

## Preliminary Evaluation of Indoor Radon Exposure Levels in Students' Halls of Residence at the Northern Campus (New Site) of the University of Cape Coast, Ghana

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**Abstract:** The study seeks to present Radon exposure levels in some rooms within halls of residence at the New Site of the University of Cape Coast, Ghana determined using LR-115 TypeII Solid State Nuclear Track Detector (SSNTD) and E-PERM detecting systems. Pieces of the plastic LR-115 detectors were covered with aluminium foil and fixed in plastic holder such that the active part (coated part) of the detector was exposed (bare), facing downwards and together with the E-PERM were placed at a location in each of the selected rooms in the halls of residence for 30 days. The voltages of the E-PERMs were taken using the SPER-1 Reader whilst the LR-115 was chemically etched to reveal the alpha tracks. The mean radon exposure level for LR-115 was 6.8 mSv (range: 3.1-9.1 mSv) while the mean exposure for the E-PERM was 3.6 mSv (range: 1.7-5.3 mSv). The results obtained also indicated that the exposure levels measured by both the E-PERM and the LR-115 detectors were generally below the Environmental Protection Agency (US-EPA) guideline limit of 8 mSv. However, some rooms had their exposure levels (measured with the LR-115 detector) above the remedial guideline limit of 8 mSv, but far below the immediate action limit of 20 mSv. Most of a student time is spent indoors. There is therefore the need to have a fair idea the radon concentration and exposure levels in rooms since radon has been identified as a carcinogenic gas.

**Keywords:** Cape coast, concentration, E-PERM, exposure, LR-115, radon

### INTRODUCTION

Radon (Rn-222) and its progeny are naturally occurring radioactive isotopes that emit mostly  $\alpha$  radiation and cause radiation exposure mainly to the lung. Radon is one of a very small number of substances which have been established to be human carcinogen on the basis of human studies. As such it is a Group 1 and Group A carcinogen, according to the classification used by the World Health Organization (WHO/IARC, 1998) and by the Environmental Protection Agency (EPA, 1987) respectively. It comes naturally from radioactive decay of Uranium, which consists of three different isotopes. About 99.3% of uranium is U-238, about 0.7% is U-235 and a trace quantity of about  $4 \times 10^{-3}$ % is U-234. The radioisotope Rn-222, with half-life of 3.84 days is the main source (approximately 55%) of internal radiation exposure to human life (ICRP, 1993). Exposure to radon progeny has been shown to cause lung cancer among workers in uranium and other mines (National Research Council (U.S.), 1988; Darby *et al.*, 1995). In the largest Epidemiologic studies assessing the lung cancer risk due to indoor radon exposure conducted so far by Pershagen *et al.* (1994) found a statistically significant excess risk of lung cancer per unit exposure.

People are exposed to radon (CNSC, 2010) every day as a result of the natural radioactive decay of uranium in soils and rocks. In addition, workers in underground mining (notably uranium mining) are exposed to many forms of radiation, including those emitted from radon during the decay of uranium ore. The implications and challenges that arise due to human exposure to radon were the motivation behind all the research carried out to study the concentration and hence exposure of radon in the environment. Presence of radon and its progenies in houses are due to different sources. Radon escaping from soil into houses is one of the major sources of contamination (Al-Sharif and Abdelrahman, 2001). Radon can flow from underground to the surface through cracks in walls, floors, joints or pipe holes and lines and naturally enters houses. Building materials are also considered as another major source of radon gas. It must be noted that the concentration of radon in indoor air varies greatly, mainly as a result of the uranium concentration and permeability of the ground, climatic factors and the construction and ventilation of the house.

However, the effect of radon is not due to the gas itself since when radon gas is inhaled, as it quickly flows out of the lung and never lingers long enough to cause damage; but the alpha-active radon progeny via

polonium-218 and polonium-214 tend to lodge in the bronchial tree which cause the effects. They emit heavy alpha particles with energies of about 6.0 to 7.8 MeV, smaller and lighter beta particles and short-wavelength gamma rays. These small bursts of energy can damage lung tissue, which leads to lung cancer (Bowen, 1979). With the increase of cancers related cases worldwide, there is the need to investigate some of the contributing factors that enhance cancer development.

In this study, SSNTDs and E-PERM-detectors were used to measure the radon concentration levels in some students' rooms within halls of residence at the New Site of the University of Cape Coast on the central coast of Ghana. The university is located five kilometers (5 km) west of the Cape Coast city, on a hill overlooking the Atlantic Ocean and situated between latitude 5°6'0" north and longitude 1°15'0" west and about 300 m above sea level. The monthly mean temperature of the area fluctuates between 28 and 32°C, respectively. The climate follows the normal pattern of the coastal region of the country. The relative humidity ranges between 68 and 90%, respectively. The annual rainfall is between 750 and 1000 mm, respectively.

## MATERIALS AND METHODS

**Experimental procedures:** Fifteen (15) 2x3 cm pieces of the plastic LR-115 detectors were cut. Each detector was covered with aluminium foil and fixed in plastic holder such that the active part (coated part) of the LR-115 detector was exposed (bare), facing downwards. The 15 plastic holders containing the detectors were each exposed together with an E-PERM at a location in each of the selected rooms in the halls of residence for 30 days. The initial voltages of the E-PERMs were taken using the SPER-1 Reader before they were exposed.

**The chemical etching and tracks counting procedures:** After the continual 30 day exposure, The LR-115 detectors were removed from the plastic holders and subjected to chemical etching in a 2.5 M analytical grade sodium hydroxide (NaOH) solution at 60°C, for 110 min in a constant temperature water bath to enlarge the latent tracks produced by alpha particles from the decay of radon. After etching, the detectors were first rinsed in flowing cold water for 30 min to stop further etching from the left-over NaOH in the track, then with distilled water. After rinsing, the LR-115 layer was peeled off the plastic hard material and air-dried in the laboratory to get it ready for the spark counting. The spark counting detector was first pre-sparked at 1000 V to enlarge the track holes and then

reset to instantaneous voltage of 750 V for the counting. A diagram of spark counter (Durrani, 2003) is shown in Fig. 1.

**E-PERM voltage reading using the SPER-1 reader:** The SPER-1 Reader (Surface Potential Electrets Voltage Reader), a high precision, non-contact voltmeter was used to take voltage readings from the E-PERM detectors. This was done by placing the electrets face down into the circular receptacle on top of the SPER-1Reader. Two voltage readings were taken by drawing the shutter knob and holding for about 5 sec and the voltage reading at each time was taken. Conversion of the two electrets voltage readings and exposure period into radon concentration using the E-PERM was done through a two-step calculation. Firstly, the Calibration Factor (CF) is determined using Eq. (1):

$$CF = A + B \times \frac{(I + F)}{2} \equiv \frac{\text{Volts}}{\frac{\text{pci}}{C} \times \text{day}} \quad (1)$$

where, *A* and *B* are constants for a particular E-PERM configuration (Moore and McCabe, 2005), *I* and *F* are the initial and the final electrets voltages; *CF* is defined as the decrease in electrets voltage when a specific electrets and chamber are exposed for one day at a Concentration (*C*) of 1pci/L of radon. The radon concentration is then calculated using Eq. (2):

$$R_{nc} = \frac{I - F - BG}{CF \times D} \quad (2)$$

where, *R<sub>nc</sub>* is the radon concentration in units of pci/L, *I* and *F* are initial and final electrets voltages, *D* is the exposure period in units of days, *BG* is the gamma background radiation given in units of radon concentration (pci/L) but is assumed to be 0 in this experiment.

**Parameters and trend of calculation for LR-115 detectors:** Using the LR-115 detectors, the radon concentration was computed as follows:

$$R_{nc} = \frac{P_E - P_B}{ET} \quad (3)$$

where,  
*P<sub>E</sub>* = Track density of exposed detector  
*P<sub>B</sub>* = Background track density of the unexposed detectors which were 18 tracks/cm<sup>2</sup>

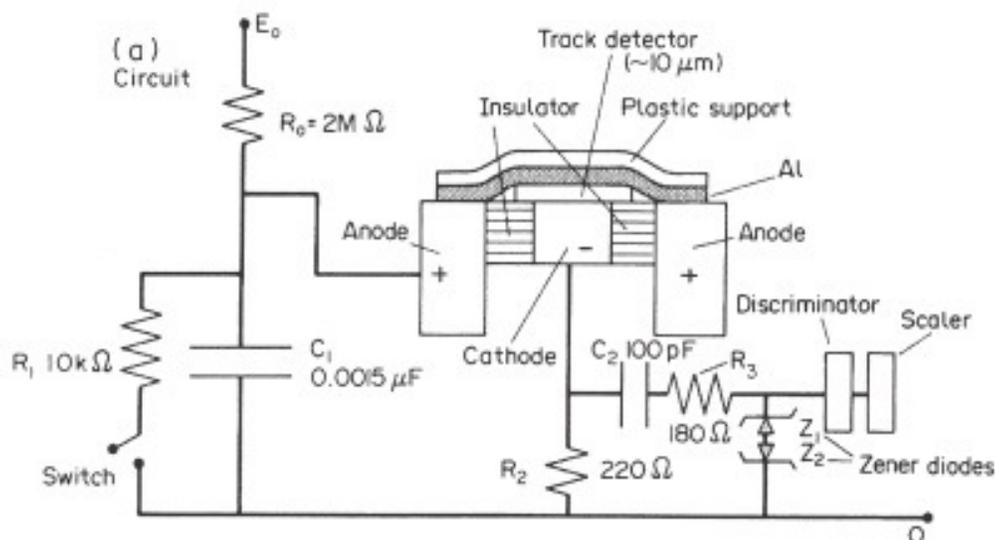


Fig. 1: Diagram of spark counter used for counting the track holes

- $E$  = Efficiency of field calibrated dosimeter
- $T$  = Exposure period in hours in this experiment
- $P_B = 18.00 \text{ tracks/cm}^2$
- $E = 0.545 \text{ tracks/cm}^2/\text{kBq/hcm}^3$

**The exposure levels in the halls:** Exposure levels (in mSv) in relation to the radon concentrations were estimated. It is established that every  $20 \text{ Bq/m}^3$  of radon concentration is equivalent to  $1 \text{ mSv}$  (ICRP, 1993). The exposure level is therefore calculated as:

$$E_{Rn} = \frac{C}{20} \times \frac{T}{24} \text{ mSv} \quad (4)$$

where,

- $C$  = Radon concentration in  $\text{Bq/m}^3$
- $T$  = The average number of hours spent by a student in a room

In this study, it was assumed a spends on the average 8 h a day in a room.

### RESULTS AND DISCUSSION

After an exposure period of 30 days and 22 h, the LR-115 and the E-PERM systems for the measurement of indoor radon concentration were evaluated using the spark counter and the Electrets Reader respectively.

The obtained counts and voltages for LR-115 and E-PERM respectively are presented in Table 1.

In all, fifteen (15) pairs of measurements for radon concentrations were obtained in the different rooms of

Table 1: Readings recorded from the detectors

Room no.	E-PERM readings		LR-115 readings no. of counts
	Initial voltage/v	Final voltage/v	
CFD-117	487	460	60
CFD-114	583	554	53
CFD-112	599	592	83
CFD-125	542	524	92
CFD-124	432	415	102
VLC-G14	522	517	119
VLC-E5	189	174	61
VLC-C27	280	273	118
VLC-C15	525	505	47
VLC-E13	160	148	121
NKR-B24	389	386	110
NKR-B14	140	121	104
NKR-B4	400	376	114
NKR-C13	378	352	107
NKR-A9	174	168	71

the selected Halls. The concentrations obtained are shown in Table 2 with their summary given in Table 3.

Radon exposure levels, corresponding to the measured concentrations and based on the assumption that a student spends on the average 8 h a day in a room are given in Table 4. Their statistical inferences are also shown in Table 5.

The mean radon exposure level for LR-115 was calculated to be 6.8 mSv while 3.6 mSv was obtained with E-PERM. This gave a ratio of about 2:1, deviating from the 1:1 expected ratio, which shows that the radon concentrations measured by the two detectors were not linearly consistent. Generally, the Radon exposure level values for the LR-115 were higher than those of the E-

Table 2: Radon concentrations

Room no.	Radon Conc/Bq/m <sup>3</sup>	
	LR-115	E-PERM
CFD-117	249	222
CFD-114	216	178
CFD-112	364	243
CFD-125	475	112
CFD-124	480	305
VLC-G14	551	231
VLC-E5	255	105
VLC-C27	536	247
VLC-C15	187	128
VLC-E13	550	315
NKR-B24	497	319
NKR-B14	467	135
NKR-B4	516	156
NKR-C13	482	303
NKR-A9	305	242

Table 3: Summary of radon concentrations

Hall of residence	E-PERM		LR-115	
	Mean (Bq/m <sup>3</sup> )	SD	Mean (Bq/m <sup>3</sup> )	SD
CFD	212.00	72.23	356.80	123.13
VLC	205.20	87.28	415.80	179.54
NKR	231.00	83.50	453.40	84.92
All halls	216.07	76.07	408.67	131.51

Table 4: Exposure levels in the halls

Room no.	Exposure level (mSv)	
	LR-115	E-PERM
CFD-117	4.1	3.7
CFD-114	3.6	3.0
CFD-112	6.0	4.0
CFD-125	7.8	1.9
CFD-124	7.9	5.0
VLC-G14	9.1	3.8
VLC-E5	4.3	1.7
VLC-C27	8.9	4.0
VLC-C15	3.1	2.1
VLC-E13	9.1	5.2
NKR-B24	8.2	5.3
NKR-B14	7.7	2.3
NKR-B4	8.5	2.6
NKR-C13	8.0	5.0
NKR-A9	5.1	4.0

Table 5: Summary of radon exposure levels

Hall of residence	E-PERM		LR-115	
	Mean (mSv)	SD	Mean (mSv)	SD
CFD	3.52	1.16	5.88	2.01
VLC	3.36	1.44	6.90	2.95
NKR	3.84	1.36	7.50	1.37
All halls	3.57	1.24	6.76	2.16

PERM. This is because the E-PERM is generally affected by temperature due to differences in expansion coefficients of the Teflon electrets, which cause it to concave or convex slightly when temperature changes. This causes the electrets surface to move slightly closer or away from the sensor during readings which results

in change in voltage value and can thus affect the radon concentration given by the E-PERM. The E-PERM is also affected by humidity and gamma radiations (e.g., from television sets) as well (E-PERM, 1974). However, the background gamma radiation was assumed to be zero (0) in the E-PERM calculations since the background radiation in Cape Coast was not known at the time this study was carried out. The LR-115 is however, not affected by temperature, humidity and gamma radiations but the counts can be affected by the residual thickness of the LR-115 foil.

The exposure levels (taking into account the occupancy factor) for the E-PERM were generally below the US-EPA remedial guideline level of 8 mSv. The mean exposure level of 6.8 mSv (range: 3.1-9.1 mSv), measured with the LR-115 at the assumed occupancy factor had over 60% of the levels falling within one (1) standard deviation and is also below the prescribed remedial guideline. Although four (4) data points (1 in VLC and 3 in NKR) were above this guideline; they are however below the US-EPA immediate action level of 20 mSv. The mean exposure levels measured with the LR-115 rated CFD as the lowest (5.9 mSv) followed VLC (6.9 mSv) and NKR (7.5 mSv) in increasing order. This classification follows the chronological order in which these Halls of residence were built. One of the sources of radon in building is the permeability of the ground which depends on the nature of the rock and soil under the building. Disturbed ground during the building process can greatly increase permeability. Hence the more recent the building the more fissured the ground around it and the higher radon concentration may be.

### CONCLUSION

In this study, level of radon exposure measurements in some Halls of residence at the New Site of the University of Cape Coast were carried out. The results indicated that the exposure levels recorded with both the E-PERM and the LR-115 detectors were generally below the US-EPA guideline level of 8 mSv. However, some rooms had their exposure levels, as measured with the LR115 detector, above the remedial guideline level of 8 mSv, but below the immediate action level of 20 mSv. This can be attributed to some factors such as poor ventilation, building materials and permeability soil around the study location. It is recommended that long-term measures be taken to check and reduce radon exposure levels, especially in students' rooms on the ground floor.

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