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Radon Exhalation Rates from Some Soil Samples in Some Areas in Bongaigaon District using Solid State Nuclear Track Detector

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Abstract

Radon (Rn, Z=86) is a naturally occurring radioactive noble gas present in soils, rocks, and water, posing health and environmental risks despite its low atmospheric concentration. Although generally inert, radon can react under special conditions and exhibits distinct physical properties such as phosphorescence at low temperatures.

Solid state nuclear track detectors (SSNTDs), particularly CR-39 (PADC), are highly effective for radon estimation and exhalation studies. These detectors, first demonstrated in dielectric solids, have since been widely applied across physics, earth sciences, space sciences, and medical sciences. Applications include nuclear reaction studies, geo-chronology, cosmic ray detection, and medical filtration techniques.

The investigated areas show homogeneous climatic conditions: cold, foggy winters, moderately cool spring and autumn, and hot, humid summers with heavy monsoon rainfall (150–260 cm) from June to September. These climatic patterns strongly influence radon exhalation rates, emphasizing the importance of continuous monitoring and detector-based assessments.

1. INTRODUCTION

There are many known and unknown gases within or around our home, in which radon gas is one of the health concerns. Radon is a naturally occurring radioactive gas found in soils, rock, and water everywhere, with the symbol Rn and atomic number 86. Radon was discovered in 1900 by Friedrich Ernst Dorn, who called it radium emanation. In 1908, William Ramsay and Robert Whytlaw-Gray named it niton (Latin *nitens* meaning "shining"; symbol Nt), isolated it, determined its density, and identified it as the heaviest known gas. Since 1923, it has been called "radon."

In the periodic table, radon occupies a position in Group VIII of Period VI. Its specific gravity, boiling point, and freezing point are 9.73, 211 K, and 202 K respectively (Lange, 1961). As a noble gas, radon was expected to be inert. However, some investigators (Stein, 1969, 1970, and 1972) reported that radon, like xenon, can react with liquid bromine trifluoride and some solid complexes of antimony halides.

When cooled below its freezing point, radon exhibits brilliant phosphorescence, which becomes yellow as the temperature is lowered and orange-red at the temperature of liquid air. A volume corresponding to an activity of 1 picocurie (Pci) of radon is about 6.7×10^{-19} cm³, with a corresponding partial pressure of less than 10^{-18} atmosphere (Evans, 1969). The average atmospheric concentration of radon is of the order of 6×10^{-18} % by volume (Clark, 1959). Radon is colourless, odourless, and tasteless, and can only be studied using special equipment.

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Fig1.1 : ^{238}U decay chain, including ^{222}Rn and its decay products (Sharma B.K., 1996)

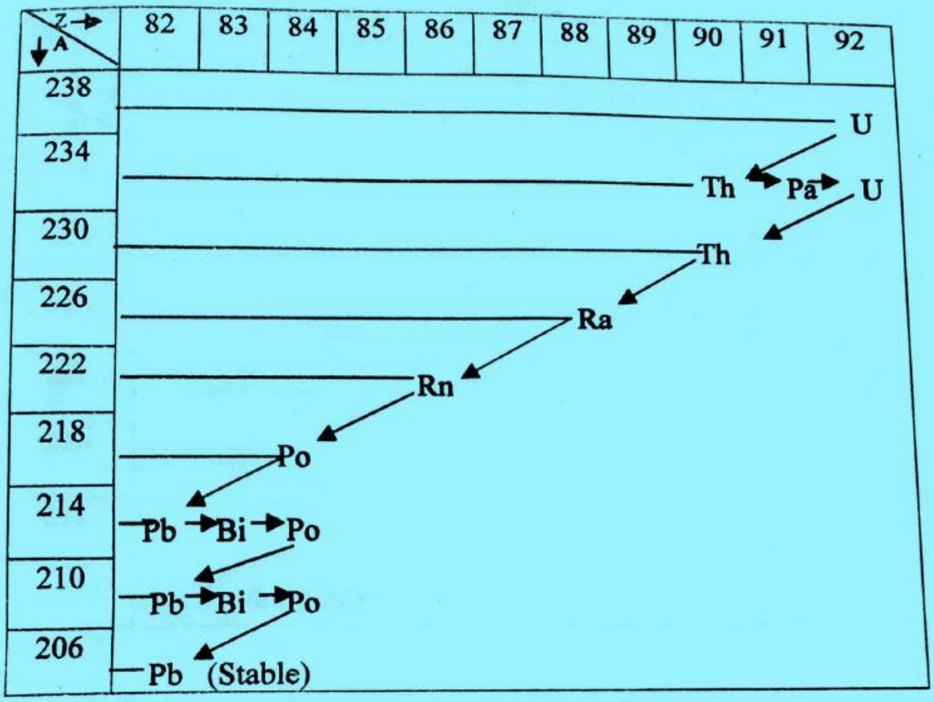

Table1.1: Radioactive series of ^{238}U(Sharma B.K., 1996)

NAME AND SYMBOL	ATOMIC WEIGHT	ATOMIC NUMBER	RADIATION	HALF LIFE PERIOD
Uranium (U)	238	92	α	4.5×10^9 years
Thorium (Th)	234	90	β	24.6 days
Protactinium (Pa)	234	91	β	1.14 min.
Uranium (U)	234	92	α	2.7×10^5 years
Thorium (Th)	230	90	α	8.3×10^4 years
Radium (Ra)	226	88	α	1590 years
Radon (Rn)	222	86	α	3.8 days
Polonium (Po)	218	84	α	3.0 min.
Lead (Pb)	214	82	β	26.7 min.
Bismuth (Bi)	214	83	β	19.7 min.
Polonium (Po)	214	84	α	1.5×10^{-4} sec
Lead (Pb)	210	82	β	22 years
Bismuth (Bi)	210	83	β	4 days
Polonium (Po)	210	84	α	140 days
Lead (Pb)	206	82	-	Stable

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Fig 1.2 : ^{232}Th decay chain, including ^{220}Rn and its decay products (Sharma B.K., 1996)

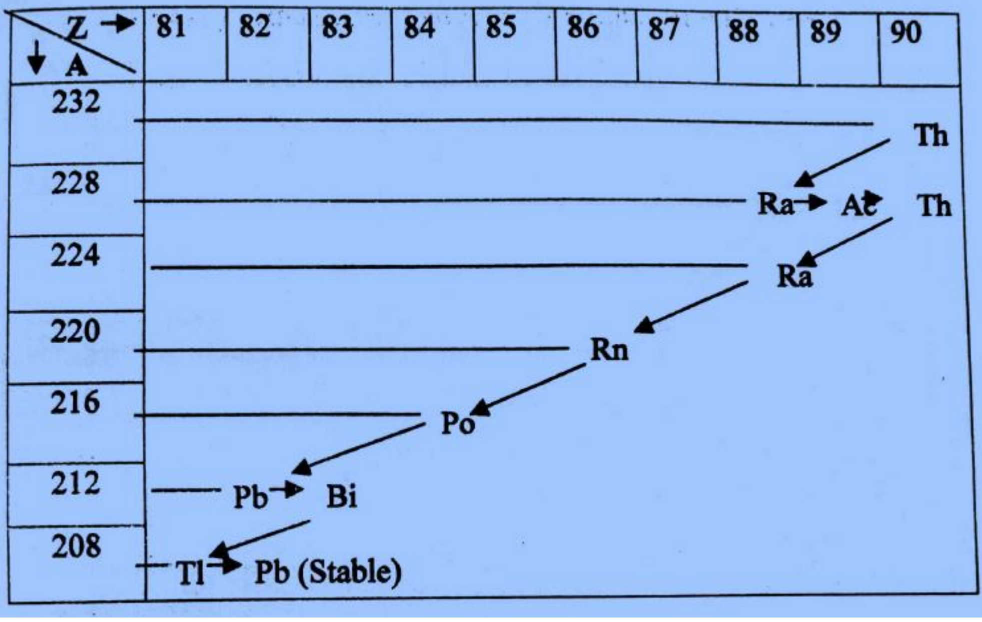

Table1.2 : Radioactive series of ^{232}Th (Sharma B.K., 1996)

NAME AND SYMBOL	ATOMIC WEIGHT	ATOMIC NUMBER	RADIATION	HALF LIFE PERIOD
Thorium (Th)	232	90	α	1.4×10^{10} years
Radium (Ra)	228	88	β	6.7 years
Actinium (Ac)	228	89	β	6.13 hours
Thorium (Th)	228	90	α	1.9 years
Radium (Ra)	224	88	α	3.65 days
Radon (Rn)	220	86	α	55 sec
Polonium (Po)	216	84	α	0.16 sec
Lead (Pb)	212	82	β	10.6 hours
Bismuth (Bi)	212	83	α	1 hour
Thallium (Tl)	208	81	β	3.1 min
Lead (Pb)	208	82	-	Stable

2. SOLID STATE NUCLEAR TRACK DETECTORS

In the present work, I have used solid state nuclear track detectors for radium estimation and radon exhalation rate measurements. The first nuclear track in dielectric solid was observed by Young (1958) in a thick sample of lithium (LIF) under an optical microscope after suitable etching. A year later, Silk and Barners (1959) observed latent damage trails produced in mica by the fission fragments of ^{235}U using a transmission electron microscope.

However, it was Price and Walker (1962), apparently unaware of Young's work, who demonstrated that etching solutions preferentially attack the damaged regions, producing enlarged pits easily observed under an optical microscope, resembling tracks in nuclear emulsions.

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Since then, etchable tracks have been observed in many crystals, glasses, and a wide variety of plastics (Fleischer et al., 1975). Different materials vary considerably in sensitivity: minerals and glasses are the least sensitive, while organic materials are the most sensitive. PADC, also known as CR-39, is by far the most sensitive material, capable of recording alpha particles with a wide range of energies (Cartwright et al., 1978; Henshaw et al., 1982; Durrani and Bull, 1987).

Afterwards, a considerable amount of work was done by various investigators to systematize this pool of information and knowledge (McCorkell, 1974; Fleischer et al., 1975). During this period, the technique was not only developed and strengthened but also applied very successfully in diverse fields (Fleischer et al., 1975).

Applications include:

- **Physics**: Studies of nuclear fission and spallation reactions (Cieslak et al., 1965), and measurement of lifetimes of heavy unstable nuclei (Fleischer et al., 1963; Prevo et al., 1964; Fleischer et al., 1965).
- **Earth Sciences**: Extensively used in geo-chronology estimation and revelation of geothermal history of geological eras (Brill et al., 1964; Fleischer and Price, 1964a, 1964b; Nagpaul et al., 1974; Virk and Koul, 1975; Singh and Virk, 1978).
- **Space Sciences**: Applications in the study of cosmic rays and extraterrestrial materials (Fleischer et al., 1967; Virk, 1977, 1979; Virk and McCorkel, 1979).
- **Medical Sciences**: Selectively etched tracks in thin layers of plastics used as fine sieves for filtration of cancer blood cells (Seal, 1964).

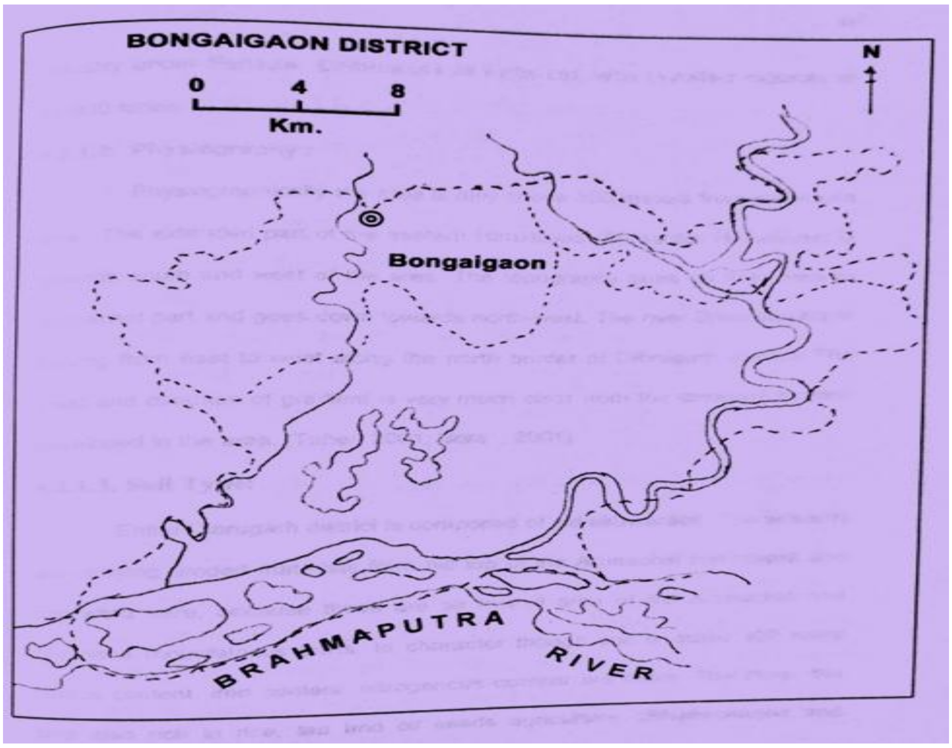

Fig 2.1: Map of Bongaigaon District showing study area

3. CLIMATE OF THE INVESTIGATED AREAS

The climate is homogeneous over the investigated areas. The principal characteristics of the climate are cold and foggy winter, moderately cool spring and autumn, and a fairly hot and humid summer.

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The summer and winter seasons are well marked, with temperature varying between 38°C and 10°C. The summer season starts around June and lasts until early September. During June, July, and August, the weather becomes very hot and humid, with average humidity between 70% and 80%. Summer rainfall is heavy, occurring mainly from late June to early September, with average rainfall ranging between 150 cm and 260 cm. Maximum rainfall generally occurs over a four-month period beginning in early June.

The winter season extends from early December to mid-March, peaking in January. The temperature begins to rise steadily from early March. Dust storms are common from late February to April (Mahanta et al., 2007).

4. RESULTS AND DISCUSSIONS

Village / Location	Sl. No.	Radon Exhalation Rates E_A (mBq $m^{-2}h^{-1}$)	Average Radon Exhalation Rates E_A (mBq $m^{-2}h^{-1}$)
Township (BRPL)	1	162.79	164.61±0.28 *
	2	162.23	
	3	165.03	
	4	168.39	
Sati Gaon	1	138.13	130.61±0.58
	2	128.67	
	3	131.47	
	4	124.20	
Dolai Gaon	1	118.04	109.71±0.80
	2	114.68	
	3	100.70	
	4	105.42	

Fig 4.1: Value of radon exhalation rates (in terms of area) from soil samples in Bongaigaon area (Assam)

- BRPL: Bongaigaon Refinery and Petrochemical Limited
- The error calculated here is statistical error

Table 4.1: Value of Radon exhalation rates in terms of mass in soil sample of Bongaigaon area (Assam)

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Village / Location	Sl. No.	Radon Exhalation Rates E_M (mBq $Kg^{-1}h^{-1}$)	Average Radon Exhalation Rates E_M (mBq $Kg^{-1}h^{-1}$)
Township (BRPL)	1	4.61	4.66±0.01
	2	4.59	
	3	4.68	
	4	4.77	
Sati Gaon	1	3.91	3.69±0.02
	2	3.64	
	3	3.72	
	4	3.51	
Dolai Gaon	1	3.34	3.09±0.02
	2	3.25	
	3	2.85	
	4	2.91	

5. Conclusions

From the present investigation of the Radon exhalation rate and radium concentration in soils collected from Bongaigaon area following conclusions can be drawn-

1. The solid state nuclear track detectors (SSNTDS) are best suited for the measurement of radium concentration and radon exhalation rate in soil samples.
2. Overall a positive correlation has been observed between the radon exhalation rate and the radium concentration of soil samples.
3. In the present investigation it is observed that concentration in soil samples is much lower than the permissible value 370 Bq Kg-1.
4. The radium concentration and radon exhalation rates comparatively higher in BRPL (Bongaigaon Refinery and Petrochemicals Limited), Bongaigaon. These are mainly industrial areas.

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