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Radon/Helium Survey of Thermal Springs of Parbati, Beas and Sutlej Valleys in Himachal Himalaya

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Abstract: India has more than 300 thermal springs spread over the entire geographical area of the sub-continent. Some of these springs have linkage with Indian mythology and are famous pilgrimage centres since historical times. The temperature of water recorded in these springs varies from 40° C to that of steam. Some of them are being exploited as a source for geothermal energy.

The purpose of this study is to measure radon and helium activity in the thermal springs of Himachal Himalaya. Radon is estimated in the soil and thermal waters using alpha spectrometry and scintillometry, respectively. The radon activity is maximum (716.3 Bq/L) in thermal spring (3) at Kasol and minimum (15.9 Bq/L) in a natural spring (bauli) at Takrer. Radon concentration is highly variable in the Parbati valley with minimum value of 2230±430 Bq/m³ recorded at Chhinjra on the banks of river Parbati and a maximum value of 57700±2050 Bq/m³ at Dharmaur, the site of uranium ore exploitation by the AMD(DAE). Helium is estimated in the thermal springs by using a Helium Leak Detector (sniffing technique). The radon and helium contents of Kasol thermal springs are correlatable with high radioactivity in the soil of the area as revealed by Alpha Guard survey in the environs of Parbati valley. The helium content recorded in thermal springs is found to vary between 15-90 ppm.

Radon and Helium are well established as geochemical precursors for earthquake prediction studies. Helium/Radon ratio seems to be a better predictive tool for earthquakes in comparison to individual radon and helium precursors.

Keywords: Thermal Springs, Earthquake, Lineaments, Radon, Helium, Alpha Spectrometry, Himachal Himalaya.

INTRODUCTION

Geothermal Atlas of India prepared by Geological Survey of India reported the location of 303 thermal springs in different States of India (Ravi Shanker et al. 1991). These springs are related to tectonic belts, grabens and fault zones and are classified (Krishna Swamy & Shanker, 1980) in 10 broad groups with major concentration in six areas (Fig.1), viz. (i) Tectonic belts of the Himalaya and the Naga-Lushai hills, (ii) Easterly and Westerly margin faults of Aravalli range, (iii) Narmada-Son lineament, (iv) Tapti graben, (v) Cambay graben, and (vi) West coast fault zone (Sharma, 1997).

Geochemical studies of some thermal springs in India have been carried out in the recent past (Singh, 1989; Singh and Bandyopadhyay, 1995). Radioactivity of thermal springs has not been reported in these studies. K.K. Dar in 1964 has reported one case study of uranium and radium measurement in the Ram Kund hot spring at Tuwa, Gujarat State, where the U/Ra ratio in spring water is twice that in the granitic rocks of the area.

The purpose of this study is to measure ^{222}Rn and ^{4}He radioactivity in the thermal springs of Parbati valley in Himachal Himalaya. Uranium mineralisation along the river Parbati and other metasediments of Kullu area in Himachal Pradesh was reported by Narayan Das et al. (1979). There are a number of thermal springs located in the Parbati valley along the Parbati river and in the Kullu valley along the river Beas. The Parbati river is a tributary of the river Beas. Some of these hot springs are known since historical times as famous pilgrimage centres, especially the ones at Manikaran and Vashishat near Manali.

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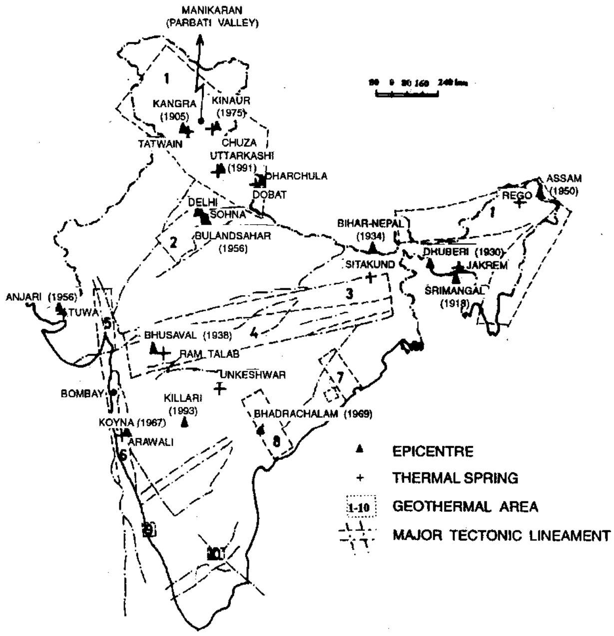

Fig.1. Map showing tectonic features, geothermal provinces, thermal springs and some major earthquakes in India. (The base map is adopted from Krishnaswamy and Shanker, 1980)

We carried out a radioactive survey in the Parbati valley earlier using track-etch technique and radon emanometry (Singh et al. 1986). Uranium and radon anomalies were recorded in soil and groundwater confirming the location of uranium mineralisation (Virk, 1990). The present survey is carried out during May-June 1997 using Alpha Guard (PQ 2000 PRO) based on pulse ionisation chamber, Alpha Scintillometer (GBH 2002) using Lucas cells and Helium Leak Detector (ASM 100 HDS).

GEOLOGY OF THE AREA

Parbati valley geothermal area extends for 40 km west to east, from Jan to Khirganga including Kasol, Manikaran, Balagarh and Pulga. The area comprises of various high grade schists and gneiss, migmatite, granite, pegmatite and quartz veins along with quartzite, carbon phyllite and limestone bands. The highly jointed and fractured quartzites at Manikaran and Kasol are the immediate control for the emergence of hot waters at these places. The regional thrust dips at 35° - 40° towards north, playing a very significant role in the upward migration of thermal fluids. The main channels of upflow appear to be the planes of intersection between steep joints/fractures in the Manikaran quartzite and comparatively low dipping (35° - 45°) thrust surface.

EXPERIMENTAL TECHNIQUES

Radon Estimation in Water by Scintillometry

Water samples were collected from the thermal springs along the Parbati river at Manikaran and Kasol. Alpha Scintillometer

GBH 2002 (GBH Electronic) with Lucas cell assembly was used to record alpha counts from one litre of spring water over an interval of 10 minutes. Radon gas emanated from radium present in the thermal waters was sucked by a pump connected to a radon bubbler. The electronic digital counter records the alpha counts and the radon activity is measured by using the calibration constant (10 counts = 1Bq/L).

Radon Estimation in Soil by Alpha Spectrometry

Alpha Guard PQ-2000 PRO (Genitron Instruments, Germany) based on pulse ionisation technique was employed for radon activity measurements in soil - gas. The special soil-gas unit consists of an Alpha Guard, Alpha pump and a modified STITZ soil-gas probe connected in series as shown in Fig. 2. The main advantages of the Alpha Guard are its fast response, higher sensitivity and a wide dynamic range which is linear over the interval 2-2 x 10^6 Bq/m^3. It is a multi-sensor unit which can measure temperature, pressure and humidity simultaneously along with radon.

Helium Estimation in Thermal Springs

Helium leak detector ASM 100 HDS (ALCATEL, France) using sniffing technique was used for helium analysis in thermal springs. It comprises of a helium gas analyser with a pumping system.

The main component of helium detector is a spectro-cell which acts as a mass spectrometer set to mass of helium. The helium ion analysis is based on the partial pressure of helium in the system which is calibrated to yield helium concentration in ppm. Thermal spring water samples were collected in air tight bottles (100cm^3) and kept indoor for a period of one month to get helium accumulation. A closed circuit technique is followed to estimate helium in the collected samples using two hypodermic syringes, air tight bottle containing silica gel and the helium leak detector. The test value of helium is displayed on the calibrated logarithmic scale showing the value in ppm as well as in terms of voltage. The whole operation is fully automatic and it can measure the helium concentration from 0.1 ppm to 100% helium.

RESULTS AND DISCUSSION

Uranium exploration survey carried out during 1985 (Singh et al. 1986) in the Parbati valley using track-etch technique and emanometry revealed some uranium and radon anomalies at Chhinjra and Kasol. Uranium concentration in the soil at Chhinjra recorded a maximum value of 86.93±1.75 ppm, while the highest value of 702 ppm was estimated for Jari quartzite in the area using alpha-autoradiography (Singh et al. 1989). The U content of water in the Kasol thermal spring was found to be 37.40±0.41 ppb and its radon

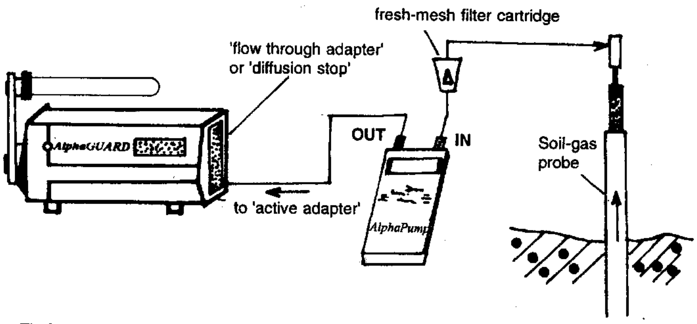

Fig.2. Alpha Guard radon monitoring in soil-gas. A similar arrangement can be used for water also.

activity was recorded as 364.45±30.34 Bq/m^3 (Virk, 1997). The uranium and radon anomalies are related to Shat-Chinnjra and Kasol mineralisation (Narayan Das et al. 1979).

Radon contents of thermal springs at Kasol, Parbati river water and natural springs (baulis) in the area determined by Alpha-Scintillometry are given in Table 1. The highest value is recorded at Kasol, 716.3 Bq/L in thermal spring (No.3), and the minimum value of 15.9 Bq/L in the drinking water from a bauli in Takrer. The river water flowing near Kasol records high radon content compared with normal drinking water due to mixing of thermal spring water in the river.

Helium estimation in thermal spring waters of Parbati, Beas and Sutlej river valleys was carried out by Helium Leak Detector. The helium contents of eight thermal springs are reported in Table 3, with the minimum value 15 ppm at Tegri and a maximum value of 90 ppm in thermal spring (No.3) at Kasol. Helium content of Manikaran spring in the vapour phase was estimated to be 100ppm and the highest value in the Rampur borehole was reported to be 2.1% by Singh (1989) using Gas Chromatography. We find the highest helium value of 90 ppm in Kasol thermal spring (KL3) which also records the highest radon value of 716.3 Bq/L. The results of our survey prove that

Table 1. Radon activity in thermal springs of Parbati valley (H.P.) using scintillometry

S.No.	Place	Spring	Radon Value (Bq/L)	Temperature (°C)	Pressure (mbar)	Rel.Humidity (%)
1.	Kasol	Thermal 1	371.9	90	846	46
2.	Kasol	Thermal 2	518.1	91	846	53
3.	Kasol	Thermal 3	716.3	91	846	68
4.	Kasol	River Water	52.4	12	846	53
5.	Bradha	Bauli 1	34.2	24	835	52
6.	Takrer	Bauli 2	15.9	19	838	85

Radon anomalies are recorded in the soil-gas in the Parbati valley during recent alpha spectroscopic (Alpha Guard) survey. The results of survey are summarized in Table 2. The highest value is recorded in Dharmaur village at the site exploited by Atomic Minerals Division (AMD) of Department of Atomic Energy. The radon concentration values at Bradha, Kasol and Takrer are almost equal, with a minimum value recorded at Chhinjra.

there is a correlation between radon and helium contents of Kasol thermal springs which are further correlated with uranium content in the water and soil of the area.

Rare Gas Emanations as precursor to Earthquakes

The rare gas emanations, especially radon and helium, have received considerable attention as geochemical precursors of

Table 2. Radon survey using Alpha Guard in the soil-gas in the environs of Parbati valley

Sr.No	Place	Radon value (Bq/m^3)	Temperature (°C)	Pressure (mbar)	Rel. Humidity (%)
1	Chhinjra	2230 ± 430	31	864	67
2	Jaan	13300 ± 695	29	875	54
3	Bradha	19600 ± 481	18	838	84
4	Kasol	19500 ± 950	29	845	46
5	Takrer	19400 ± 1060	19	838	85
6	Dharmaur	57700 ± 2050	17	834	91

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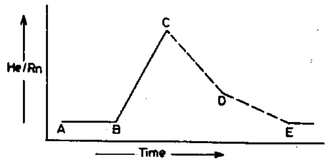
Table 3. Helium activity in thermal springs of Parbati and Kullu valleys (H.P.)

S.No.	Place	Spring code	Spring Temp. (°C)	^{4}He content (ppm)
1.	Manikaran	MK1	94.4	50
2.	Brahm Ganga	MK2	94.4	30
3.	Tegri	MK4	40.4	15
4.	Kasol	KL1	92.2	60
5.	Kasol	KL2	92.3	70
6.	Kasol	KL3	91.2	90



A – B : He/Rn ratio under normal conditions
B – C : Rise in He/Rn ratio as stresses accumulate at depth
C – D : Drop in He/Rn ratio prior to triggering of the shock
D – E : Drop back in He/Rn ratio after the shock

Fig.3. A conceptual model of He/Rn ratio as a predictive tool of earthquakes in a seismic area.

impending earthquakes (Areshidze et al.1992; Bella et al. 1995; Virk et al.1995,1997). The physical basis of the radon and helium anomalies before an impending earthquake have yet to be fully understood in terms of a comprehensive theoretical model. However, a conceptual model (Sharma, 1997) will be used as a predictive tool for major earthquakes in N-W Himalaya, under a coordinated Himalayan Seismicity project sponsored by DST, New Delhi. The various stages of the conceptual model, shown in Fig.3, are as follows:

(i) Under normal conditions, helium to radon ratio (quotient) may have some constant value depending on the geology and meteorological conditions at the monitoring site (Segment AB).

(ii) The stresses causing an earthquake build up around the hypocentre. During this phase, first helium is affected at deeper layers and its emanation rate increases, hence He/Rn ratio rises sharply (Segment BC).

(iii) When the stress reaches upper crustal layers, radon emanation is enhanced from rocks under excessive strain and hence He/Rn quotient falls suddenly (Segment CD); this is an alarm signal for the impending earthquake.

(iv) After the quake, both Rn and He drop down to normal values (Segment DE) as the ground conditions stabilise.

We have set up He/Rn monitoring stations at Palampur in the Kangra valley and Manikaran in the Parbati valley to test this hypothesis as a predictive tool for earthquakes in N-W Himalaya. The preliminary results are quite encouraging in case of Sundernagar earthquake which occurred on July 29,1997, of magnitude 5.1 on Richter scale as estimated by Wadia Institute of Himalayan Geology (WIHG), Dehradun.

The He/Rn results will form part of a separate publication to be communited later when sufficient data is collected at both the monitoring stations.

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