

## Measurement of Radon Gas Level in Ashanti Region and Design of a Radon Vulnerability Map for Ghana

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**Abstract:** To draw a Radon vulnerability map for Ghana and to ascertain the variation of Radon gas levels with passing years in the Lake Bosomtwi area, Ashanti Region, Ghana, samples were collected in four villages around the lake and analyzed in the Nuclear Physics Laboratory of the Physics department of the Kwame Nkrumah University of Science and Technology. The results obtained were compared with results from previous years and it was clear that year 2006 had the lowest average radon gas level of 99.95 pCi/L or 3.70 KBq/m<sup>3</sup>, with year 2001 having the highest of 167.2 pCi/L or 6.19 KBq/m<sup>3</sup>. Overall the average radon gas level between the years 2001 to 2006 for the Lake Bosomtwi area was 130.94 pCi/L and this value according to the United States' Environmental Protection Agency is within the range of 0.1WL-1WL (20-200 pCi/L) which means that exposures in this range are considered greatly above average for residential structures. A vulnerability map of Ghana shows that research work have been conducted in the following regions Western, Central, Greater Accra and Ashanti and other regions like Eastern, Volta and the Northern parts of Ghana have experience little or no research.

**Key words:** Concentration, decay, Radiation exposure, Radon gas, Uranium

### INTRODUCTION

Radon is a cancer-radioactive gas found in nature ([www.radon.com/radon/radon\\_facts.html](http://www.radon.com/radon/radon_facts.html), 2005). It has no colour, odour or taste and is chemically inert. Its source is from uranium. As the uranium molecule decays to form stable lead, a process taking many, many years, it changes from one radioactive element to another in a sequence known as the Uranium Decay Cycle. Partway through this cycle, the element radium becomes radon which as a gas moves up through the soil to atmosphere. Uranium is found in most soils and in granite ([www.rpii.ie/radon/natsurv.html](http://www.rpii.ie/radon/natsurv.html), 2005). Radon, Rn-222 ( $T_{1/2} = 3.82$  days), is a daughter product of radium, Ra-226, which in turn is derived from the longer-lived antecedent, U-238. Thoron, Rn-220 ( $T_{1/2} = 56$  sec) is a daughter of thorium, Th-232, which is present in larger amount in the earth's crust than radon. Because of thoron's short half-life, it is essentially all gone before it leaves the ground, and is of no significant radiobiologic consequence ([www1.umn.edu/eoh/hazards/hazardssite/radon/radonriskassessment.html](http://www1.umn.edu/eoh/hazards/hazardssite/radon/radonriskassessment.html), 2005).

The potential hazard of radiation exposures to radon gas and its daughter products from natural background has been highlighted in the world of scientific press and has become a matter of concern and a source of confusion to the public. Home owners are besieged with devices to measure radon levels, and may not know what to do about the results they get. The Environmental Protection

Agency (EPA) has issued guidelines, as has the National Council on Radiation Protection and Measurement (NCRP), the International Commission on Radiation Protection (ICRP) and other groups concerned with radiation protection matters ([www.physics.isu.edu/radinf/radon.html](http://www.physics.isu.edu/radinf/radon.html), 2005).

The risk of lung cancer associated with lifetime inhalation of radon in air at a concentration of 1Bqm<sup>-3</sup> (37.027pCi/L) was estimated on the basis of studies of underground miners. The values were based on risk projections from three follow-up studies. These three reports used data from 4 to 11 cohorts of underground miners in seven countries and developed risk projections of  $1.0 \times 10^{-4}$ ,  $1.2 \times 10^{-4}$ , and  $1.3 \times 10^{-4}$  per unit concentration in air (1 Bq/m<sup>3</sup>), respectively. The three values were for a mixed population of smokers and nonsmokers. The risk of lung cancer (discussed in two reports of the National Research Council and one of the National Institutes of Health) posed by lifetime exposure to radon (<sup>222</sup>Rn) in water at 1 Bq/m<sup>3</sup> was calculated to be  $1.3 \times 10^{-8}$ . An increase in the number of radiation particles that pass through the human body correlates to an increase in the chance of developing cancer. Therefore, the risk to people is proportional to the length of exposure and the radon concentration in air (linear, no-threshold hypothesis). However, the radon risk begins to level off for extremely high concentrations, like for miners, because more lung cells are killed off by the radiation rather than becoming cancerous and some radiation is wasted on the already

killed cells (the 19 "inverse exposure-rate effect"). But at lower concentrations, like in residences, every emitted particle will have an impact (Natalie and Philip, 1997).

The objective of this survey was to ascertain radon gas emanation levels with time in the Ashanti region and to determine possible hazardous radon emanation levels. Also to put together results obtained for compilation as a national database and come out with a radon vulnerability map of surveyed areas. It is very worrying to know that Ghana has no information on its radon emanation levels, which means there are people living in areas with high radon levels without any knowledge. Thirdly to educate the average Ghanaian on the hazardous effect of radon gas, and how to handle such hazards, through organized forums, symposiums and published data.

## MATERIALS AND METHODS

**Area to be surveyed - selected villages around lake bosomtwi:** The Lake Bosomtwi community is one of the most interesting research areas in Ghana due to the geological nature of the area. Radon surveys already conducted shows very interesting developments and hence the need for an in-depth study so that further extrapolation will be made to cover the whole Ghana.

**Sampling area:** Sampling area will be around the Lake and some communities close to the Lake. An area further away from the community will be surveyed to serve as a buffer.

**Sampling method:** Profiles were set-up and these profiles were 2 m apart, soil samples was collected at depths of 10 cm and about 50 to 100 g of soil quantity was collected and sent to the Laboratory for analysis

**Sampling:** Even though the samples were in groups and belong to the same community care was taken so that soil samples collected were clearly identified as to which particular spot it was picked from.

To begin, a station was first selected; the station had enough space around it for profiling. Ten (10) profiles were made on each location; these profiles were about 2 m apart and in reference to the selected station. Five (5) holes were made on every profile and soil samples weighing about 100 g were collected from depths of 10 cm. the soil samples were bagged and labeled.

The under listed materials and equipment were used in the sample collection

- A hollow stainless steel tube of about 2.5 inches in diameter and 3 feet long for cutting through the soil
- A steel rod to prevent distortion of the stainless steel holder

- A wooden rod to cushion the stainless steel against the hammer impact
- Opaque polythene bags for holding the soil sample
- Sledge-hammer

### Procedure:

**Sample preparation:** Each soil sample picked up from the field was dissolved in about 100 cc of water and the resulting mixture was shaking thoroughly to enable the water to absorb the radon gas trapped by the soil sample. The mixture was then allowed to settle for about 2 weeks so that all the various gaseous composition of the soil will be fully dissolve in the water.

**Procedure to obtain results:** The RDU-200 carrying case was opened and the knurled screw unfastened on the bubbler tube slide. This allowed the bubbler tube to be moved sideways to an extend of its slide.

- The heavy rubber tubing from the vacuum pump provided with the RDU-200 was connected to the pump input port on the console.
- RDX-012 was connected to the Scintillator cell connector on the RDU-200 making sure to push so hard so that it was fit into place.
- The vacuum valve was opened to make sure that the flash valves were closed.
- The cell was evacuated using the pump provided to a gauge reading between 20 to 30 inches of mercury. The valve was then closed.
- The bubbler tube was then filled with solution.
- With the flow regulator knob in the fully closed position the flow valve was opened.
- Slide suction at the top of the bubble was provided by slightly opening and closing the regulator.
- Checking of the gauge on the vacuum pressure was regular.
- The flow regulator knob was slowly opened to position where it could take 3 min to reduce the vacuum gauge to zero. This time interval ensured the complete degassing of the Radon gas.

Overall, about 400 samples were collected from 4 different villages around Lake Bosomtwi and this was done within the period of 14th to 17th January, 2006 after which they were processed and measurements taken at the Physics department of Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

**Radiation counts:** Radon detector analyzer (RDA-200) was the instrument used in the radiation counting. The alpha emitting properties of the short-lived Radon daughters were used to determine the radioactivity counting ability of the RDA-200. Each cell was put in turn into the photomultiplier tube chamber of the RDA-

Table 1: A table showing Depth/cm and Radon concentration/pCi/L for the year 2001

Depth/cm	Radon concentration/ pCi/L		
	Mini	Maxi	Average
10	92.4	187.7	167.2
20	102.1	220.1	195.5

Table 2: A table showing Depth/cm and Radon concentration/pCi/L for the year 2002

Depth/cm	Radon concentration/ pCi/L		
	Minimum	Maximum	Average
10	104.7	240.9	150.59
20	106.5	250.1	201.3
30	140.8	250.2	195.8
40	135.0	294.5	204.1
50	190.2	298.9	203.2

200 after filling with radon gas. Sixty seconds was allowed before counting to allow any light that may have been seen by the PMT to dissipate.

The power toggle was set to INT and Ra/Am switch set to the Ra and time (MIN) knob set to two minutes. After the sixty seconds the sample button was pressed to start the two minutes count. The display button count was recorded after the buzzer signaled with its sound. The process was then repeated for all other samples to obtain results. A detail approach to calculating results is represented in Appendix.

## RESULTS

These results were obtained from the evaluation of the following:

- Calculation of average radon concentration around the Lake Bosomtwi area from the year 2001 to the year 2006
- Study variation of radon concentration with passing years

**2001:** In the year 2001, Radon research conducted at the Lake Bosomtwi area was more of Geophysics research even though it still made use of the changing concentration of radon gas emanation from the soil (Table 1).

### Overall:

Minimum Value = 92.4 pCi/L.  
 Maximum Value = 220.1 pCi/L  
 Average Value = 167.2 pCi/L or 6.19 KBq/m<sup>3</sup> (Jonathan and Samet. 1998)

**2002:** Research work in 2002 was mainly to find out how radon emanation from the soil is affected by depth, for this reason soil samples were collected from different

Table 3: A table showing depth/cm and radon concentration/pCi/L for the year 2003

Area	Radon concentration/ pCi/L <sup>-1</sup>		
	Minimum	Maximum	Average
Duasi	36.22	335.14	192.43
Tepaso	11.35	295.14	180.54
Tumiabu Atonbisi	11.89	75.41	58.28
Adwafo	10.33	132.12	99.25
Mmorontuo	3.91	67.25	54.45
Kusuaso	19.56	87.37	71.19

Table 4: A table showing Depth/cm and Radon concentration/pCi/L for the year 2006

Area	Radon concentration/ pCi/L <sup>-1</sup>		
	Mini	Maxi	Average
Adwafo	31.90	135.57	74.43
Kusuaso	39.83	143.54	82.94
Duasi	95.69	191.39	146.73
Tepaso	55.82	143.54	95.70

depths and analyzed using the Radon Degassing Unit-200 (RDU-200) (Fig. 1) and the Radon Detector Analyzer-200 (RDA-200) for degassing and analysis. Samples were collected in a village named Abonu (Table 2).

### Overall:

Minimum Value = 104.7 pCi/L.  
 Maximum Value = 298.9 pCi/L .  
 Average Value = 150.59 pCi/L or 5.572 Kbbq/m<sup>3</sup> (Wan *et al.*, 1992)

**2003:** In 2003 the sample area was widened to help monitor accurately the emanation of radon to help predict the possible occurrence of an earthquake. Samples were collected from 6 different areas namely Adwafo Town, Tepaso Village, Mmorontuo Village, Ataa Junction, Tumiabu Atonbisi Village and Duasi Village (Table 3).

### Overall:

Minimum Value = 3.91 pCi/L.  
 Maximum Value = 335.14 pCi/L.  
 Average Value = 106.02 pCi/L or 3.92 KBq/m<sup>3</sup> (Fleischer *et al.*, 1975)

### 2006 (Table 4):

#### Overall:

Minimum Value 31.90 pCi/L.  
 Maximum Value 191.39 pCi/L.  
 Average Value 99.95 pCi/L or 3.70 Kbbq/m<sup>3</sup>.

In Fig. 2, based on the similarities of pattern of results between from 2003 and 2006 it can clearly be seen that radon gas levels have little or no change with passing years if geological and climate condition remain virtually the same. Areas like the Greater Accra, Central, Western and Ashanti regions have not experienced any significant



Fig. 1: Radon Degassing Unit-200 with a cell and a glass tube containing sample. (Diagram of set-up)

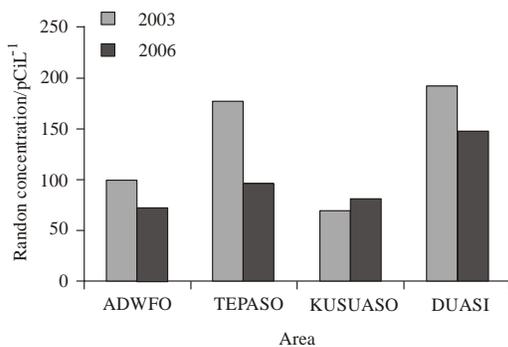


Fig. 2: Comparison of Radon gas level between years 2003 and 2006 at Lake Bosomtwi

change in climatic and geological condition and for this reason results obtained in the 90's could still be valid and hence their application in the development of the vulnerability map.

Figure 3 compares the variation in variables may be used to plot a chart. The results obtained from this survey was compared with results from previous years and a plot of radon concentration levels verses years was made. Year 2001 had the tallest bar standing slightly above 160 pCi/L with 2002 being within the 140-150 pCi/L range. These values are very high compared to other years and it's quite reasonable because different villages around the lake have different radon concentration and since these results were from single villages the possibility of high in accuracy because different villages were selected around the circumference of the lake so these results gave concentration levels exist.

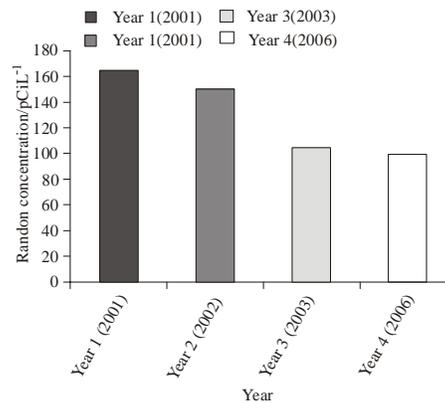


Fig. 3: Variation in Radon concentration with passing years

2003 and 2006 had an increase a more accurate value for radon gas level. 2003 had a concentration a little above 100 pCi/L and 2006 had a concentration slightly below 100 pCi/L.

An overall average which is an average of all the results obtained within 2001 to 2006 was calculated and a value above the 120 pCi/L mark on the plot was obtained.

**Radon vulnerability map of Ghana:** Fig. 4, is a vulnerability map of radon gas concentrations in different parts of Ghana. This map was developed based on both previous and current research works. The map shows areas in Ghana where some research work have been conducted; it can be observed that regions such as Western, Central, Greater Accra and Ashanti have



Fig. 4: Vulnerability map of Radon gas levels in Ghana

experienced more research work than regions like Eastern, Volta and the Northern parts of Ghana. With the increasing awareness in radon, every part of Ghana may undergo some form of sampling soon then a national average radon concentration can be developed. The map apart from showing areas which have undergone some research, it also gives the estimated radon gas concentration and the year in which the research was conducted. These values are dependable because the variation in radon gas concentration with passing years is not very great at lake Bosomtwi and hence it can be assumed that these values obtained elsewhere will share similar properties.

## DISCUSSION

**Comprehensive radon analysis from Lake Bosomtwi:** Radon analysis at Lake Bosomtwi has been an ongoing activity for quite sometime now. Results obtained even though hasn't been at alarming level further research into radon levels always brings out very interesting results. These results are interesting because it gives a clearer picture of how human and climatic activities are affecting the Eco-System. Over the years radon gas levels from the results obtained have been fluctuating with minimum and maximum values changing and this fluctuation may be attributed to various reasons such as:

- Change in climatic condition
- Inhabitation/Settlement

- Human Activities (Farming, Building, Development, etc.)

**2001:** The results obtained in the 2001 radon research conducted at Lake Bosomtwi was a comparison of soil depth to radon concentration. An average calculated for the 10cm and 20cm depth where the sample was collected gave a minimum value of 92.40 at 10 cm and a maximum of 220.10 pCi/L at 20cm as in Table 1. Overall an average of 167.20 pCi/L for the 10cm depth 195.5 pCi/L for the 20cm, but for the sake of this experiment, only the average for the 10cm will be considered.

**2002:** Research work in 2002 was an improvement of the results obtained in 2001; The expected result was to ascertain the effect of soil depth on radon gas emanation. The results obtained showed a minimum of 104.7 pCi/L at 10 cm and a maximum of 298.90 pCi/L at 50 cm as in Table 2. The results proved that depth really had an effect on radon emanation. In this work also only the average for 10 cm was considered.

**2003:** 2003 saw a different turn in the radon research. Samples were collected in six (6) different villages around the lake and the results showed that Duasi Village had the maximum value both for the sample count and the average, with Mmorontuo Village having the minimum for the sample count and the average. A minimum value of 3.91 pCi/L and a maximum of 35.14 pCi/L were

recorded with an overall average of 106.02 pCi/L as in Table 3.

**2006:** A confirmation analysis was done on the results obtained in 2003, so four (4) of the six (6) villages which recorded high values in 2003 were sampled again. Of all the villages, a minimum value of 31.90 pCi/L was recorded by Adwafo village and Duasi got the maximum value of 191.39 pCi/L as in Table 4. Overall calculated average was 99.9 pCi/L.

Overall, 2001 had the highest average radon gas level of 167.20 pCi/L, with 2006 recording the lowest average of 99.95 pCi/L. The averages for 2001 and 2002 were from single villages so do not give a true reflection of radon gas level in the Lake Bosomtwi area compared to that of 2003 and 2006 because those averages were from samples collected all around the lake. The results also show a downward trend from 2001. In the period 2001 to 2006 the average radon gas level at the Lake Bosomtwi area is 130.94 pCi/L, this value according to the United States' Environmental Protection Agency is within the range of (20-200) pCi/L.

### CONCLUSION

In conclusion this research work was a success. A lot more findings and research tactics were developed after which the following conclusion were made;

- The average radon gas level in the Lake Bosomtwi area for the 2006 is 99.95 pCi/L and this result was obtained from four (4) Villages.
- Average radon gas level between the periods 2001 to 2006 is 130.94 pCi/L.
- Variation in radon gas levels show a slight reduction from the results in 2003.
- A vulnerability map of Ghana shows that research work have been conducted in the following regions Western, Central, Greater Accra and Ashanti and other regions like Eastern, Volta and the Northern parts of Ghana have experienced little or no research.

#### Appendix:

**Calculation of results:** These are the calculations which yielded the results above. Samples collected were counted till the counts were taken. The time difference in minutes between sample collection and counting and correction factor were determined. The delay constant and corrected count were also calculated.

#### Example 1

Sample from station 1	
Cell number 1	
Cell background count	1.00
Two minutes sample count	4.40
Sample count per minute	2.20
Net count per minute (CPM)	1.20
Collection time	10 am (17/01/06)
Analysis time	10 am (02/02/06)

Time up to middle of count	10 min
Total time of delay ( $\Delta t$ )	14 days x 24 h x 60 min + 10 min
= 40330 min	
Total decay factor $e^{-\lambda \Delta t}$	= 0.079
Decay Constant of radon	= 0.0001258 per min
Corrected net count per min	= cpm/df
	= 1.20/0.079
	= 15.19 cpm

**Calculation of cell efficiency:** The cell efficiency was calculated to convert counts per minute into activity unit of pico curie since the method was standardized. This was done by filling the cells with radon from the Pylon radon source under count per minute.

#### Example 2

Cell number	1
Cell Background count	1
Net count per minute	254.73

$$\text{Cell efficiency} = (\text{cpm} \times \text{sc} \times \text{c}) / (3 \times 60 \times \text{DA} \times \text{A})$$

$$= (254.73 \times 1.0010 \times 1.00094) / (3 \times 60 \times 2.66 \times 0.97)$$

$$= 0.55 \text{ cpm/dpm}$$

#### Calculation of activity of radon gas:

Activity = 15.19 / (0.55 × 60) dpm = 0.46 dps  
 But 1 dps = 1 Bq  
 Activity = 0.46 Bq  
 Volume of cell = Volume of gas = 1.3 × 10<sup>-4</sup> m<sup>3</sup>  
 Activity = 0.46 Bq / (1.3 × 10<sup>-4</sup> m<sup>3</sup>) = 3.54 × 10<sup>3</sup> Bq/m<sup>3</sup>  
 Also 37 Bq/m<sup>3</sup> = 1 pCi/L<sup>2</sup>

$$\text{Hence; } 3.54 \times 10^3 \text{ Bq/m}^3 = (3.54 \times 10^3 \text{ Bq/m}^3 \times 1 \text{ pCi/2L}) / 37 \text{ Bq/m}^3$$

$$= 95.70 \text{ pCi/L}$$

- SC : Sequential correction for activity greater than ten (10) Successive samples = 1.00  
 C : Correction factor for radon decay during Counting = 1.0094  
 DA : Dispensing Activity = 2.66 Bq  
 A : Correction factor for radon decay from the time of collection to start of counting = 0.97  
 3 : Number of alpha emitters  
 60 : To convert decay per second (dps) to decay per min (dpm)

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