of the National Nuclear Research Institution (NNRI) of Ghana Atomic Energy Commission (GAEC).

Exposing the detector: The prepared detectors were placed in the corners of rooms away from the open windows and doors and held in position by tag pins for a period of three (3) months uninterrupted. At the research site, the alpha particles in the air strike the active layer of the detector resulting in molecular chains of the active layer being broken into shorter chains and submicroscopic narrow (~3-10 nm) trails of damage are left behind. Alpha particle paths, also known as latent tracks, depend on the alpha energy produced. However, these tracks are too small to be visible and the films must be processed.

Chemical etching and counting of tracks: A water bath filled with water to about 60% of its capacity and maintained at 60ºC, had a beaker containing 2.5 M of NaOH etchant solution immersed in it so that only the top of the beaker stood out of the water. The bath was covered to prevent evaporation of the etchant and to allow for thermal equilibrium.

The plastic detectors from the filter papers and the thin sheath of polythene covering the unexposed sides were removed. The detectors are tired with twine for label and suspended in the etchant horizontally for 90 mins. After this time, the detectors were removed from the etchant by means of the thread, immediately rinsed thoroughly with distilled water to stop further etching activity and dried in open air for about 10 minutes. The latent tracks then become visible tracks as a hole under optical microscope. The total number of tracks is then counted using a tally counter to obtain the radon gas concentration.

RESULTS AND DISCUSSION

The radon concentration level is summarized in Table 1. The first column gives the identification of the house, the second the average of 3 measurements presented as a single entry, the third and fourth columns gives the duration of exposure of the films and background count respectively. Each alpha particle strike on the detector leaves a latent track which becomes visible after etching in a suitable solution. The number of tracks on the detectors reflects the concentration of radon gas and its progeny. The visible tracks are counted under the optical microscope and the higher the number of tracks, the higher the concentration. These are presented in colu5-8.

When an individual spends time in an atmosphere that contains radon and its decay products, the part of the body that receives the highest dose of ionizing radiation is the bronchial epithelium, although the extra thoracic airways and the skin may also receive appreciable doses. In addition, other organs, including the kidney and the bone marrow, may receive low doses (Kendall and Smith, 2002). A national reference level for radon represents the maximum accepted radon concentration in a residential dwelling and is an important component of a national programme. For homes with radon concentrations above

Table 1: Calculated values of track density, background density, radon concentration in 30 selected houses. ϵ = calibration factor = 1 (assumed); Area: 0.2 m^2

House no.	Average count	Time (T, h)	Background count	ρ(tk) Track/m^2	ρB(track/m^2)	ρ(tk)- ρB(track/m^2)	Conc. (Bq/m^3)
1	14.67	1872	3	73.33	15	58.33	31.16
2	15.33	1872	2	76.67	10	66.67	35.61
3	10.33	1872	3	51.67	15	36.67	19.59
4	23.33	1872	4	116.67	20	96.67	44.52
6	25.00	1872	3	125.00	15	110.00	58.76
7	21.67	1872	3	108.33	15	93.33	49.86
8	23.67	1872	3	118.33	15	103.33	55.20
9	28.67	1872	2	143.33	10	133.33	71.23
10	16.33	1872	3	81.67	15	66.67	35.61
11	22.33	1872	2	111.67	10	101.67	54.31
12	16.33	1872	3	81.67	15	66.67	35.61
13	18.33	1872	2	91.67	10	81.67	43.63
14	22.33	1872	3	111.67	15	96.67	51.64
15	39.67	1920	5	198.33	25	173.33	90.28
16	32.33	1920	2	161.67	10	151.67	78.99
17	21.67	1920	2	108.33	10	98.33	51.22
18	23.67	1920	3	118.33	15	103.33	53.82
19	23.67	1920	2	118.33	10	108.33	56.42
20	31.67	1920	3	158.33	15	143.33	74.65
21	41.67	1920	3	208.33	15	193.33	100.69
22	23.67	1920	3	118.33	15	103.33	53.82
23	40.00	1944	4	200.00	20	180.00	92.59
24	23.33	1944	4	116.67	20	96.67	49.73
25	32.00	1944	3	160.00	15	145.00	74.59
26	11.00	1944	2	55.00	10	45.00	23.15
27	31.33	1944	4	156.67	20	136.67	70.30
28	25.33	1944	2	126.67	10	116.67	60.01
29	23.33	1944	2	116.67	10	106.67	54.87
30	26.33	1944	4	131.67	20	111.67	57.44

these levels remedial actions may be recommended or required. In view of the latest scientific data, WHO proposes a reference level of 100 Bq/m^3 to minimize health hazards due to indoor radon exposure. However, if this level cannot be reached under the prevailing country-specific conditions, the chosen reference level should not exceed 300 Bq/m^3 which represents approximately 10 mSv per year according to recent calculations by the International Commission on Radiation Protection (ICRP, 1993).

This research reveals that out of 30 selected houses, the minimum indoor radon gas concentration was 19.59 Bq/m^3 while the maximum was found to be 100.69 Bq/m^3. The average radon concentration from the 30 selected houses was calculated as 57.45 Bq/m^3. The houses which have high concentration of indoor radon gas than average value were observed to have small size and lower numbers of windows for ventilation. In addition, because the buildings site is low it is possible that the soil contributes partially to the observed radon gas. A possible way of reducing the radon concentration is to elevate the site by filling with laterite and gravels to about four feet high before erecting foundations of building to minimize the flow of soil gas.

Comparing the results obtained during the research to the recommended concentrations of WHO and ICRP, it can be established that the maximum concentration obtained is just marginally above the recommended level of 100 Bq/m^3 but well within the ICRP recommended concentrations of 300 Bq/m^3.

CONCLUSION

Solid state nuclear track detectors can be used in the long-term measurement of radon gas concentration in residential sites since measurement should be more than one month. The method has been observed with advantages for measuring indoor radon gas concentrations.

The average indoor radon gas concentration level was found to be 57.45 Bq/m^3 which are below the world average indoor radon gas concentration level. The values from the houses were found to be less than action level. Hence the community living in houses in the Brakwa area is considered from radon poisoning. As a way to mitigating or further lowering the indoor radon level in the community, it is suggested that:

- Windows need to be opened so allow for proper ventilation and reduction in soil gas.
- In some case, it is recommended that windows be widened with the installation of new ones by the owner.

- Future buildings must be elevated by filling with laterite and gravels to about four feet height before commencing with foundation of the building. These will serve to minimize soil gas.

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