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Technical Data

Radon variations in Soil and Groundwater of Bhilagana valley, Garhwal Himalaya, India

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Radon measurements were made in the soil-gas and groundwater present in various lithological units and across the major tectonic zone (Munsiari and Bhatwari-Ramgarh Thrust) located between Ghansali and Ghuttu area in Bhilangana valley of the Garhwal Himalaya, India. High concentrations of radon were observed both in soil-gas and groundwater samples located close to the tectonic planes. Overall radon concentration in this area was found to be controlled by lithology, structure and associated uranium mineralization.

KEY WORDS: radon, Garhwal Himalaya, groundwater, uranium mineralization, thrust and faults.

I INTRODUCTION

Radon, ^{222}Rn, is immediate decay product of radium, ^{226}Ra, which in turn, is derived from the decay of uranium, ^{238}U. Radon is chemically inert gas and tends to migrate readily in air or water but the migration is limited due to its short half life (3.82 days). The radon potential for a given region is likely to be the result of a combination of properties of the underlying rocks and of the soil, such as the distribution of uranium and radium, porosity, permeability and moisture content, as well as meteorological and seasonal variations.[1~8] Radon transport in soil occurs by two processes; diffusion and convective flow.[9] Diffusion is major radon transport process in soil having low permeability whereas convective transport process tends to dominate in highly permeable soil.[10] For some geological situations, radon migrates long distances from its place of origin and can be detected by α- Particle recorder at the earth's crust.[11~12] TANNER[13] has also suggested that squeezing in zones of compression causes a net upward and outward flow of soil-gas, thereby upward shifting of the near surface profile of radon concentration.

The studies in the Himalayan region have demonstrated that the tectonic processes, types of rocks and geohydrological characteristics of rock mass control the concentrations of radon in soil and groundwater.[14] In the present study, an attempt has been made to find out the radon variations in soil and groundwater and its relation with lithology and associated regional structure in the Bhilangana valley of Garhwal Himalaya, India.

II GEOLOGY OF THE AREA

The major geologic structures of the Himalaya comprise relatively uniform bands along the Himalayan belt[15, 16] for a length of about 2,500 km (**Fig. 1**). The Proterozoic to Lower Tertiary sedimentary rocks of the Tethys Himalaya and Precambrian metamorphic rocks of the Higher Himalaya are present in the north of the Main Central Thrust (MCT). The Lesser Himalaya, composed largely of pre-Tertiary low-grade metasediments, is bounded in the south by the Main Boundary Thrust (MBT). The Sub-Himalaya represents the foothills of the Himalaya and comprises Tertiary–Quaternary sedimentary sequence. The southern limit of the Sub-Himalaya corresponds to the Himalayan Frontal Thrust (HFT) that transported Sub-Himalayan sediments southward over the Indo-Gangetic Plain. Sediments of the Indo-Gangetic Plain fill a flexural basin formed by subduction of Indian continental block beneath Eurasia.[17, 18]

The Bhilangna Valley is located in the Tehri district of Uttarakhand in Garhwal Himalaya, India. A number of workers[19~24] have studied the geology of the Bhilangana area in detail. Two main physiographic units; the Higher Himalaya and the Inner Lesser Himalaya are exposed in this Valley. These units are consisting of different lithotectonic units separated by regional scale thrust planes (**Fig. 2**).

The Higher Himalaya represents the "Central Craystallines" which is recognized as a distinct tectonic unit thrust over the Lesser Himalayan sedimentary sequences along Main Central Thrust.[15] The Central Crystalline of the Higher Himalaya is divisible into two distinct units of metamorphic rocks showing diverse metamorphic character, petrological composition and

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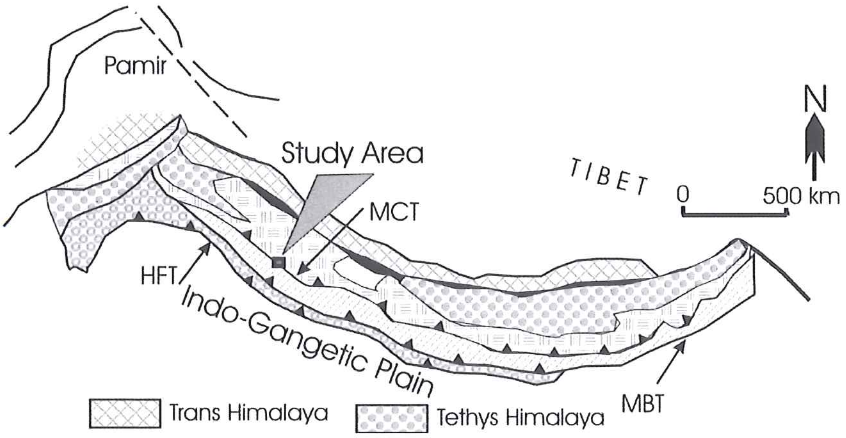

Fig. 1 Simplified geologic map of the Himalayan range. MCT = Main Central Thrust; MBT = Main Boundary Thrust, HFT = Himalayan Frontal Thrust.

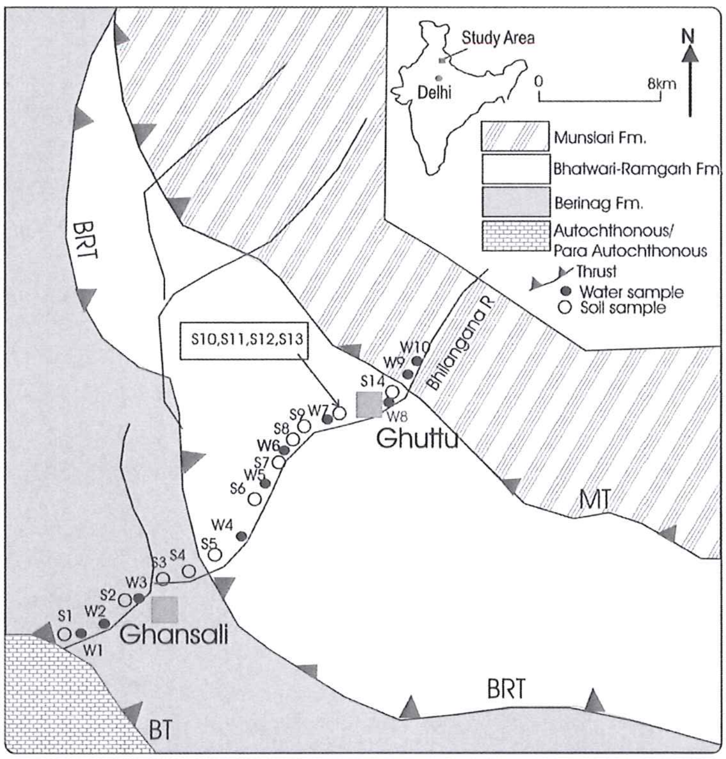

Fig. 2 Study area. Tectonic map simplified after Valdiya's paper[27] of the Ghansali-Ghuttu area showing various litho-units, structure and location of soil and water radon samples (MT = Munsiari Thrust, BRT = Bhatwari-Ramgarh Thrust, BT = Berinag Thrust).

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structural patterns. The first unit being the kyanite-silliminite-garnet bearing paragneiss and schist with the calc silicate rocks constituting the Vaikrita Formation[25] and the second unit being the meso to epi-grade para and ortho-gneiss and schist with calc silicate, marbles, granites and their mylonitic equivalent forming the Munsiari Formation. These units constitute the root zone rocks of the far traveled detached pieces (nappe and klippe) in the Lesser Himalaya.

In the study area, the Berinag Formation is separated by the Berinag Thrust in the south and by Bhatwari-Ramgarh Thrust (BRT) in the north. The lithology of Berinag Formation is consist of coarse grained sericitic, white massive and purple conglomeratic quartzite having rounded to well rounded clasts of fine grained quartzite called Berinag quartzite and closely associated with coarse grained amphibolite and metavolcanics interbedded with green quartzite. Bhatwari-Ramgarh Formation is delimited from underlying Berinag Formation by Bhatwari-Ramgarh Thrust and overlying from Munsiari Formation by Munsiari Thrust. The Bhatwari Formation comprises biotite rich mylonitized quartz porphyry interbedded with schistose grey phyllite, diorite, grey slates, sericite quartzite with schistose phyllite, granite porphyry with schist and at places chlorite schist with amphibolite. Munsiari Formation is composed of sericite-chlorite schist intrbedded with sheared amphibolite and bands of mylonitized biotite rich porphoyroblastic gneissose granite and augen gneiss. The number of NW-SE, N-S and NE-SW trending local faults/joints were observed in the rocks. These faults fracture and joints influence the groundwater recharge and location of springs.

III EXPERIMENTAL PROCEDURE

The radon measurement was made in groundwater using radon emanometry technique. In this technique, 750 ml of water sample was collected in a one liter radon tight reagent bottle connected in a closed circuit with a Lucas cell through an electrical pump for bubbling of water samples and a tube containing $CaCl_2$ to absorb the moisture. Air was circulated in the closed circuit for 10 minutes until the radon formed a uniform mixture with the air and the resulting alpha counts were recorder. The system was left undisturbed for four hours. A time gap of four hours is necessary to allow radon and its alpha emitting daughters to come in equilibrium. An average of five measurements was taken for a single water sample.

In soil-gas radon emanometry, auger holes, each 60 cm in depth and 6 cm in diameter, were left covered for 24 h so that the amount of radon and thoron became stable. All measurements were carried out in the afternoon under the stable weather condition in different geological formations of the area. The soil-gas probe was fixed in the auger hole and formed an airtight compartment. The rubber pump, soil-gas probe and alpha detector were connected in a close circuit. The calibration factor of 1 count/minute = 66 Bq/m^3 was used to convert the recorded alpha counts in Bq/l.[26] Detail experimental procedure for measurements of radon in soil and water is discussed elsewhere.[6]

The daily and long term variation in near surface soil-gas radon concentration was measured by Barasol alpha logger. It measures radon continuously at pre-defined measuring cycle. Beside radon, other parameters like atmospheric pressure and temperature were also measured simultaneously. The sensitivity of this logger for radon is 66 Bq/m^3 and the temperature probe accuracy is better than 0.1°C. The equipment has 1 MB flash memory, which can store continuous data of 1 year. For installation of alpha logger, one meter deep hole with diameter of 10 cm was dug with the help of a soil auger. The instrument was placed vertically, so that the detection chamber faces toward the ground.

IV RESULTS AND DISCUSSION

The radon measurements in soil and groundwater were made mainly in three lithotectonic units between Ghansali and Ghuttu area in Bhilangana valley of the Garhwal Himalaya. The lithotectonic units and the measured radon concentration in soil and water are given in **Table 1** and the sample locations are shown in **Fig. 2.**

The soil cover in the area is thin and varies from 10 cm to 200 cm. However, thick soil cover is observed in river terraces. Except the river terraces, the soil is mostly derived from the underlying or surrounding rocks. Therefore, the soil composition generally reflects that of the underlying rocks. The radon produced is predominantly a function of the uranium content of the bedrocks.

The Berinag Formation is separated by the Berinag Thrust in the south and Bhatwari-Ramgarh Thrust (BRT) in the north. The main rock type of this formation is quartzite and metabasic with intercalation of phyllite and chlorite schist. Radon concentrations in soil and spring water of this formation were found to vary from 9.3 kBq/m^3 to 32.3 kBq/m^3 and from 5.0 Bq/l to 6.9 Bq/l, respectively. The Berinag Formation is overlain by the Bhatwari-Ramgarh formation at higher altitude towards the north, contains uranium mineralization in the Bhilangana valley.[27, 28] During erosion and transportation of the rocks of the Bhatwari-Ramgarh formation, the uranium minerals got deposited at lower altitude in the soil of the Berinag formation. The combined effect of uranium mineralization and the presence of the nearby thrust plane (BRT) may be responsible for the higher concentration of radon in soil sample #S_1 (32.3 kBq/m^3). The low value of radon concentration near the thrust (Sample #S_4) may be due to presence of impervious layer, which does not allow radon to escape from fault region to measurement site.

Bhatwari-Ramgarh formation of higher Himalaya consists of sheared granitic gneisses, porphyritic gneisses, phyllite, talc schist, mica schist, mylonites and quartzo-feldspathic schist. Radon concentrations in soil and groundwater of this formation were found to vary from 3.6 kBq/m^3 to 84.2 kBq/m^3 and 34.8 Bq/l to 168.2 Bq/l, respectively. The high values of radon concentrations in the soil (84.2 kBq/m^3 and 53.4 kBq/m^3) were observed in samples S_5 and S_{14}. Both the samples are located just on the Bhatwari-Ramgarh Thrust (BRT) and Munsiari Thrust (MT). Overall, high radon concentration was observed in five groundwater samples in this area. Three water samples were taken from the hand pumps (W_5, W_6 and W_8) and two samples (W_4 and W_7) from the natural perennial joint controlled springs. The highest radon value 168.2 Bq/l was recorded from a water of deep hand pump (sample W_5). The increased radon values in the area are possibly due to the uranium mineralization associated with mylonitised granitic gneisses[27] and the presence of different thrust/shear planes, which provide easy pathway to escape radon gas from the deeper part of the crust.

Munsiari formation bounded to the north by the Vaikrita Thrust and in the south by the Munsiari Thrust (MT). The lithology of Munsiari formation comprises mesograde metamorphic, predominantly augen gneisses of granodioritic-granitic percentage and phyllonites. Radon concentrations in the groundwater of this formation vary from 121.7 Bq/l to 160.1 Bq/l. The higher value of radon in water sample #W_9 (160.1 Bq/l) is possibly due to the continued movement along the different shear planes, exhibiting extreme shearing and mylonitization.[29]

Radon concentration in groundwater was measured from the joint/fault related and colluvial related springs. The higher

Table 1 Radon concentrations in soil and groundwater in different litho-tectonic units, Garhwal Himalaya.

Zone	Lithotectonic unit	Sample No.	In soil kBq/m^3	In water Bq/l
Higher Himalaya	Munsiari Formation	W_9	--	160.1 ± 4.8
		W_{10}	--	121.7 ± 3.7
	---------- Munsiari Thrust ----------			
	Bhatwari-Ramgarh Formation	S_5, W_4	53.4 ± 1.6	88.6 ± 2.7
		S_6, W_5	49.3 ± 1.5	168.2 ± 5.0
		S_7, W_6	3.6 ± 0.1	125.4 ± 3.8
		S_8, W_7	35.9 ± 1.1	--
		S_9	6.8 ± 0.2	--
		S_{10}, W_7	18.6 ± 0.6	34.8 ± 1.0
		S_{11}	40.1 ± 1.2	--
		S_{12}	38.5 ± 1.2	--
		S_{13}	6.5 ± 0.2	--
		S_{14}, W_8	84.2 ± 2.5	136.3 ± 4.1
	---------- Bhatwari-Ramgarh Thrust ----------			
	Berinag Formation	S_1, W_1	32.3 ± 1.0	6.9 ± 0.2
Inner Lesser Himalaya		S_2, W_2	12.1 ± 0.4	5.9 ± 0.2
		W_3	--	5.0 ± 0.2
		S_3	9.3 ± 0.3	--
		S_4,	8.7 ± 1.6	--
	---------- Berinag Thrust ----------			

radon values (121 Bq/l to 160 Bq/l) were recorded in joint/fault related springs. These higher values are possibly due to the increased ratio of rock surface area to water volume and presence of uranium mineralization in the area. Whereas, low radon concentration was recorded in colluvial type springs (5 Bq/l – 6 Bq/l). The high porosity of such springs does not allow the accumulation of radon in water because of the natural de-gassing. Similar observations at other colluvial springs in Garhwal Himalaya and in Doon valley of outer Himalayan belt further strengthen hydrogeological controls on radon emanation processes (5).

It is well known that the temporal variation of radon concentration is a complicated function of several factors.[30~33] In order to measure the diurnal changes in soil-gas radon concentration, continuous radon probe (Barasol MC2) was used from February 24, 2006 to July 8, 2006 at 1 meter depth near Ghuttu area in Garhwal Himalaya. This probe also records the soil temperature and atmospheric pressure. The measuring cycle was kept at 30 minutes per sample. The variation in continuous radon concentration along with soil temperature and atmospheric pressure is shown in **Fig. 3**. The variation in soil-gas radon concentration was not found related with the change in soil temperature and atmospheric pressure. However, occasionally, daily temperature and pressure changes were observed to influence overall radon emission intensities by a small fraction.

V CONCLUSION

The measured radon concentrations in soil and groundwater

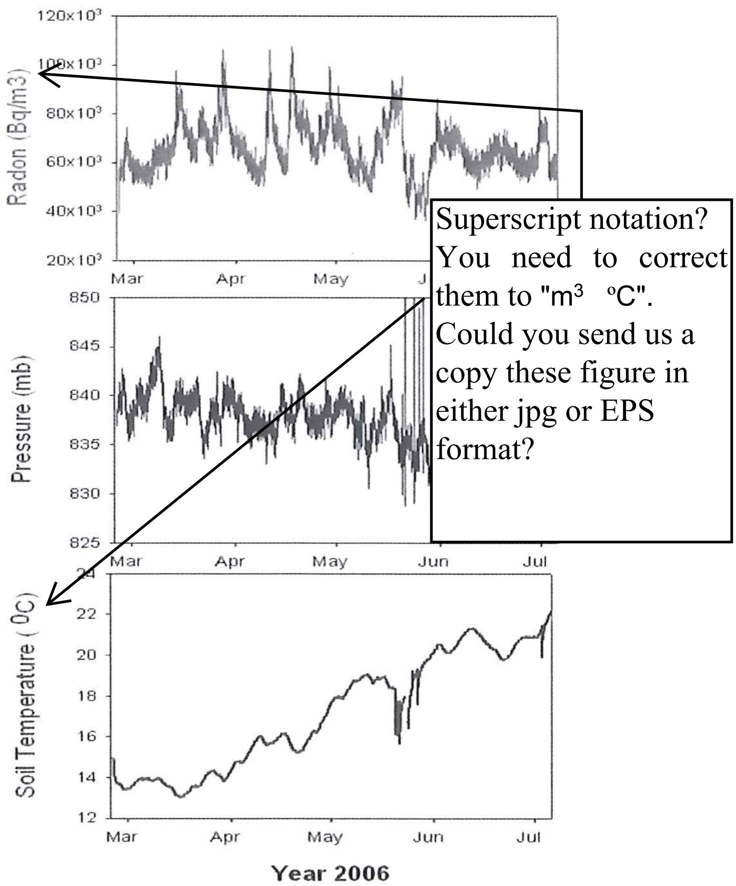

Fig. 3 Continuous radon, atmospheric pressure and temperature plots from the Ghuttu area.

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in the study area are found to be controlled by the presence of uranium mineralization, lithology and associated fault and thrust. Superficial and shallow colluvial springs show relatively low radon concentration. On the other hand, higher radon concentration values are, in general, found to be associated with springs that are controlled by fault/joint or thrust lineaments irrespective of the underlain rock type within the same geological formation, which indicate the control of tectonic features on radon emanation.

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