Radon Gas Measurements in Deep Gold Mines

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ABSTRACT

We report measurements of radon gas concentration in two deep gold mines in Ghana, *viz* Tarkwa Goldfields and Prestea Goldfields.

Radon concentrations measured underground at Tarkwa were in the range 56 Bq m^{-3} to 268 Bq m^{-3}. Corresponding values for Prestea were 43 Bq m^{-3} to 878 Bq m^{-3}.

These results represent the first published data on underground radon concentration in deep gold mines in Ghana.

Measurement of the radon gas was done by means of the solid state nuclear track technique, with CR-39 plastic as a recording medium for the alpha particles from radon decay.

The study is part of a nation-wide radon monitoring programme.

Keywords: Radon monitoring, gold mines, nuclear track

INTRODUCTION

In underground mining, one of the important aspects of the environment requiring control is the atmosphere of the working places.

Records have shown that uranium and tin mine workers have a high risk of cancer, as a result of exposure to radon gas [1]. However, very little data exist on radon levels in deep gold mines, particularly in Ghana, where the mining sector is a mainstay of the economy.

We report measurements of radon gas concentration in two deep gold mines in Ghana, *viz* Tarkwa Goldfields and Prestea Goldfields. These are the first published data on underground radon levels in deep gold mines in Ghana. The study is part of a nation-wide radon monitoring programme.

Environmental control objectives require that the air in an underground mine be conditioned to meet quality and quantity levels near to surface values. Although threshold limits are based on human safety and tolerance, increasing concern is being expressed for standards of human comfort as well.

The main health risks associated with radon stem from its short-lived radioactive daughters, since most of the radon gas itself will be quickly exhaled by a normal healthy person.

In the deep mine atmosphere, and particularly one that is almost stagnant or quiescent, stratification of gaseous impurities may occur. A heavy gas, such as radon, will stratify against the floor, and a lighter one near the roof. Ventilation therefore tends to be of high importance in the control of the environmental conditions of a deep mine.

The radon emanating properties of rocks depends on geologic type, although there may be large variation in radon emanation within a geologic type.

Weiffenback [2] identified geological regions for the state of Maine in United States and compared rock types with the results of a survey of radon concentration in wells. He found that the radon concentration in areas of granitic bedrock were greatest.

Ghana geologically lies within the Pre-Cambrian Guinea shield of West Africa. The oldest rocks belong to the Birrimian system, which is mainly argillaneons sediment, metamorphosed lavas and intrusive igneous rocks [3]. The rocks of the Birrimian age are of high economic importance, consisting of slates, phyllites and schists. The Prestea Goldfield lies on a belt of Birrimian sediments and lavas.

The Tarkwaian rock system is arenaceous in character, and made up of quartzites and phyllites, green dike and gabbro. Most of the gangway in Tarkwa Goldfields have quartzite as the base rock formation, with a few being of combinations of quartzite, green dike and gabbro.

EXPERIMENTAL PROCEDURE

Underground Measurement

Measurement of the radon gas underground was done by the closed can technique of solid state nuclear detection [4]. Thin-sheet aluminium cans, cut into 5cm x 6cm cylinders with a volume of 150cm-3, were covered with perspex lids and sealed to leave a hole of approximately 3cm diameter in the perspex lid. This hole was covered with filter paper, and to the side of the filter paper facing the interior of the can, a 2cm z 2cm piece of CR-39 plastic was fixed.

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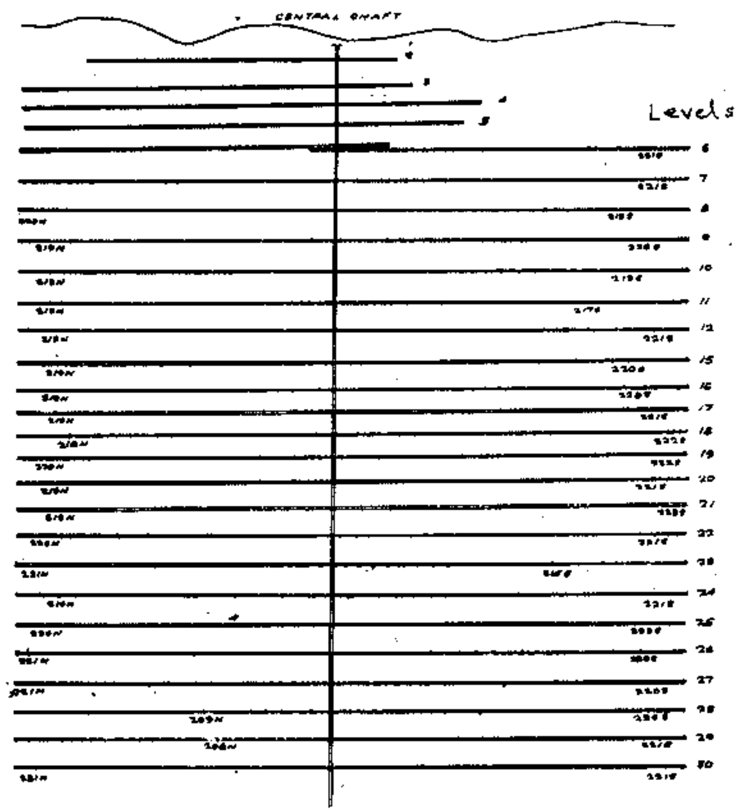


Fig. 1: Outline of the central shaft of Prestea with various "Levels"

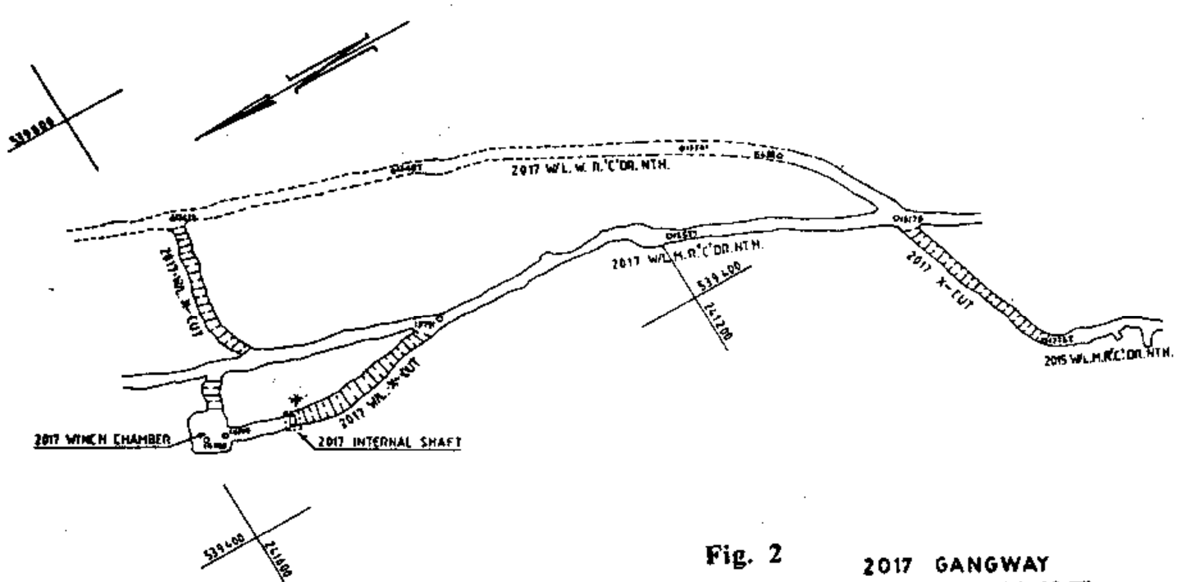


Fig. 2

2017 GANGWAY
SCALE 1 INCH TO 80 FT.

The CR-39 plastic was used to register the tracks of alpha particles from the decaying radon gas. The filter paper, as a filtering membrane, cuts out thoron (Rn-220, half life 56s) to ensure that the alpha tracks registered are due to radon gas (Rn-222, half-life 3.82) and its plateout alpha-emitter daughters, polonium-218 (half-life 3.1 min) and polonium-214 (half life 1.6 x 10-6s).

In the underground mine, there is a vertical shaft as entry into the deep mine, and horizontal drives known as the "levels" (Fig. 1). Each level is separated by an interval of 45 metres from the next nearest level. The drives can be up to three kilometres distance away from the shaft station or shaft gangway. In the drives along the sidewalls, at 22.5 metres intervals, are the cross cuts sometimes used to link other drives in situations where there are many shafts.

Radon measurements were made along the main central shafts and drives in Prestea and Tarkwa Goldfields. The cans were mounted, one at the shaft gangway and another along the drives or cross-cuts in the drives. The location of the mounted cans, and the geological information on the two deep mines are listed in Tables 1 and 2.

Figures 2 - 4 show the sectional plan of a typical underground location where the cans were mounted. Figure 5 is a photograph of a can mounted in a drive.

LOCATION OF CANS IN THE DRIVES		GEOLOGICAL INFORMATION
10 LEVEL	Gangway	Quartzite
	Tramming drive (Bin)	Quartzite
12 LEVEL	Gangway	Quartzite
	Level cross-cut	Quartzite
14 LEVEL	Gangway Transformer S'tn	Quartzite/Dike and GABBRO
	Level cross-cut	Quartzite, Green Dike and GABBRO
17 LEVEL	Gangway	Quartzite, Green Dike and GABBRO
	Winder house	Quartzite
18 LEVEL	Gangway	Quartzite
	Level drive	Quartzite Reef
20 LEVEL	Gangway	Qartzite
	Winder house	Qartzite
24 LEVEL	2416 incline	Quartzite
25 LEVEL	2525 subdrive 2 north	Quartz Reef (Conglomerate) Dike (Green) Quartz
	2525 subdrive 1 south	Quartz Reef

Table 1. Location of the mounted can and the geological information at Tarkwa Goldfields.

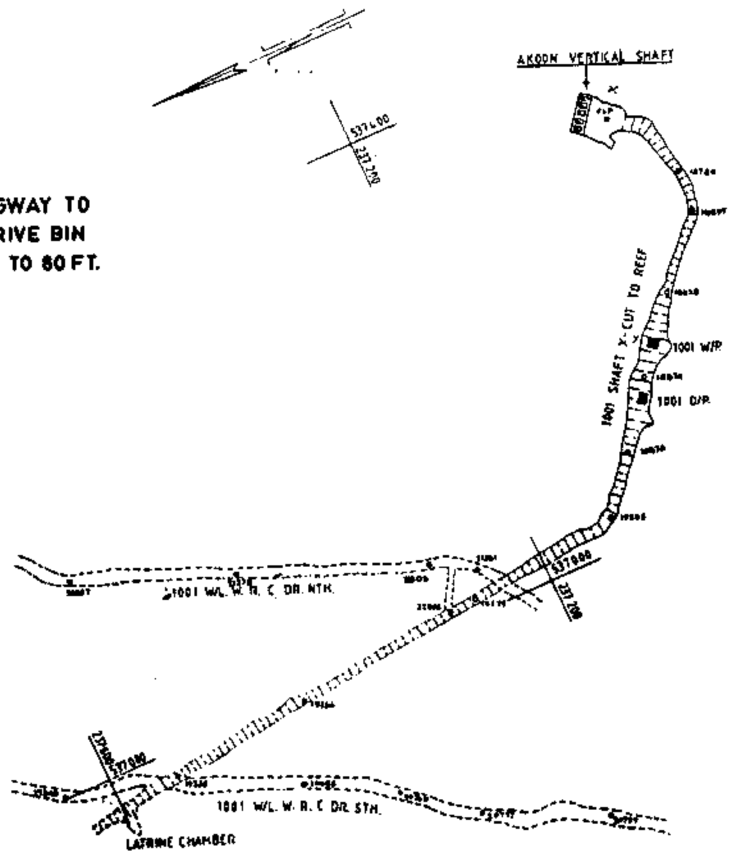


Fig. 3

10 LEVEL GANGWAY TO TRAMMING DRIVE BIN
SCALE 1 INCH TO 80 FT.

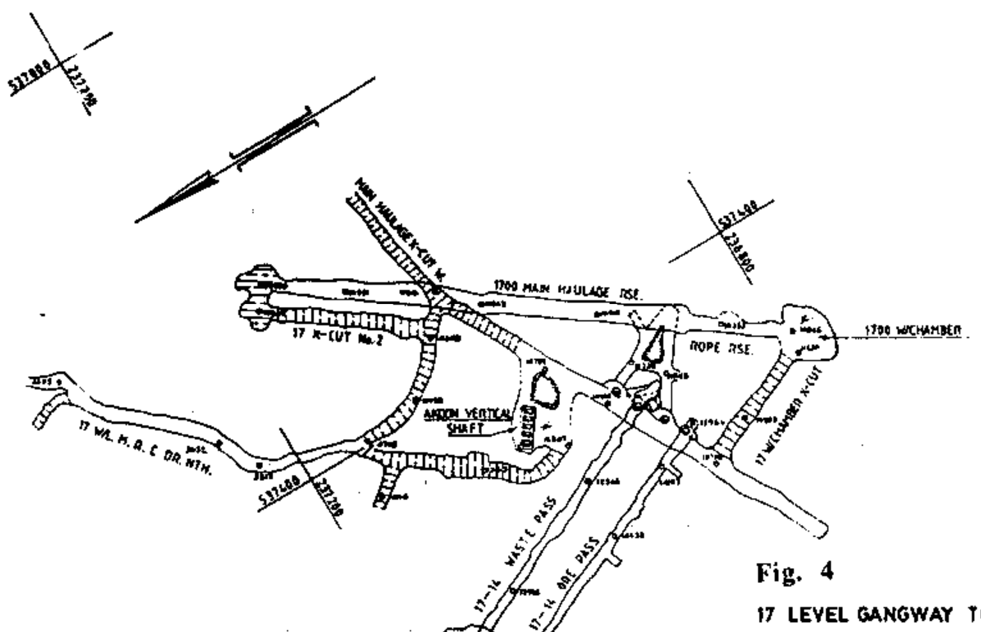


Fig. 4

17 LEVEL GANGWAY TO WINDER HOUSE
SCALE 1 INCH TO 80 FT.

LOCATION OF CANS IN THE DRIVES		GEOLOGICAL INFORMATION
6 LEVEL	Gangway	Carbon Phyllite and Quartz
	258 south cross-cut	
9 LEVEL	Gangway	Carbon Phyllite and Smoky Quartz
	252 south cross-cut	Carbon Phyllite and Metavolcanic Rock
12 LEVEL	Gangway	Carbon & Siliceous Phyllite and Quartz
	224 south cross-cut	Carbonaceous Phyllite and Siliceous Phyllite
15 LEVEL	Gangway	Carbonaceous Phyllite & Schiztose (Metasediments)
	235 south cross-cut	Sulphidic, Carbonated Phyllites & Quartz Reef
23 LEVEL	Gangway	Phyllite and Quartz Metavolcanic
	224 south cross-cut	Arsenopyrite, Carbonated Metavolcanic & Phyllites
30 LEVEL	Gangway	Quartz and Phyllite
	Number 4 shaft	Quartz and Phyllite

Table 2. Location of the mounted cans and the geological information at Prestea Goldfields.

In any measurement location, the can with CR-39 plastic was left for a period of three and half months. Over this period, a good number of alpha-particle tracks were registered to ensure good counting statistics for the radon gas which diffuses into the can. Data collection was spread over two exposure periods, a total of seven months.

Surface Measurements

Measurement of radon gas at ground level was made in the offices, laboratories and workshops of the two mines. By the closed can techniques of solid state nuclear track detection [4], CR-39 plastic was exposed in these occupational environments for two periods, each of three and half month duration. In all, eleven locations at Tarkwa and fifteen locations at Prestea were monitored for the ground level radon measurements.

Measurement of Physical Parameters

In the deep mine, the physical parameters that are likely to affect radon gas concentration include the air flow rate, temperature, and humidity.

The vane anemometer was used to measure the air velocity. Two methods were used, *viz.* the fixed - point traversing method and the continuous traversing method. In the fixed - point traversing method, the air way cross section is first divided into a number of imaginary equal areas. This is followed by the measurement of the air velocity at the centre of each area, and estimation of average velocity. In the continuous traversing method, the entire airway is traversed slowly at a uniform speed.

Location of cans in the Drives		Track density (Bqm^{-3})	Radon concn. (Bqm^{-3})	
				level's mean
10LEVEL	Gangway	2178.6±105.4	124.9±6.0	97.3± 7.5
	Tramming drive (Bin)	1214.3± 78.7	69.6±4.5	
12LEVEL	Gangway	1816.3± 96.3	104.2±5.6	122.3± 8.4
	Level's cross-cut	2449.0±111.7	140.4±6.4	
14LEVEL	Gangway T'former s'tion	1673.5± 92.4	96.0±5.3	145.4± 9.3
	Level's cross-cut	3398.0±131.7	194.8±7.6	
17LEVEL	Gangway	3428.6±132.1	196.6±7.6	157.9± 9.6
	Winder house	2076.5±102.9	119.1±5.9	
18LEVEL	Gangway	2173.5±108.6	124.7±6.2	127.3± 8.9
	Level's cross-cut	2265.3±110.9	129.9±6.4	
20LEVEL	Gangway	1658.2± 92.0	95.1±5.3	95.7± 7.5
	Winder house	1678.6± 92.5	96.3±5.3	
24 LEVEL	2416 incline	1617.4± 90.8	92.7±5.2	92.7±5.2
25LEVEL	2525 subdrive 2 north	3806.1±139.4	218.2±8.0	217.9±11.0
	2525 subdrive 1 south	3794.1±132.7	217.6±7.6	

a. RESULTS FROM THE RANDOM MEASUREMENTS AT TARKWA GOLDFIELDS

Table 3a. Track density and radon conc., at Tarkwa Goldfields, (underground) the first period, with exposure time of 3 1/2 months

The average velocity will then be estimated from the indicated reading on the anemometer. The airflow rate, Q, is calculated from the average velocity, V, and the cross-sectional area of the airway, A, as

$$Q = V A \ m^{-3} \ s^{-1}$$

An average of four measurements was taken.

The temperature was recorded by an ordinary thermometer, while the humidity measurements were made with a whirling hygrometer.

Chemical Etching and Track Counting

At the end of the exposure period, the CR-39 plastic were etched in 6M Na-0H at 70°C for 3.5 hours. Counting of the alpha particle tracks was done on an optical microscope at 400x magnification.

Results and Discusssion

The track density on each exposed piece of CR-39,

Location of cans in the Drives		Track density (tracks/cm²)	Radon concn. (Bqm⁻³)	level's mean
10L LEVEL	Gangway	1476.6± 82.8	87.3±5.0	73.4± 6.4
	Tramming drive (Bin)	1006.5± 68.3	59.4±4.0	
12L LEVEL	Gangway	1316.3± 82.0	75.5±4.7	105.5± 7.9
	Level cross-cut	2295.9±108.2	135.4±6.4	
14L LEVEL	Gangway T'former S'tion	964.3± 70.1	56.9±4.1	118.7± 8.5
	Level cross-cut	3061.2±125.0	180.5±7.4	
17L LEVEL	Gangway	3438.8±120.3	202.8±7.1	157.8± 9.2
	Winder house	1913.3± 99.0	112.8±5.8	
18L LEVEL	Gangway	1903.1± 98.5	112.2±5.8	125.0± 8.6
	Level cross-cut	2336.7±109.2	137.8±6.4	
20L LEVEL	Gangway	1821.4± 96.4	107.4±5.7	107.6± 8.0
	Winder house	1828.5± 96.6	107.7±5.6	
24 LEVEL	2416 incline	1673.5± 92.4	98.7±5.5	98.7±5.5
25L LEVEL	2525 subdrive 2 north	3403.0± 132.0	200.7±7.8	234.5±11.9
	2525 subdrive 1 south	4551.0±152.6	268.3±9.0	

Table 3b. Track density and Radon concn. at Tarkwa Goldfields (underground) the second period with exposure time of $3\ ^{1}/_{2}$ months

Location of cans in mine offices	Track density (track/cm^2	Radon concn. (Bqm^{-3})
Chief of Personnel		
Personnel	663.3±58.2	36.4±3.2
Stores Department	581.2±48.9	30.8±2.7
Accounts	561.2±48.9	30.8±2.7
Akoon Shaft top	673.8±58.5	36.8±3.2
Electrical Shop	561.2±48.9	30.8±2.7
Carpentary Shop		
Foundary	756.8±66.7	41.6±3.1
Assay Department	***	***
Mill Department	566.2±48.5	30.3±2.4
Security	607.1±55.7	32.4±3.0

*** Plastic was destroyed by rodents

Table 4a. Track density and Radon concn. at Tarkwa Goldfields (the mine offices), the first period of exposure for 3 $^1/_2$ months.

Location of cans in the mine offices	Track density (tracks/cm^2)	Radon concn. (Bqm^{-3})
Chief Personnel	750.0±1.8	41.5± 3.4
Personnel	734.7±61.2	40.8±3.4
Stores Department	673.5±58.6	37.3±3.2
Accounts	720.0±63.9	39.8±3.5
Akoon Shaft top	617.4±56.1	34.2±3.1
Electrical shop	808.1±64.1	44.6±3.6
Carpentary shop	637.8±52.1	35.3±2.9
Foundary	672.5±55.9	37.2±3.1
Assay Department	786.7±63.3	49.1±4.0
Mill Department	708.2±60.2	38.2±3.3
Security	795.9±63.7	44.0±3.5

Table 4b. Track density and Radon concn. at Tarkwa Goldfields (the mine offices), the second period of exposure for 3 $^1/_2$ months

Location of cans in the Drives		Track density (tracks/cm^2)	Radon concn. (Bqm^{-3})	Radon concn. (Bqm^{-3}): level's mean
6L LEVEL	Gangway	989.8± 71.1	58.4±4.2	100.7± 7.0
	260 South cross-cut	2423.5±111.2	142.9±6.0	
9L LEVEL	Gangway	1392.8± 84.3	92.1±6.0	156.2± 8.7
	254 South cross-cut	3872.5±140.6	220.3±8.3	
12L LEVEL	Gangway	714.0± 60.4	42.6±3.6	347.6±14.5
	224 South cross-cut	11086.3±237.6	652.5±14	
15L LEVEL	Gangway	1061.2± 78.5	62.6±4.3	
	235 South cross-cut	***	***	
23L LEVEL	Gangway	1381.8± 82.7	78.1±6.0	135.4± 9.2
	224 South cross-cut	[illegible]	[illegible]	
30L LEVEL	Gangway	***	***	166.1± 7.1
	Number 4 Shaft	[illegible]	286.1±7.1	

*** Plastics were destroyed by miners.

Table 3a. Track density and Radon concn. at Prestea Goldfields (underground), the first period of exposure, for 2 1/2 months.

Location of cans in the Drives		Track density (tracks/cm^2)	Radon concn. (Bqm^{-3})	Radon concn. (Bqm^{-3}): level's mean
6L LEVEL	Gangway	1173.5± 70.6	69.9±4.2	90.2± 7.2
	258 South cross-cut	1857.1± 97.3	110.5±5.8	
9L LEVEL	Gangway	1867.4± 97.6	111.2±5.6	192.8±10.1
	254 South cross-cut	4608.8±140.0	274.3±8.3	
12L LEVEL	Gangway	836.7± 69.3	49.8±3.9	463.8±16.8
	224 South cross-cut	10744.9±274.3	877.7±16.3	
15L LEVEL	Gangway	1056.1± 67.0	62.9±4.0	
	235 South cross-cut	***	***	
23L LEVEL	Gangway	1097.9± 67.8	64.3±4.0	110.7± 7.5
	224 South cross-cut	2640.0±106.6	157.1±6.3	
30L LEVEL	Gangway	***	***	174.2± 7.3
	Number 4 Shaft	2928.8±122.2	174.3±7.3	

*** Plastics were destroyed by miners.

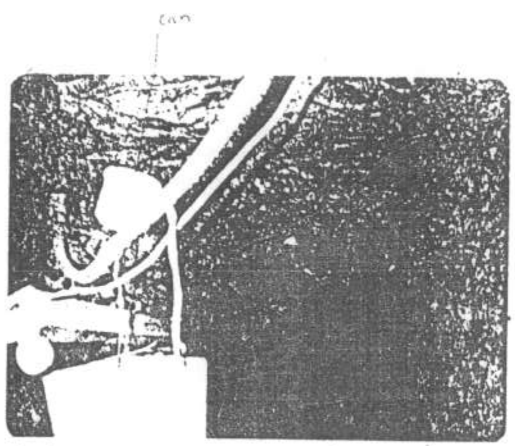
Table 3b. Track density and Radon concn. at Prestea Goldfields (underground), the second period of exposure, for 3 1/2 months.

LOCATION OF THE CANS IN THE MINE OFFICE	TRACK DENSITY (tracks/cm^2)	RADON CONCN. (Bqm^{-3})
CHIELF GEOLOGY	612.3±51.0	32.7±2.7
GENERAL MINES MANAGER	760.2±62.3	40.6±3.3
CHIELF MINING ENGINEER	719.4±60.6	38.4±3.2
TRANSPORT YARD	678.6±58.8	36.3±3.1
SECURITY	591.8±55.0	31.6±2.9
UNDERGROUND MANAGER	846.9±65.7	45.2±3.5
SHAFT COLLAR	629.3±51.7	33.6±2.8
SHAFT CONTROL ROOM	1102.0±75.0	58.9±4.0
CRUSHER HOUSE	720.0±63.9	38.5±3.4
BALL ROOM	887.8±70.1	47.4±3.7
ASSAY DEPARTMENT	831.6±65.1	44.8±3.5
OUTSIDE ASSAY DEPT.	867.4±66.5	46.7±3.6
ENGINEERING DEPARTMENT	877.6±66.9	46.9±3.8
CARPENTARY SHOP	617.4±56.1	33.0±3.0
ROASTER SECTION		

Table 6a: Track density and radon concn. at Prestea Goldfields (the mine offices) during the first period of monitoring (3 1/2 months exposure time).

LOCATION OF CAN IN THE MINE OFFICE	TRACK DENSITY (tracks/cm^2)	RADON CONCN. (Bqm^{-3})
CHIEF GEOLOGY	1010.2±71.8	60.1±4.3
GENERAL MINES MANAGER	826.5±64.9	49.2±3.9
CHIEF MINING ENGINEER	816.3±64.5	48.6±3.8
TRANSPORT YARD	1051.0±73.2	62.6±4.4
SECURITY	933.7±68.0	55.6±4.1
UNDERGROUND MANAGER	780.6±63.1	46.5±3.8
SHAFT COLLAR	795.9±63.7	47.4±3.8
SHAFT CONTROL ROOM	1020.4±72.2	60.7±4.3
CRUSHER HOUSE	862.3±66.3	51.3±4.0
BALL ROOM	974.5±70.5	58.0±4.2
ASSAY DEPARTMENT	699.0±59.7	41.6±3.6
OUTSIDE ASSAY DEPT.	964.3±70.1	57.4±4.2
ENGINEERING DEPARTMENT	892.9±67.5	53.2±4.0
CARPENTARY SHOP	1280.6±80.8	76.2±4.8
ROASTER SECTION	1076.5±74.1	64.1±4.4

Table 6a. Track density and radon concn. at Prestea Goldfields (the mine offices) during the second period of monitoring (3 1/2 months exposure time).



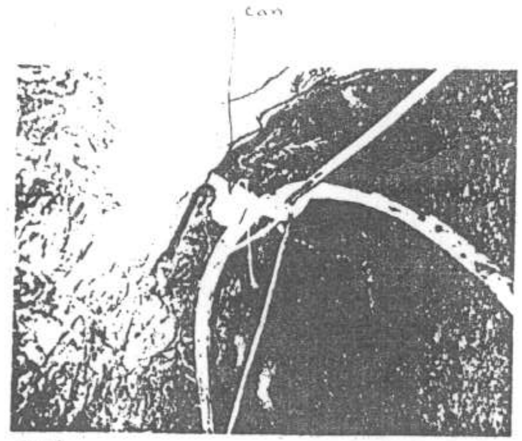


Fig. 5 Picture of can mounted in drives.

Fig. 6a. Variation of Radon concn. at the Gangway with Depth below surface at Tarkwa (for two different measurements)

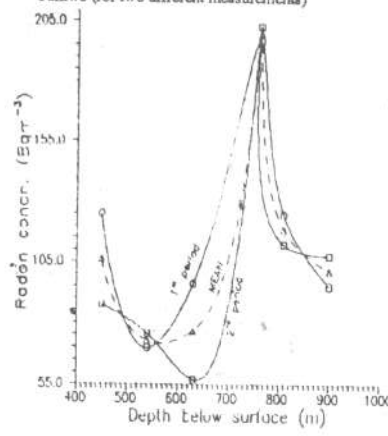


Fig. 6c A plot of Mean Radon concn. with the Ave airflow rates at the Gangways at Tarkwa Goldfields

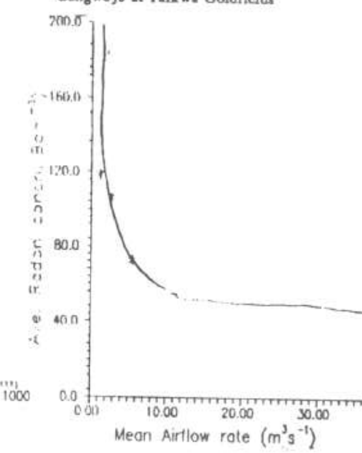


Fig. 6b. A plot of Mean Radon concn. with Ave. temp. at the Gangways at Tarkwa Goldfields.

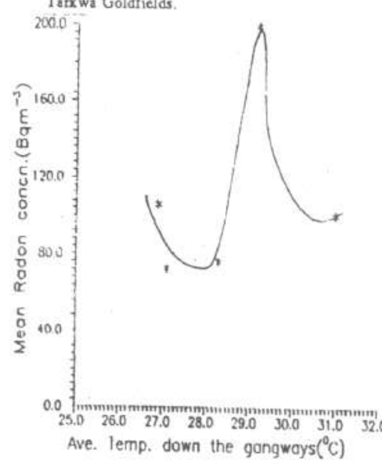


Fig. 6d. A plot of Mean Radon conon. with the Percentage Humidity at Gangways at Tarkwa Goldfields.

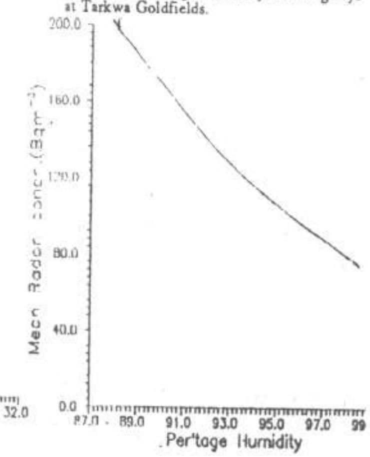


Fig. 7a. Variation of Radon concn. at the Gangways with Depth below surface at Prestea (for two different measurements).

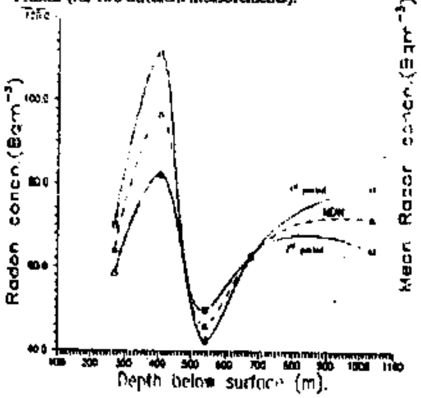


Fig. 7c. A plot of Mean Radon concn. with the Ave. Airflow rates at the Gangways at Prestea Goldfields.

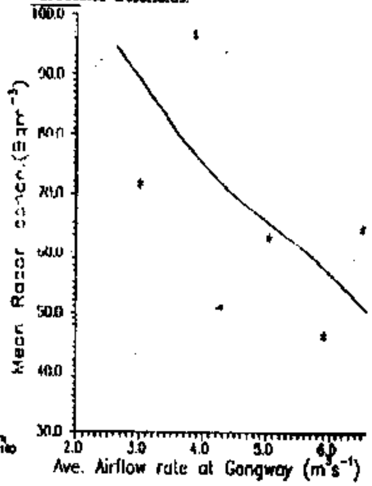


Fig. 8a. Variation of Radon concn. in the Drives with Depth below surface at Tarkwa, (for two different measurements).

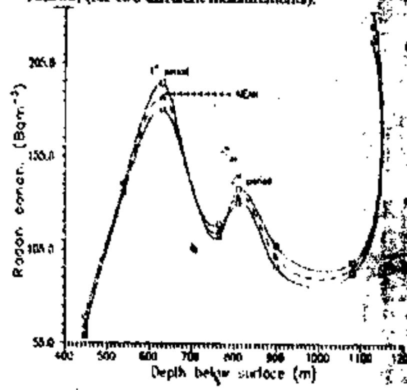


Fig. 8c. A plot of Mean Radon concn. with the Ave. Airflow rate of the drives at Tarkwa Goldfields.

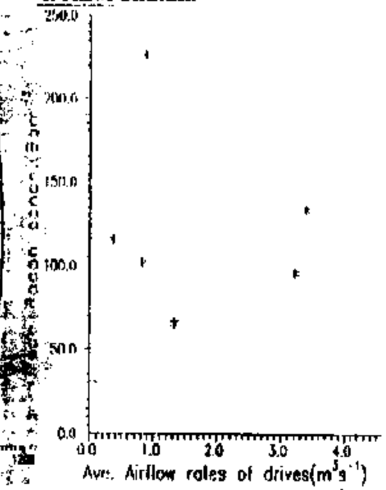


Fig. 7b. A plot of Mean Radon concn. with Ave. Temp. at the Gangways at Prestea Goldfields.

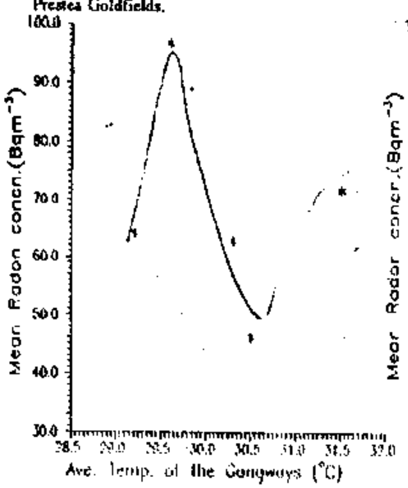


Fig. 7d. A plot of Mean Radon concn. with the Percentage Humidity at the Gangways at Prestea Goldfields.

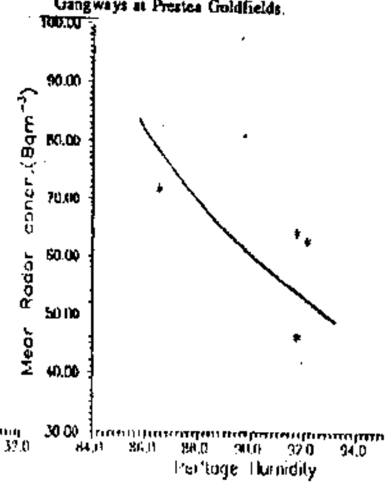


Fig. 8b. Variation of Mean Radon concn. with Ave. temp. in the drives at Tarkwa Goldfields.

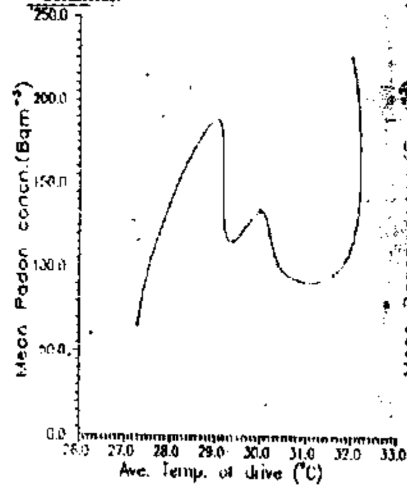
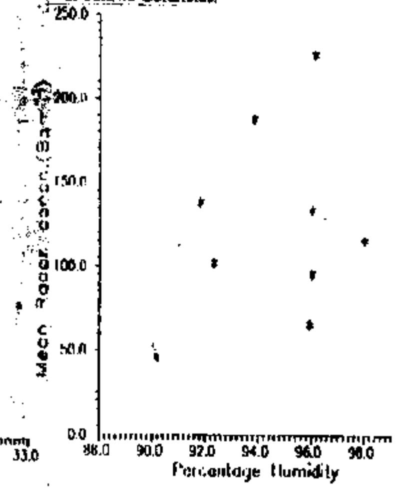


Fig. 8d. A plot of Mean Radon concn. with Percentage Humidity of the drives at Tarkwa Goldfields.



was converted to radon concentration on the basis of a calibration factor of 150 Bq m-3 h/tracks/cm2. This calibration factor was obtained from CR-39 plastics which sere exposed to radon gas of known concentration.[5].

Results of the radon measurements at the two goldfields are listed in Tables 3-6. Underground radon concentrations were found to be in the range (56.9 ± 4.1) Bq m^{-3} to (268.3 ± 9.0) Bq m^{-3} at Tarkwa and (42.6 ± 3.6) Bq m^{-3} to (877.7 ± 16.3) Bq m^{-3} at Prestea. Radon concentrations in the surface environments were (30.3 ± 2.4) Bq m^{-3} to (49.1 ± 4.0) Bq m^{-3} at Tarkwa and (31.6 ± 2.9) Bq m^{-3} to (76.2 ± 4.8) , Bq m-3 at Prestea. Figures 6 & 9 show the variation of radon concentration with depth below ground surface, and temperature, humidity and air flow rate.

Various environmental conditions have been found to affect the rate of radon exhalation. Stranden *et al* measured increased radon exhalation from concrete with increase in temperature [6]. However, Auxier *et al* found that within the temperature range 23°C to 43°C, the temperature of concrete has very little effect on radon exhalation rate [7].

Temperature values measured underground at Tarkwa were between (26.9 ± 0.8)°C and (32.0 ± 1.5)°C. At Prestea, values ranging from (27.0 ± 0.3)°C to (34.0 ± 1.4)°C were recorded. Corresponding values of humidity were in the range (88.1 ± 3.1)% to (98.0 ± 2.3)% for Tarkwa, and (88.5 ± 2.6)% to (98.6 ± 3.0)% for Prestea. Over the same period, the air flow rates underground were between (0.82 ± 0.27)m^3s^{-1} and (37.8 ± 2.1) m^3 s^{-1} at Tarkwa. At Prestea, underground air flow rates were in the range (0.39 ± 0.1) m^3s^{-1} to (5.86 ± 0.77) m^3s^{-1}. In both Tarkwa and Prestea deep mines the lowest values of air flow rates were recorded at cross-cuts, and the highest values in the gangway. Fig. 10 shows a typical ventilation duct from the 17 Level gangway to an active working area at Tarkwa. These ducts, and similar human intervention measures such as electric fans, together ensure a bearable underground environment.

The variation of radon concentration with physical parameters does not fit into simple mathematical modelling. However, Figs. 6b and c; 7b & d; 8b & c and Fig 9b & c point to the fact that higher levels of airflow rates contribute to reduction of radon concentrations. This

Fig. 9a. Variations of Radon concn. the cross-cuts with Depth below surface at Prestea. (for two different measurements).

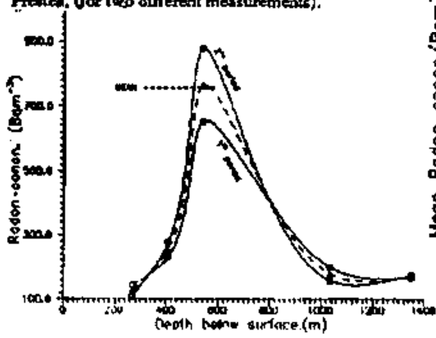


Fig. 9c. A plot of the Mean Radon concn. with Ave Airflow rates in the cross-cuts at Prestea Goldfields.

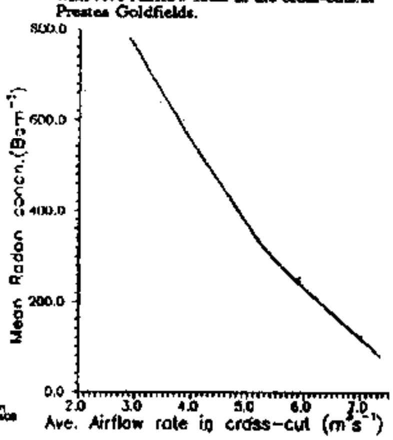


Fig. 9b. A plot of the Mean Radon concn. with the Ave. Temp. in the drives (cross-cut) at Prestea Goldfields.

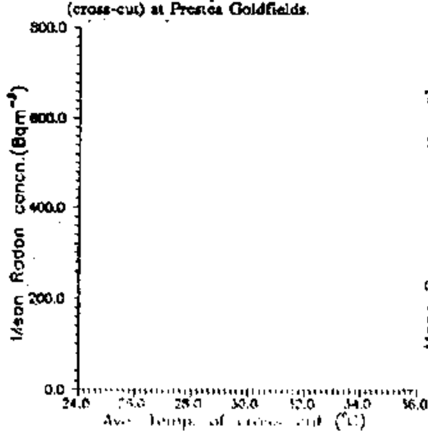
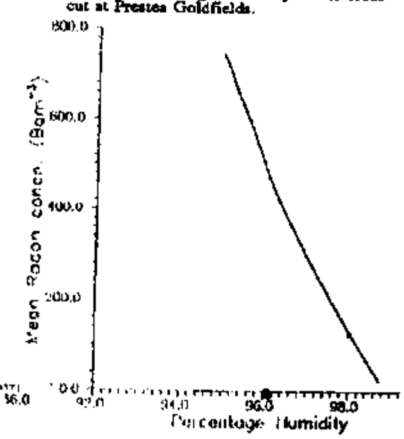


Fig. 9d A plot of the Mean Randon concn. with the Percentage Humidity of the cross-cut at Prestea Goldfields.



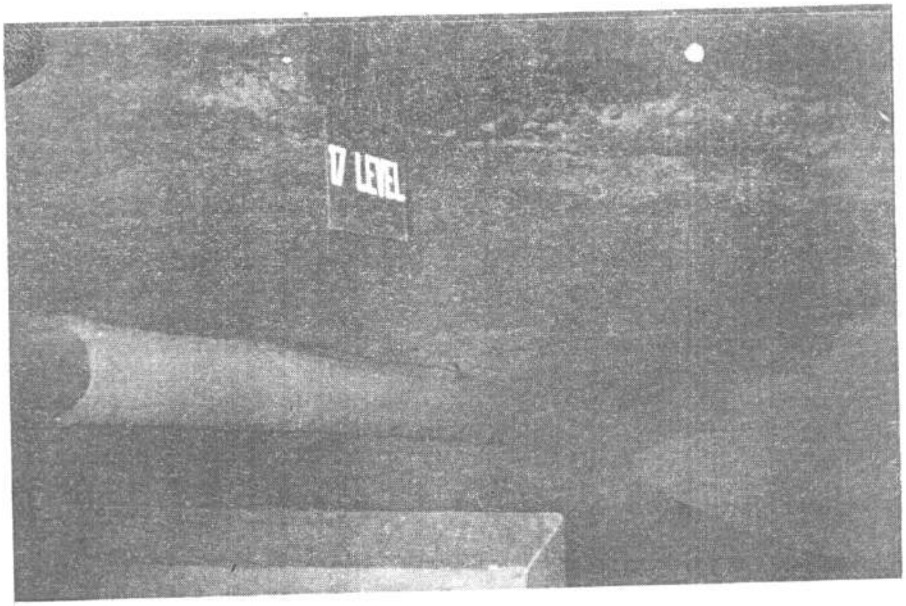


Fig. 10. Ventilation duct from 17 Level gangway to an active working area at Tarkwa

may be due to some amount of dilution by air sucked through the ventilation ducts, as well as good air circulation through the use of the electric fans.

Down the gangway at Tarkwa, the radon concentration shows a maximum at approximately 765 metres (ie. the 17 levels) below surface. Most Levels of the gangway have quartzite as the base formation, but at the 17 Level it is quartzite, green dike and gabbro.

In the drives at Tarkwa, two peaks are observed in the radon concentration variation with depth; one at 630 metres (14 Level)) and another at 1125 metres (25 Level), as the rock formation changes from a combination of quartzite and green dike conglomerate.

At Prestea, the radon concentration down the gangway shows a slight increase at a depth of 405 metres (9 Level) and drops to lower values further down the shaft.

The rock formation does not change much along the shaft, except at the 15 Level where the vertical shaft intercepts a fault line or a fissure zone running from the north-west to south east of the Goldfield. The increase of airflow rate down the shaft, together with the carbonaceous nature of the rocks might account for the low radon concentration.

The radon concentrations measured in the gangway at Prestea, and in both the gangway and drives at Tarkwa are below the recommended value of 110 Bq m^{-3} set by the National Radiological Protection Board (NRPB) of UK for a supervised area [8]. In the drives at Prestea, the radon concentration was highest at 540 metres below surface (the 12 Level 224 south cross-cut). The recorded value of 652.5 Bq m^{-3} was well above the 370 Bq m^{-3} recommended by NRPB for a controlled area of a mine [8]. The other cross-cuts at Prestea have radon concentrations above the 110 Bq m^{-3} recommended for a supervised are [8]. Very low airflow rates were recorded in the cross-cuts at Prestea. The direction of the air is from the gangway into the drives. The direction of the cross-cuts openings allows for little exchange of air between the drive and the cross-cuts.

At both Prestea and Tarkwa, the radon concentration measured in the occupational area at surface were lower than in the underground environment. Place like the crusher house, the mill house and the assay department where the main processing of the ore is carried out, have radon concentration below the 110 Bq m^{-3} recommended by NRPB for supervised areas [8]. Most of the working areas have been sited on hill tops and are well ventilated.

CONCLUSIONS

Previous work done on the exhalation rates of tailings from the two Goldfields indicate that Tarkwa tailings have higher radon concentration than Prestea tailings[9]. However, our results show that Tarkwa underground environment has lower radon concentration than that of Prestea. The Tarkwaian rock system is strong and well compacted elastic sediment compared to the loose Birrimian sediment which Prestea is mining. Therefore, the compactness of the Tarkwa rock will be a factor in curtailing the release of radon into the environment. In addition, Tarkwa has a better ventilation system than Prestea.

Setting standards for remedial action to protect mine workers from exposure to radon requires judgement based on scientific data. This work has set the scene for systematic documentation of information on the underground environment of deep mines in Ghana.

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