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Radon Measurements in Soils along the Coast of Accra from Teshie to Nyanyano, Southeastern Ghana

Paulina E. Amponsah[1, 2], Aba B. Andam[2], and Irene N. Akoto[1]
[1]*National Nuclear Research Institute, Ghana Atomic Energy Commission, Legon-Accra, Ghana*
[2]*Graduate School of Nuclear and Allied Sciences, Ghana Atomic Energy Commission, Legon-Accra, Ghana*

Corresponding author:
P. E. Amponsah, National Nuclear Research Institute, Ghana Atomic Energy Commission, P. O. Box LG 80, Legon-Accra, Ghana
E-mail: pekua2@yahoo.com

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A study has been undertaken along the coast of Accra (Teshie to Nyanyano) in the Greater Accra Metropolitan Area to investigate the emission of soil radon gas in the area using Lenin Resin (LR) 115 cellulose nitrate detectors. Twenty seven sampling points were considered for the investigation. A set of detectors were buried at a time and were replaced fortnightly for a period of 2 weeks. Three exposures were made at each location. Due to logistics constraints, the detectors were buried in phases over a period of 15 weeks. After the exposure period, the detectors were etched, air dried in the laboratory and the registered alpha tracks were counted using the Spark counter. The track density was calculated and the radon gas concentration was computed. The radon concentrations ranged from 1.40 kBqm^{-3} to 282.87 kBqm^{-3} for the period of monitoring. The average soil radon concentration measured during the period of the survey was 24.41 kBqm^{-3}. Local earthquakes of magnitude ranging from 1.1 to 2.8 on the Richter scale were recorded during the study. Continuous monitoring of the gas could confirm high emanation with the activity of the coastal boundary fault.

Keywords: *Ghana, soil radon concentration, coastal boundary fault, seismic activity, radon gas emanation and faults.*

1 Introduction

Radon in soils along the coast of Accra (Teshie to Nyanyano) has been measured to determine the level of the concentration in the largely dominated fishing area. The soil radon gas survey was conducted to establish the correlation, if any, between gas emanation and the activity of the coastal boundary fault, a major fault in the study area (Figure 1). Faults are known to be a perfect passageway for the migration of the gas. Soil gas radon concentrations have been used extensively to map active faults, as faults and fractures in the underlying rocks provide paths of high permeability and, therefore, serve as conduits for radon gas migration (Teng, 1980; Burton *et al.*, 2004). High concentrations of the gas can also pose health hazards to inhabitants.

Radon (^{222}Rn) is one of the naturally occurring isotopes that can be used in geological, seismic and tectonic studies. It has a half-life of 3.8235 days and, therefore, can be used appreciably for such a study. The gas occurs in most soils and rocks due to the presence of small quantities of uranium and radium (its direct parent nuclides), and it can migrate for long distances through fractured rocks and overlying soils. When the gas is released into the soil, it decays and emits alpha particles. Alpha sensitive detectors buried in the soil at various depths are able to record the alpha particles produced by ^{222}Rn decay and its plate-out daughters (Burton *et al.*, 2004; Amponsah *et al.*, 2008).

Fault systems in the study area

South-eastern Ghana is bounded by 2 major fault zones, i.e. the Akwapim fault and the coastal boundary fault. The coastal boundary fault lies parallel with the coast of Ghana and is about 3 km offshore. The fault defines the contact between Jurassic and Tertiary sedimentary units and is believed to have developed during the Jurassic and continued to be active during Cretaceous and Tertiary times. The coastal boundary fault intersects the Akwapim fault at Nyanyanu, a coastal town near Accra where the investigation was carried out. The intersection is marked by intense shearing and fracturing at the beach (Blundell and Banson, 1975). Bacon and Banson (1979) attributed the seismicity of south-eastern Ghana to the level of activity of the Akwapim fault and the coastal boundary fault. The selected area is characterised by extensive fractures and faults. The area has also been investigated to be a seismically active zone in south-eastern Ghana (Amponsah, 2002).

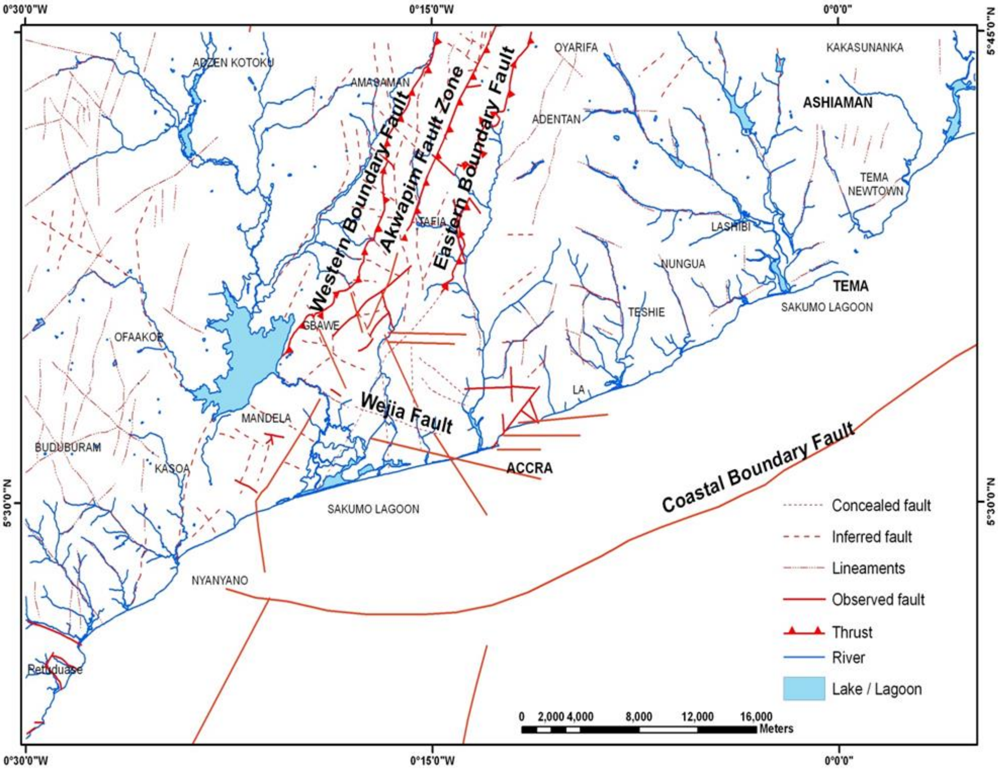

Figure 1. Fault map of the study area (modified from Muff and Efa, 2006).

2 Materials and methods

Measurement of the gas was done using a closed tube. Twenty seven (27) samples were employed at a sampling spacing of 500 m. Lenin Resin (LR) 115 cellulose nitrate detectors manufactured by Kodak Pathé in France were used for the measurements. The dimensions of the detectors used were 2 cm x 2 cm. The detectors were fixed on wooden stoppers, fitted unto a polyvinyl chloride plastic tube (length 25 cm) and buried in holes as shown in Figure 2. The tubes were buried at a depth of 75 cm. The holes were covered at the top and the detectors were exposed for 2 weeks. After the exposure period, the detectors were removed and replaced with a new set. Three exposures were made at each location over a period of 15 weeks (14 April 2004 – 4 August 2004). The detectors were detached from the stoppers and etched in a 2.5 M NaOH solution at a temperature of 60 °C for 110 min. It was then rinsed in running water and the thin film of a plastic cover was peeled off and air dried in a laboratory. The registered alpha tracks were counted using the Spark counter.

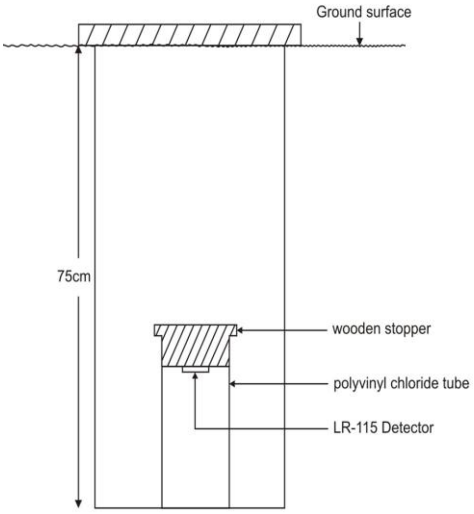

Figure 2. Set up for the radon gas measurement.

The radon data obtained were analysed. For each detector, 4 counts were made and the average value was taken. The track density was calculated using the average tracks counted and the area of the field of view of the electrode. The radon gas concentration was computed using the calibration factor (*k* = 0.29) obtained by the Ghana Atomic Energy Commission and verified in an inter-comparison exercise organised by the Environmental Protection Agency of the United States of America and the International Atomic Energy Agency (Oppon *et al.*, 1999).

3 Results and discussion

The radon concentrations registered during the period of monitoring ranged from 1.40 kBqm^{-3} to 282.87 kBqm^{-3}. The average soil radon concentration measured during the period of the survey was 24.41 kBqm^{-3}. Table 1 shows the radon concentrations of the 3 sets of detectors exposed. Detector number 15 registered 282.87 kBqm^{-3} during the first round of exposure, but much less during the second and third exposures. This could be attributed to moisture from rain water, which prevented the passage of the gas. It rained during the period when the second and third detectors were exposed (GMSD, 2004).

Earthquakes of magnitude ranging from 1.1 to 2.8 on the Richter scale were located in the area during the study (Table 2) (Amponsah *et al.*, 2008). Continuous monitoring of the gas could ascertain the correlation between gas emanation and seismic events.

Table 1. Radon concentration of 3 sets of detectors exposed (14 April – 4 August 2004).

Detector number	Set 1	Set 2	Set 3	Mean	Standard deviation
	Concentration/kBqm^{-3}				
1	37.00 ± 0.008	2.63 ± 0.002	9.54 ± 0.004	16.39 ± 0.005	14.85
2	27.72 ± 0.007	17.24 ± 0.006	14.51 ± 0.005	19.82 ± 0.006	5.70
3	102.84 ± 0.014	6.29 ± 0.003	11.91± 0.005	40.35 ± 0.007	44.25
4	29.12 ± 0.007	5.32 ± 0.003	41.65 ± 0.009	25.37 ± 0.003	15.07
5	5.73 ± 0.002	7.09 ± 0.004	5.43 ± 0.003	6.08 ± 0.003	0.72
6	13.32 ± 0.005	2.12 ± 0.002	3.87 ± 0.003	6.43 ± 0.005	4.92
7	26.98 ± 0.007	9.38 ± 0.004	12.10 ± 0.005	16.15 ± 0.005	7.73
8	2.72 ± 0.002	1.56 ± 0.002	6.26 ± 0.003	3.51 ± 0.002	2.00
9	282.87 ± 0.023	29.69 ± 0.008	33.20 ± 0.795	115.25 ± 0.275	118.53
10	31.12 ± 0.008	---	15.09 ± 0.005	23.10 ± 0.007	8.01
11	64.37 ± 0.011	15.38 ± 0.005	14.92 ± 0.005	31.55 ± 0.007	23.20
12	11.28 ± 0.005	4.45 ± 0.003	14.53 ± 0.053	10.09 ± 0.020	4.20
13	60.60 ± 0.011	5.07 ± 0.003	14.58 ± 0.005	26.75 ± 0.006	24.25
14	6.98 ± 0.004	13.77 ± 0.005	35.92 ± 0.008	18.89 ± 0.006	12.36
15	282.68 ± 0.023	12.87 ± 0.005	24.02 ± 0.007	106.52 ± 0.012	124.65
16	27.44 ± 0.007	2.88 ± 0.002	11.74 ± 0.005	14.02 ± 0.005	10.16
17	25.02 ± 0.007	20.60 ± 0.006	14.32 ± 0.005	19.98 ± 0.006	4.39
18	23.25 ± 0.007	3.29 ± 0.001	14.63 ± 0.528	13.73 ± 0.018	8.17
19	44.35 ± 0.009	19.85 ± 0.006	32.64 ± 0.008	32.28 ± 0.008	10.00
20	4.96 ± 0.003	30.19 ± 0.008	4.32 ± 0.003	13.16 ± 0.005	12.05
21	10.58 ± 0.004	10.55 ± 0.004	10.51 ± 0.004	10.55 ± 0.004	0.03
22	6.52 ± 0.004	9.50 ± 0.004	21.15 ± 0.634	12.39 ± 0.214	6.31
23	3.04 ± 0.002	1.40 ± 0.002	7.91 ± 0.004	4.12 ± 0.003	2.77
24	42.53 ± 0.009	16.59 ± 0.006	46.78 ± 0.009	35.30 ± 0.008	13.34
25	11.13 ± 0.005	4.91 ± 0.003	4.73 ± 0.003	6.92 ± 0.004	2.98
26	60.84 ± 0.011	33.98 ± 0.008	---	47.41 ± 0.010	13.43
27	3.36 ± 0.03	6.55 ± 0.004	9.75 ± 0.004	6.55 ± 0.013	2.61

--- Detectors were tampered with.

Research into the radon concentration in soils in Ghana is ongoing. There is, therefore, no standard or acceptable threshold value for the soil radon concentration in the country as reference information. However, the mean of the data set (as used in similar research studies) was used as the threshold or background value (Cuff, 2001; Wrixon *et al.*, 1988; Rannou, 1989).

Radon risk maps made in Israel have categorised radon emissions below 10.00 kBqm^{-3} as low emissions, from 10.00 kBqm^{-3} to 50.00 kBqm^{-3} as moderate and above 50.00 kBqm^{-3} as high emissions (Vulcan and Shirav, 1996). All values higher than 50.00 kBqm^{-3} were classified as anomalous in the study.

A plot of the concentrations of radon gas from the 3 sets of detectors exposed and the mean of the data set indicated detector positions 9 and 15 as having very high emissions (Figure 3). The high concentrations could be due to intense fracturing/faulting in the area.

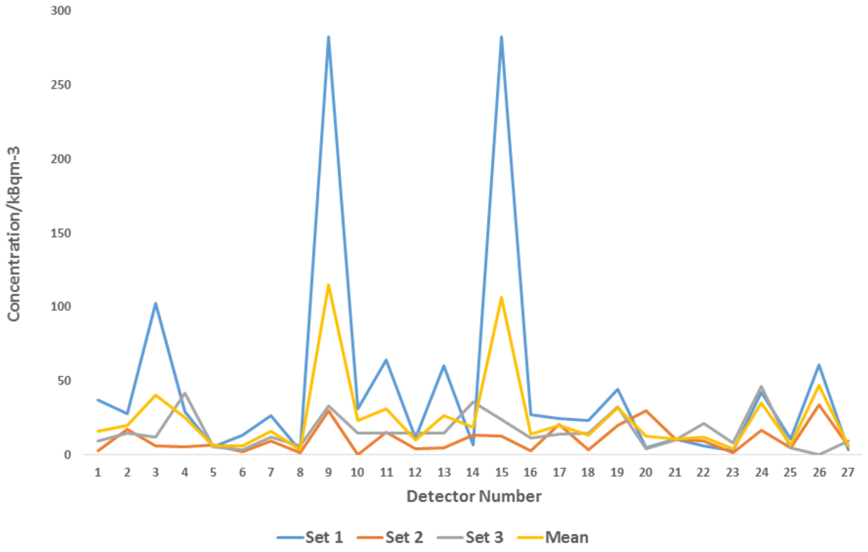

Figure 3. *Soil radon concentration from Teshie to Nyanyano (set 1, set 2, set 3, and the mean).*

Table 2. *Seismic events recorded during the study by the Geological Survey Department, Ghana, in 2004.*

Date	Origin Time	Latitude, °	Longitude, °	Depth, km	Magnitude (Richter scale)
	Hr Min Sec				
14-04-04	20 46 47.69	5.48N	0.71W	---	1.5
21-04-04	18 11 59.49	5.82N	0.27W	---	1.3
24-04-04	18 54 43.36	5.82N	0.13W	58.7	2.8
29-04-04	16 05 7.22	5.66N	0.11E	---	1.1
31-07-04	06 43 36.40	5.55N	0.19W	---	1.5
28-08-04	09 28 28.43	5.91N	0.39W	---	2.2
31-08-04	20 46 32.24	5.85N	0.30W	21.8	2.1

--- *Uncertain depth.*

4 Conclusion

The results of the study demonstrated that 55% of the area surveyed registered moderate emissions of the gas, 22% of the emissions were below the acceptable value of 50.00 kBqm^{-3} and 23% were highly anomalous. The high emissions can be attributed to the presence of faults and fractures, which are common in the area. Monitoring soil radon gas in the area has actually helped to establish the fact that radon gas emission is high along faults and fractures. From the survey, it can be concluded that areas with anomalous emissions are the most likely places for seismic activity. This generally suggests that anomalous areas should be critically investigated before any more residential buildings are constructed as continuous inhalation of the gas can cause cancer of the lungs. The already built up areas should be properly ventilated in order not to expose occupants to any health hazards.

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Radono matavimai pietrytinės Ganos Akros pakrantės nuo Teši iki Nianiano dirvožemyje

Paulina E. Amponsah[1, 2], **Aba B. Andam**[2] **ir Irene N. Akoto**[1]

[1]*Nacionalinis branduolinių tyrimų institutas, Ganos atominės energetikos komisija, Legonas-Akra, Gana*
[2]*Branduolinių ir jungtinių mokslų absolventų mokykla, Ganos atominės energetikos komisija, Legonas-Akra, Gana*

(gauta 2014 m. gegužės mėn.; priimta spaudai 2015 m. birželio mėn.)

Tyrimas buvo atliktas Akros pakrantėje (nuo Teši iki Nianiano) Didesniojoje Akros Metropolio teritorijoje, siekiant ištirti dirvožemyje esančio radono dujų emisijas, naudojant Lenino Resino (LT) – 115 celiuliozės nitrato jutiklius. Buvo pasirinkti dvidešimt septyni bandinių paėmimo taškai. Visas jutiklių komplektas vienu metu buvo užkastas į dirvožemį ir pakeistas po dviejų savaičių. Kiekviename taške buvo atlikta po tris bandymus. Dėl susisiekimo apribojimų, visi jutikliai buvo užkasti per ilgesnį nei penkiolikos savaičių periodą. Po išlaikymo periodo jutikliai buvo išėsdinti, išdžiovinti oru laboratorijoje ir, naudojant Spark skaičiuotuvą, buvo užregistruoti alfa pėdsakai. Buvo apskaičiuotas pėdsakų tankis ir radono dujų koncentracija. Radono koncentracijos ribos stebėjimo periode buvo nuo 1,40 $kBqm^{-3}$ iki 282,87 $kBqm^{-3}$. Vidutinė per tyrimo laiką išmatuota dirvožemio radono koncentracija buvo 24,41 $kBqm^{-3}$. Tyrimo metu buvo fiksuojami vietiniai žemės drebėjimai, kurių dydis pagal Richterio skalę siekė 1,1-2.8. Nuolatinė dujų stebėsena galėtų patvirtinti didelį dujų kilimą dėl pakrantės ribos poslinkio.

Raktiniai žodžiai: *Gana, dirvožemio radono koncentracija, pakrantės ribos poslinkis, seisminis aktyvumas, radono dujų kilimas ir sprūdžiai.*